TEXAS COMPTROLLER of PUBLIC ACCOUNTS
SUSAN
COMBS

May 6, 2008

Ladies and Gentlemen:

Reliable and affordable energy is critical to our state's ability to maintain strong economic growth. Texas has long been a leader in the energy industry and today has nearly one-quarter of the nation's oil reserves and about one-third of natural gas reserves. Texas also leads the nation with more than a quarter of all U.S. refining capacity. The energy industry plays a leading role in the Texas economy, employing nearly 375,000 people who earned more than $35 billion in total wages in 2006.

Fossil fuels — oil, gas and coal — continue to meet most energy needs for Texas, the U.S. and the world. Nearly all our vehicles remain powered by oil products, and about 87 percent of Texas' electricity is generated from the fossil fuels — coal and natural gas, with nuclear energy providing about 10 percent.

The use of renewable resources is on the rise, and Texas leads the nation in renewable energy potential. Texas has the resources and technical expertise to take advantage of increased use of a wide variety of renewable energy sources, including solar, wind, geothermal, biofuels and hydrogen.

The Energy Report, available at www.window.state.tx.us/specialrpt/energy/, is intended to serve as a reference tool for anyone seeking to understand the current Texas energy environment as they consider the potential impact of new policies. Texas remains at the forefront of the nation's energy industry. As such, the direction Texas takes in energy policy will help mark the path for the nation. Texas — and the rest of the world, for that matter — almost certainly will meet future energy demands using a wide variety of resources, and our state is well positioned to benefit from the increasing diversification of the nation's energy portfolio.

The Energy Report Executive Summary includes an overview of the energy industry in Texas, brief reviews of 17 fuel sources, an overview of energy uses and a summary of government financial subsidies for energy.

We recognize that energy prices are volatile and have increased significantly in recent months. Our report uses the most recent data available, which allows us to compare prices, production and consumption across different fuel sources. We have provided extensive source references so readers can check for updated data, while using this report as the basis for a basic understanding of the Texas energy landscape.

Sincerely,

Susan Combs

Susan Combs

WWW.WINDOW.STATE.TX.US • P.O. BOX 13528 • AUSTIN, TX 78711-3528 • 512-463-4000 • TOLL FREE: 1-800-531-5441 • FAX: 512-463-4965

THE ENERGY REPORT
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CHAPTER 1
Introduction

Reliable and affordable energy is a cornerstone of modern life. We use energy, mostly in the form of gasoline derived from crude oil, to power the vehicles that ferry us to work and play. Electricity from coal, natural gas, nuclear or wind power provides us with light, powered appliances, heating and cooling. And some sources of energy are used as chemical feedstocks to make other products, an industry in which Texas is a world leader. Our standard of living, then, depends upon readily available sources of energy.

Energy use historically has been tied to population and economic growth. Texas' population is expected to continue to increase for decades to come, and our economic growth will depend on the availability of energy.

For much of the twentieth century, Texas' economy was tied to the oil and gas industry, which accounted for more than one-quarter of the gross state product at the height of the oil boom in the early 1980s. Tax revenues from energy production and use, particularly oil and gas, have long contributed a significant share of state revenues; at their peak in the early 1980s, tax revenues from oil and gas alone accounted for more than a quarter of all state revenue. Though the state's economy has diversified over the last 25 years, and the share of our economy accounted for by oil and gas has declined, the industry has seen a recent resurgence due to rising oil and gas prices and remains a major component of the Texas economy and contributor to the state's fiscal coffers.

DIVERSIFYING OUR ENERGY PORTFOLIO

Texas, like most of the world, still relies on fossil fuels to meet most of its energy needs. Resources such as oil, gas and coal have been relatively abundant and inexpensive. And all of these fossil fuels benefit from an energy infrastructure developed over decades to make use of them. Unfortunately, these fuels are not without drawbacks.

Texas and the U.S. as a whole are increasingly reliant on foreign imports to meet our petroleum needs. While neighboring countries Canada and Mexico are the largest and fourth largest sources, respectively, of U.S. oil imports, much of the world's reserves of oil and gas are found in politically unstable regions of the world, and in some cases are controlled by governments hostile to the U.S.

Furthermore, burning fossil fuels can have an environmental impact. Our government established policies decades ago that have ameliorated some of the air and water quality problems associated with the use of fossil fuels. A growing environmental concern today, however, relates to unregulated "greenhouse gas" emissions. Congress is debating plans that would limit such emissions, especially of carbon dioxide. Indeed, major financiers in the U.S. are working now to set up markets to trade carbon emission permits in the event that new laws are enacted.

The possibility of such policies, combined with rising oil and gas prices, has prompted a wave of investment in alternative energy sources, as well as new technologies to reduce the negative consequences of fossil fuels. Wind and solar power, biofuels and other renewable resources are increasingly important. And recently revised federal regulations have renewed interest in nuclear power.

Fortunately, Texas has the resources, both natural and human, to lead the way in developing new sources of energy. We have an abundance of renewable and clean fuel sources, including the winds of the Panhandle, West Texas and the Gulf Coast; the sunlight of West Texas; the forests of East Texas; uranium in South Texas that is mined and then enriched for use in nuclear reactors; and land that might be used to grow crops for the next generation of ethanol and other biofuels.

Thanks to its history as a leading energy producer, Texas has an abundance of technical, legal, financial

Texas has an abundance of technical, legal, financial and research expertise that can be deployed to meet the challenges of providing energy for its growing population and economy.

and research expertise that can be deployed to meet the challenges of providing energy for its growing population and economy.

Texas is uniquely positioned to lead the way in developing new technologies that will allow us to use fossil fuels in a more efficient, environmentally friendly manner; to make the technological advances necessary to make better use of our abundant renewable resources; and to reduce the demand for energy through efficiency gains.

In fact, Texas is already making progress in the transition from traditional fossil fuels. Texas, for example, is the nation's leader in installed wind capacity, though wind still generates less than three percent of the state's electricity. We also are the nation's leading producer of biodiesel. And two of the first new commercial nuclear applications in decades are for projects to be built in Texas.

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About This Report

Comptroller staff conducted exhaustive research on the existing and potential resources Texas can employ to meet its energy demands. We talked to scores of individuals in the energy sector; visited mines, power plants, research centers and control rooms; and studied thousands of research reports.

One thing we heard repeatedly is that there is no single solution to meeting our energy needs. And almost everyone seems to agree that Texas — and the rest of the world, for that matter — will have to rely on an array of resources to meet those needs. This new energy portfolio will include renewable resources, nuclear power, and traditional fossil fuels linked with new technologies to reduce their environmental impact.

It is important to remember, however, that there are *always* tradeoffs to be considered in energy policy. The fuels we have relied on for decades, despite recent increases in the cost of oil and gas, will continue to be the dominant means to meet specific energy needs. Our current energy infrastructure is designed to take advantage of them. Any policies that discourage their use, directly or indirectly, will likely entail costs to taxpayers and consumers.

This report is intended to be a resource for policymakers as they consider such tradeoffs. It provides an overview of a variety of energy sources that Texas can use to meet its future energy demands, with a fact-based assessment of each. Our report frames the critical issues and presents the objective information Texans will need to make informed choices about one of the most important issues facing the state.

Texas has the opportunity to influence the expanding public debate over energy use and production. Our state — and our choices — can set a new direction for the nation.

CHAPTER 2
Overview

The energy industry plays a critical role in the Texas economy. The strength of the state's economy depends upon reliable and affordable energy supplies. As the state's population increases and its economy grows and evolves, it is vitally important to continue meeting this demand.

In basic terms, energy is used to perform work. Initially, this work was performed through our own labors, then by domesticated animals and now, increasingly, by machines. For any person, animal or machine, work requires an energy source or fuel. Bread consumed by laborers allowed them to move stones that became the great pyramids; grass eaten by oxen drove wagon trains across the West; and diesel fuel enables modern trucks to haul freight nationwide.

Today, Texans use energy for cooling and heating their homes and powering appliances; in industrial applications, such as petroleum refining and chemical production; and for a variety of commercial applications, from preparing crops for market to manufacturing goods. Energy also is consumed in the form of transportation fuel, both for personal transport and to move goods and provide services to consumers. And about 30 percent of all energy consumed in the state is used to generate electricity.[1]

Reliable and affordable energy is an important factor in economic development. In 2007, for example, two large manufacturing companies rejected possible expansion sites near Boise, Idaho because the area could not guarantee the necessary electric power, costing the area as many as 1,000 jobs.[2]

And disruptions to our energy supplies are costly. A massive electrical blackout on August 14, 2003, affected eight states and 50 million people in the northeastern U.S., costing the nation's economy between $4.5 billion and $12 billion in economic activity.[3] According to the Electric Power Research Institute, Texas loses between $7.3 billion and $11.5 billion annually to power outages, losses second only to California's.[4]

ENERGY RESOURCE TRENDS

Mankind's energy use has shifted over the centuries. Coal powered the industrial revolution. A century ago, it provided most home heating and fueled steam locomotives. But new technologies allowed people to find cleaner and more convenient fuels; today, coal is used almost exclusively as a boiler fuel in large electric power plants, where economies of scale allow it to be used efficiently, with reasonably effective emissions controls. Coal is the most abundant and economic fossil fuel available to the nation, but wider use of it may be limited by concerns about air pollution and carbon emissions.

In the last century, petroleum came to dominate heating, industrial and transportation uses, due to its flexibility, including its ease of storage and transportation. Abundant, cheap oil changed Texas forever; it is almost certainly the most important industry in the state's history.

Today, oil continues to be the backbone of the state's industrial sector, and fuels virtually all of Texas' transportation systems, whether by air, land or water. The significant jump in oil prices during the past decade — from $12 per barrel in 1998 to more than $110 per barrel today — may spur some technological advances and fuel switching in the transportation sector.[5]

Over time, the U.S. has become more dependent on petroleum imports. In 2006, total liquids supply (including crude oil and refined products) from foreign sources accounted for 60 percent of U.S. supply.[6]

Natural gas initially was a nuisance byproduct of oil production that was commonly eliminated by "flaring" it at the wellhead. After pipelines allowed natural gas producers to connect with their customers, it began to play a significant role in meeting Texas' energy needs. In 1970, the price of natural gas was 62 cents per thousand cubic feet (in 2000 dollars). Today's prices are more than 10 times this amount; in 2005, they averaged $6.50

Oil continues to be the backbone of the state's industrial sector, and fuels virtually all of Texas' transportation systems, whether by air, land or water.

per thousand cubic feet. Despite higher prices, natural gas is still a highly valued, clean fuel that has become a Texas mainstay for industrial applications and electricity production.

Commercial nuclear power is an offshoot of the nation's enormous investment and expertise in nuclear technology for military purposes. Nuclear power can produce large amounts of heat that is best suited for use in very large power plants, and it has some very desirable features (such as low-cost fuel and extremely long run times between refueling) as well as significant drawbacks (very high front-end costs, long regulatory and construction lead times, and unique safety and security concerns).

Texas has a great assortment of energy options available to power its future.

Renewable energy represents a vast palette of natural energy resources, encompassing usable energy from the sun, wind, biomass (plant materials and animal waste), water and the earth itself (geothermal energy). These are fundamentally different from conventional fuel sources in that they are renewed by nature over short time cycles and hence are not depletable, as are fossil fuels. Renewable energy sources are virtually infinite, offering great promise for our long-term energy needs. Technology is the key to making use of these abundant but challenging resources, as they tend to be more dispersed and lower in energy density than fossil fuels.

Energy efficiency can help meet our energy needs by reducing our demand for energy. Better power plants, advanced auto technology and energy-saving lighting and appliances have proven that economic growth can be achieved with lower energy consumption. More efficient technology under the hood can stretch a tank of gas by many miles. Actions to reduce customer demand and consumption are the quickest and often the lowest-cost options for meeting short-term energy needs.

A growing economy and population will require more energy than can be saved with improved efficiency. But Texas has a great assortment of energy options available to power its future. As the supply of traditional fuels become less certain and more costly, advanced technology will play an increasingly important role.

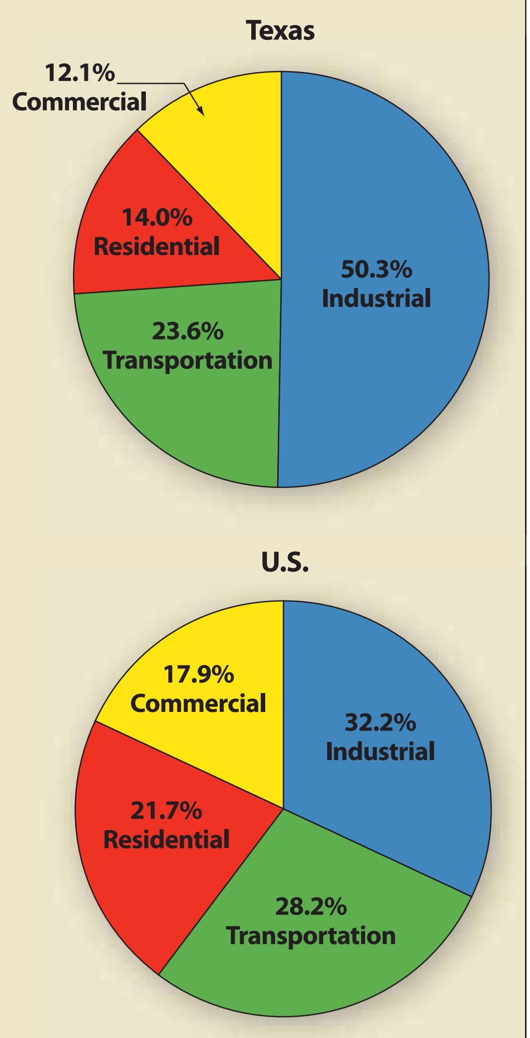
Note: The following sections include data through 2005, as this is the most recent data available across all fuel sources in a standard format. Subsequent chapters frequently rely on more recent data related to their topics.

TEXAS ENERGY CONSUMPTION

Texas' energy use is tied to its large population, hot climate and extensive industrial sector. Compared to the U.S., Texas has a high concentration of energy-intensive industries, such as aluminum and glass manufacturing, forest products, petroleum

EXHIBIT 2-1

Energy Consumption by Sector, Texas vs. U.S., 2005



Source: U.S. Energy Information Administration.

refining and petrochemical production.[7] Texas industries account for 50 percent of all energy used in Texas, while U.S. industrial energy use makes up 32 percent of total U.S. energy consumption (**Exhibit 2-1**). (Energy consumption commonly is divided between four end-use sectors — residential, commercial, industrial and transportation.) In other words, much of Texas' energy consumption fuels industries producing products used across the U.S. and around the world.

Texas thus leads the nation in energy consumption, accounting for 11.5 percent of all U.S. energy use and 18 percent of industrial use. Texas leads the states in the use of oil, natural gas, coal and electricity, consuming over 11.5 quadrillion British Thermal Units (Btu). California was second with more than 8 quadrillion Btu.[8]

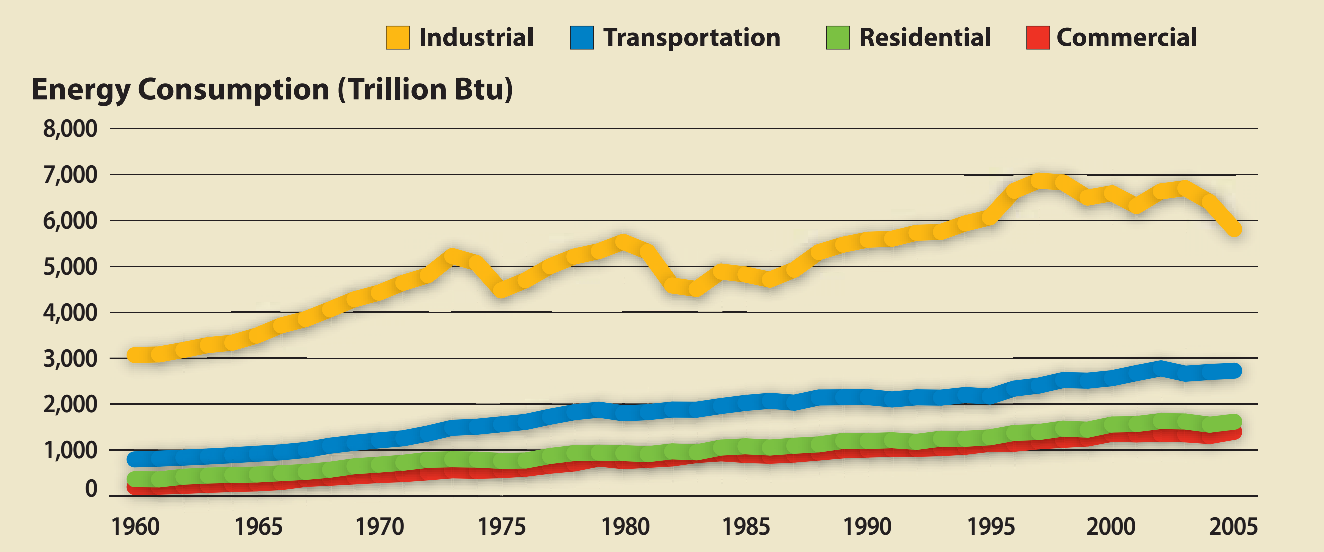
Total energy consumption has increased by an average of 2.2 percent annually since 1960. Residential and commercial consumption both increased gradually, while the demand for transportation fuel rose more rapidly, a trend reflecting a growing population and an expanding economy. Industrial consumption is much more variable than the other sectors, as it is more sensitive to higher energy prices and economic slowdowns. Industrial consumption fell by 13.3 percent from 2003 to 2005, due to higher energy prices and greater investments in efficiency. This paralleled efficiency gains prompted by higher energy prices in the early 1980s (**Exhibit 2-2**).

Energy use per person in Texas also has decreased in recent years and is at its lowest level since 1965 (**Exhibit 2-3**). Combined residential and commercial per capita consumption in Texas was slightly below the U.S. average in 2005, with 132 and 134

Heat value as measured in British Thermal Units or Btu, is one of the few ways to make apt comparisons among hydrocarbon fuels; such comparisons are used throughout this report. These fuels have varying energy qualities and are traded by different measures of weight or volume, but all are put to the same use — producing heat. Oil, for example, is traded by the barrel, which is equivalent to 42 U.S. gallons. Gasoline, diesel and heating oil are traded by the gallon. Natural gas is measured by volume — in thousand (Mcf), million (MMcf), billion (Bcf) or trillion (Tcf) cubic feet — or by heat value, usually dekatherms (1 million Btu). In the U.S., coal is measured by the short ton (2,000 pounds) or, in other parts of the world, by the metric "tonne," equivalent to about 2,200 pounds.

Exhibit 2-2

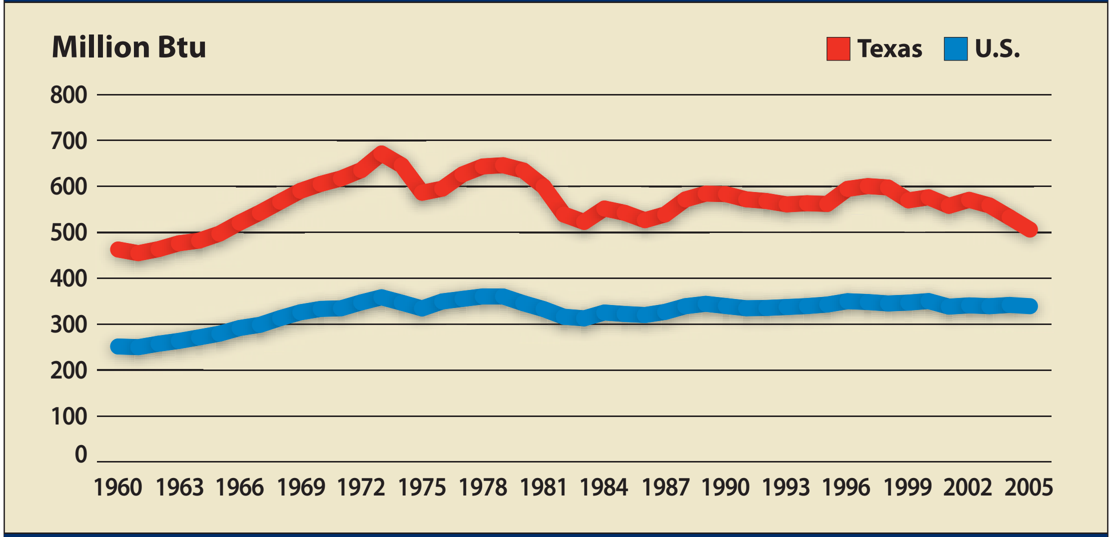
Texas Annual Consumption by Sector



Source: U.S. Energy Information Administration.

Exhibit 2-3

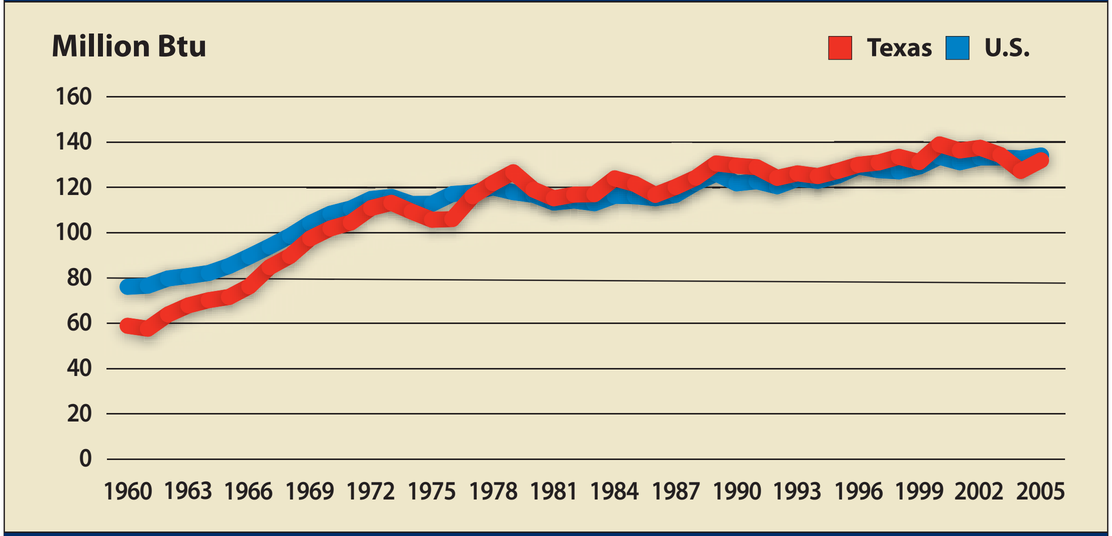
Total Per Capita Energy Consumption



Sources: U.S. Energy Information Administration and U.S. Census Bureau.

Exhibit 2-4

Residential and Commercial Per Capita Energy Consumption



Source: U.S. Energy Information Administration.

Decreasing energy intensity is an indication of greater energy efficiency and structural changes in the economy, such as growth in less energy-intensive industries like services.

million Btu, respectively (**Exhibit 2-4**). To no surprise, Texas per capita industrial consumption is well above the U.S. level, but Texas per capita industrial consumption has dropped steadily in recent years to its lowest level since 1960, the first year for which data are available (**Exhibit 2-5**). Per capita transportation use also has declined in recent years (**Exhibit 2-6**).

Furthermore, the energy "intensity" of the Texas economy — or its energy use per dollar of gross state product (GSP) — fell by nearly 68 percent between 1970 and 2005 (**Exhibit 2-7**).[9] Decreasing energy intensity is an indication of greater energy efficiency and structural changes in the economy, such as growth in less energy-intensive industries like services. Pricing also has an effect, as energy intensity declines more during periods of high energy prices.Texas and the U.S. have become increasingly more reliant on imported fuel, but as **Exhibit 2-7** demonstrates, our economy is less dependent on energy in general.[10]

TEXAS PRIMARY ENERGY SOURCES

Primary energy resources are those used for direct-use applications (primarily heating and manufacturing); transportation fuels; and the production of secondary energy sources such as electricity (**Exhibit 2-8**).

Direct uses include the burning of combustible materials to produce heat for homes and office buildings and to turn raw materials into finished products in industrial applications. Direct use accounted for 45.8 percent of all Texas energy consumption in 2005, for applications such as the manufacturing of chemicals, petroleum products, paper and metal (**Exhibit 2-9**). Energy for direct-use applications decreased by nearly nine percent in 2005, largely from declines in industrial energy consumption.

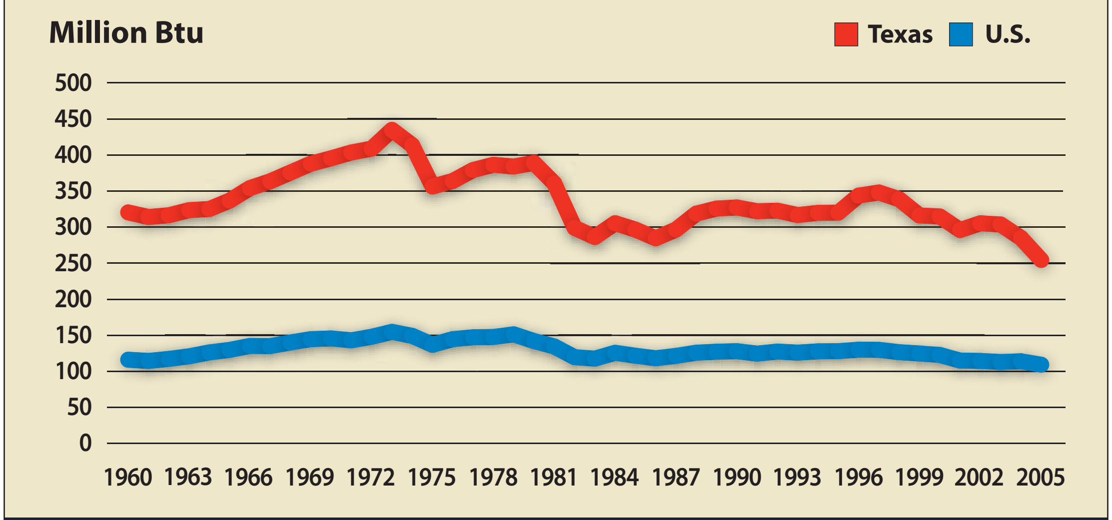
Texas energy consumption for transportation rose by an average 2.7 percent annually between 1965 and 2005, and accounted for 23.6 percent of all energy use in the latter year.

Among the markets for primary energy, electricity is Texas' fastest-growing type of energy consumption, rising by an annual average of 4.2 percent between 1965 and 2005. The production of electricity now accounts for over 30 percent of the state's energy use, up from 13 percent in 1965.[11]

Texas leads all states in the use of petroleum, as large quantities of petroleum are used in industrial

EXHIBIT 2-5

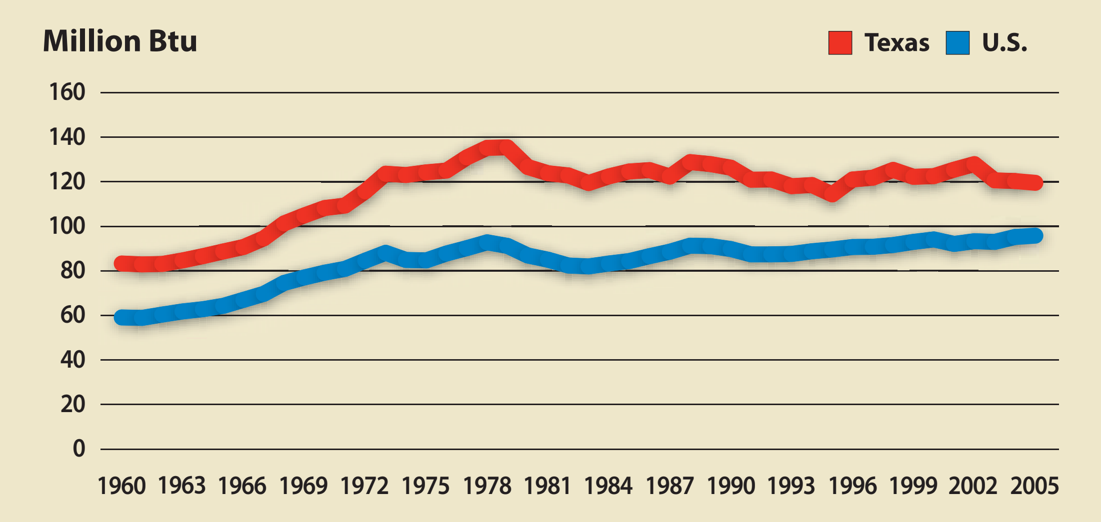
Per Capita Industrial Consumption



Source: U.S. Energy Information Administration.

Exhibit 2-6

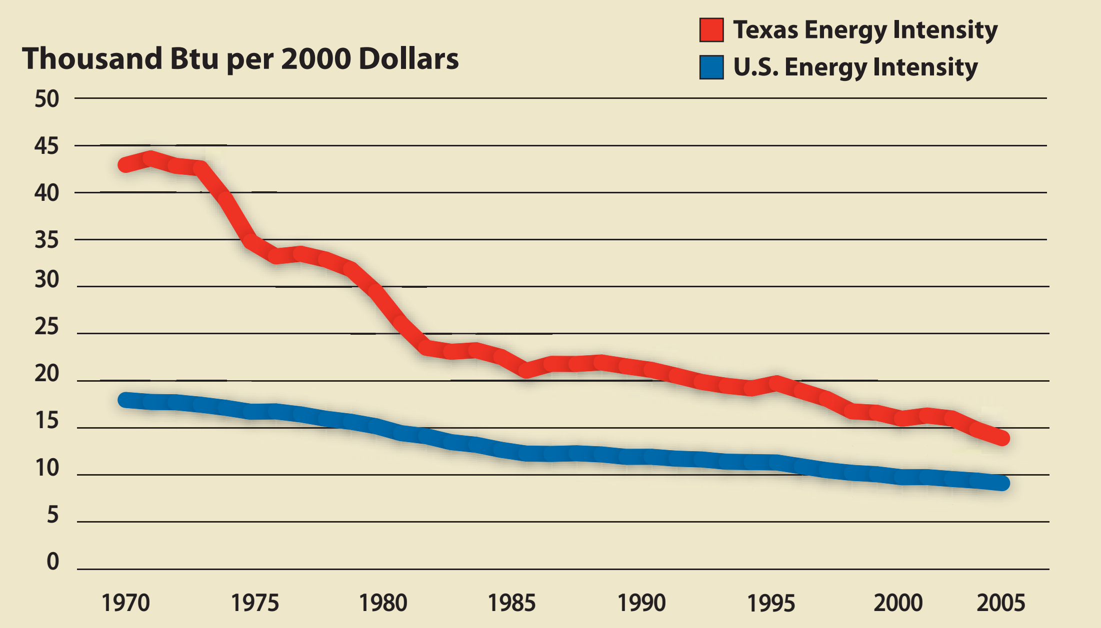
Per Capita Transportation Consumption



Source: U.S. Energy Information Administration.

Exhibit 2-7

Energy Use Per Real Dollar of Gross Domestic Product



Sources: U.S. Energy Information Administration and U.S. Bureau of Economic Analysis.

Exhibit 2-8

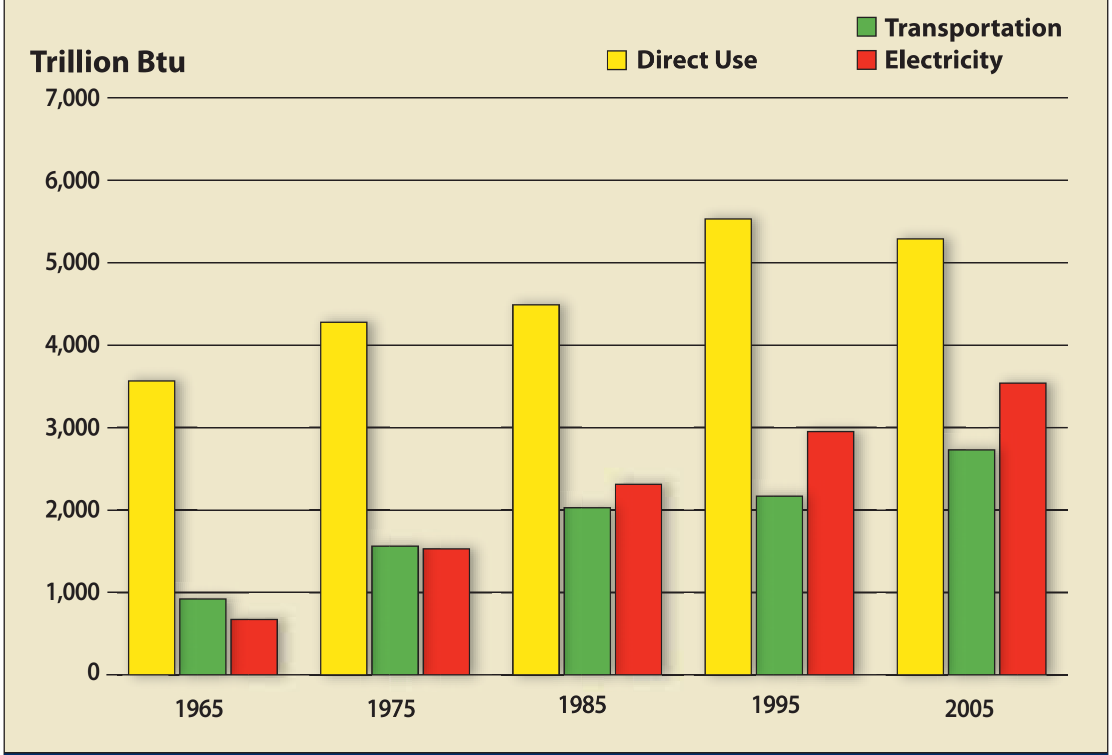
Primary Uses of Energy

Energy Source	Direct Use	Electricity	Transportation
Petroleum	x		x
Natural Gas	x	x	
Coal		x	
Uranium		x	
Solar	x	x	
Wind		x	
Biomass	x	x	x
Water		x	
Geothermal		x	

Source: Virtus Energy.

Exhibit 2-9

Texas Primary Energy Use



Source: U.S. Energy Information Administration.

applications relative to other states. In 2005, petroleum accounted for 50.8 percent of Texas industrial energy use, and Texas consumed 30.5 percent of the petroleum used for industrial purposes in the U.S. A major reason for the large share is Texas' use of liquid petroleum gas (LPG) for petrochemical production, as Texas used more LPG than all other states combined. For all sectors, Texas used 14 percent of U.S. petroleum.

Texas leads the U.S. in natural gas use, accounting for 16 percent of U.S. consumption. Texas' large share is mostly due to industrial consumption and electricity generation. For example, natural gas accounted for 49.4 percent of Texas electricity production in 2005, compared to 18.7 percent in the U.S. Texas' natural gas consumption fell by 20 percent from 2003-2005 to its lowest level since 1987, due to higher prices and a steep decline in industrial use.

Demand for coal and nuclear energy remained steady in 2005. While still accounting for a fraction of total energy use, renewable energy usage rose by 35 percent between 2000 and 2005, almost entirely due to wind-powered electric generation. In all, energy consumption in Texas fell by 3.4 percent in 2005 (**Exhibit 2-10**).[12]

Fossil fuels — crude oil, natural gas and coal — account for 94.5 percent of Texas energy consumption and 85.9 percent of U.S. consumption (**Exhibits 2-11** and **2-12**). As stated, natural gas plays a larger role in Texas due to the state's abundant supply and use for electric generation.

ENERGY BY END USE SECTOR

Texas per capita residential consumption of electricity is far greater than the national average. Other states rely more heavily, for example, on oil and gas for residential energy needs, and thus have lower average electricity consumption. The commercial sector in Texas also uses a large amount of electricity. The industrial sector depends principally on oil and gas but also uses a significant amount of electricity; the transportation sector is nearly 100 percent petroleum-dependent (**Exhibits 2-13**, **2-14** and **2-15**).

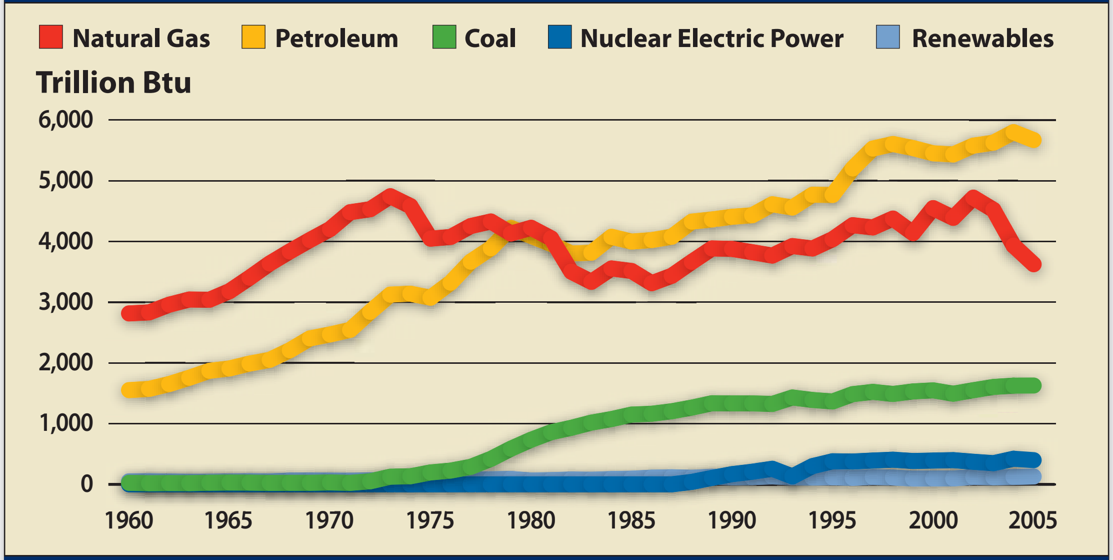
ELECTRICITY GENERATION

Natural-gas fired power plants supplied nearly half of Texas' electricity in 2005. This differs significantly from the national pattern. In the U.S. as a whole, nearly half of all electricity was generated by coal in 2005; only 20 percent came from natural gas. Over the past 10 years, electricity

For decades, Texas has led the states in energy production and remains the nation's largest producer and refiner of oil and gas.

Exhibit 2-10

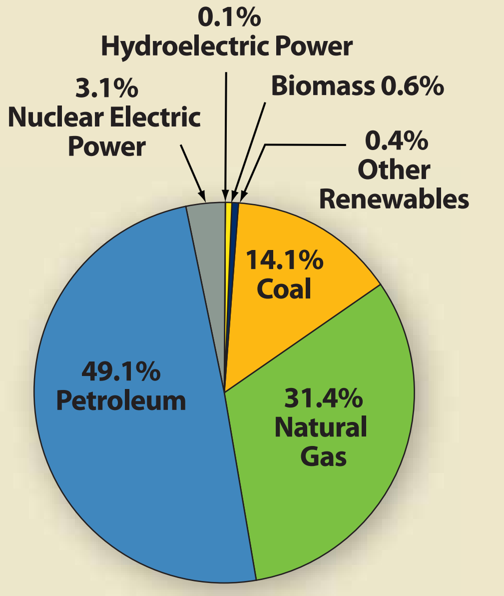
Texas Primary Energy Consumption



Source: U.S. Energy Information Administration.

Exhibit 2-11

Texas Primary Energy Use, 2005

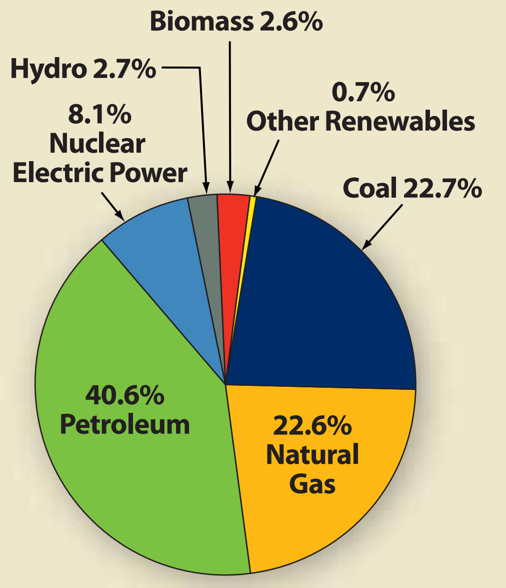


Note: Numbers may not total due to rounding and because net interstate electricity flows and losses are excluded.

Source: U.S. Energy Information Administration.

Exhibit 2-12

U.S. Primary Energy Use, 2005

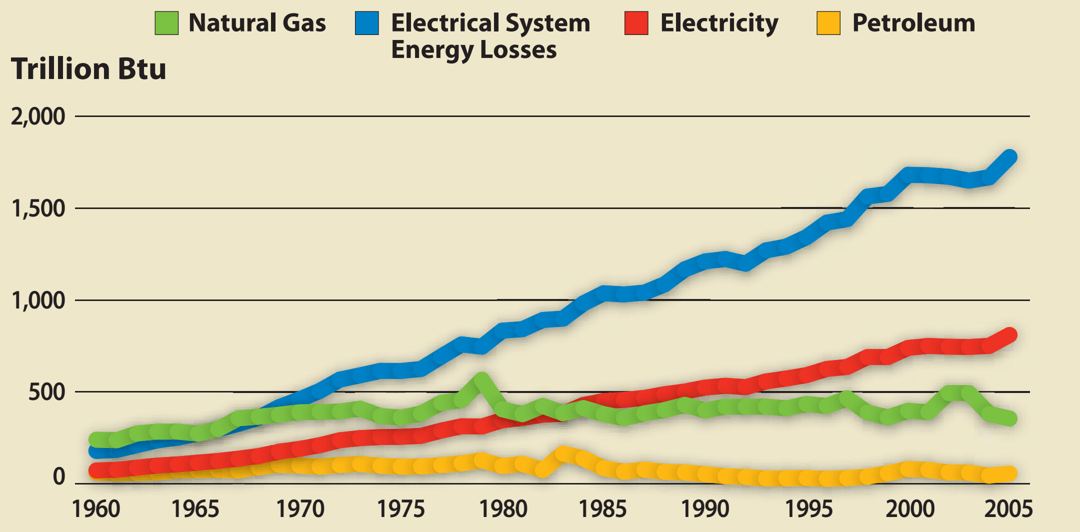


Note: Numbers may not total due to rounding and because net interstate electricity flows and losses are excluded.

Source: U.S. Energy Information Administration.

Exhibit 2-13

Texas Residential and Commercial Energy Consumption by Source



Source: U.S. Energy Information Administration.

production from nuclear power has remained relatively constant and in 2005 accounted for about 10 percent of Texas electricity generation. Due to increases in wind power, non-hydroelectric renewable energy accounted for 2 percent of Texas electricity generation (**Exhibit 2-16**).[13]

Texas Energy Production

For decades, Texas has led the states in energy production and remains the nation's largest producer and refiner of oil and gas. Texas has ample reserves of lignite coal, which can be used to generate

State Government Energy Spending

Texas state government consumes a great deal of electricity and transportation fuels. In fiscal 2007, state agencies spent $323 million on energy.

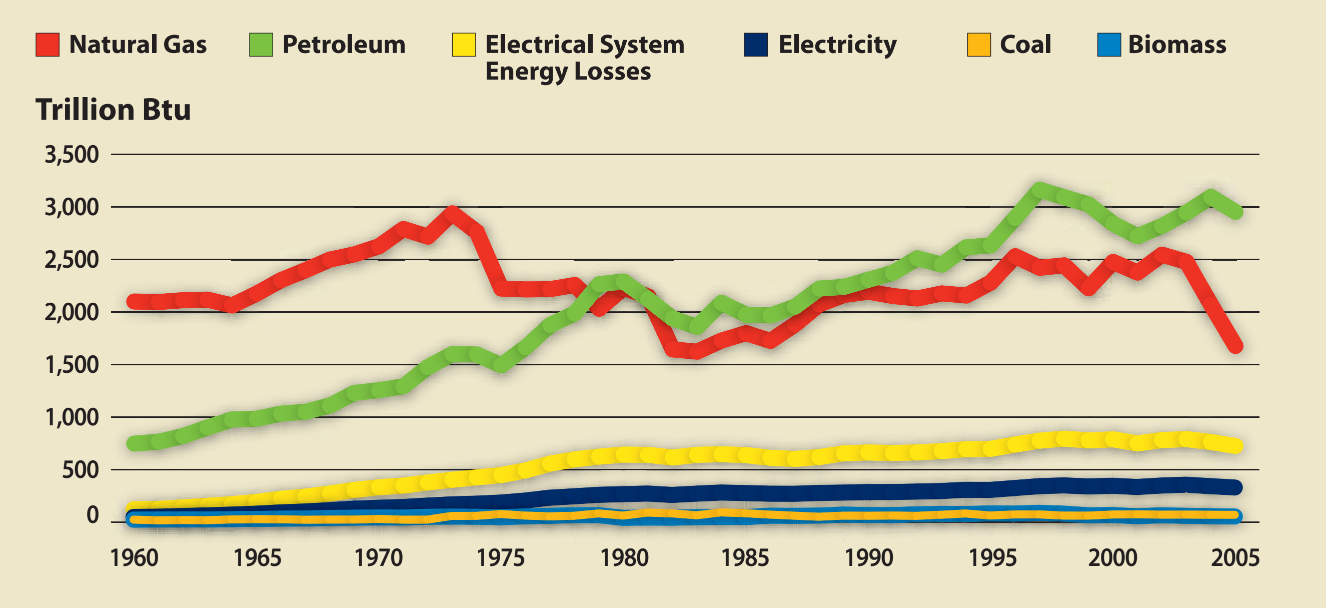
Texas State Government Energy Spending, Fiscal 2007

Description	Expenditures
Petroleum Products Used in State-Owned or Leased Vehicles and Other Equipment	$75,546,109.23
Petroleum Products Used in State-Owned or Leased Aircraft	1,134,052.50
Electrical Utilities	205,447,358.12
Natural and Liquefied Petroleum Gas Utilities	31,955,983.02
Thermal Energy (purchases of steam and hot and cold water)	9,094,583.95
Total	**$323,178,086.82**

Source: Texas Comptroller of Public Accounts.

Exhibit 2-14

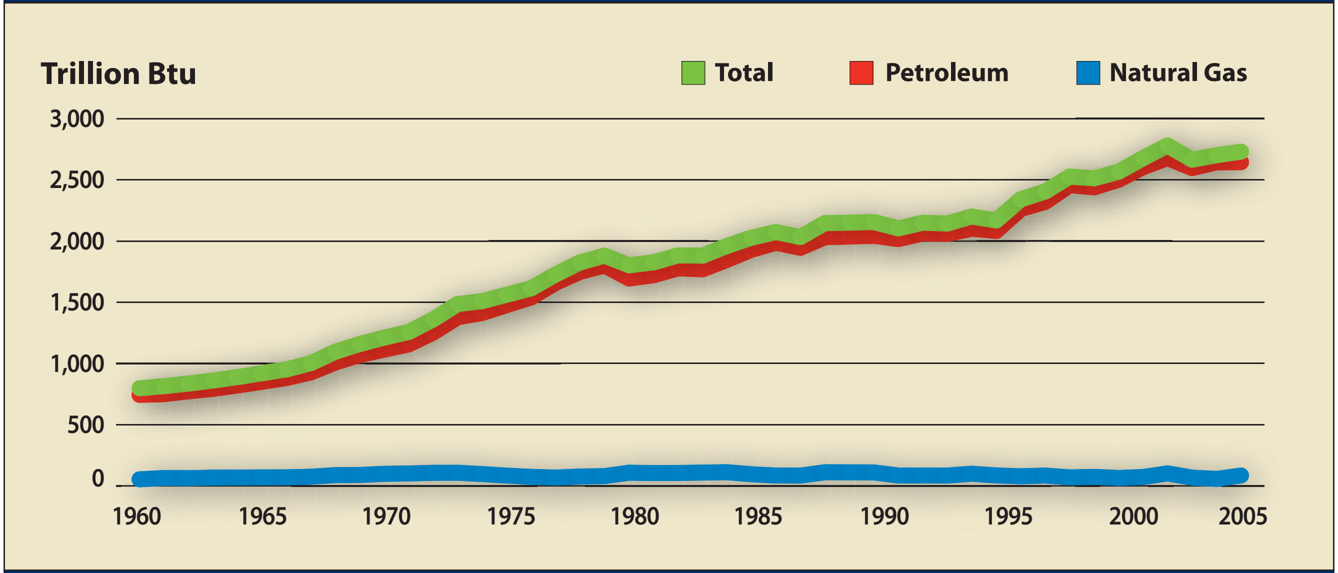
Texas Industrial Energy Consumption by Source



Source: U.S. Energy Information Administration.

Exhibit 2-15

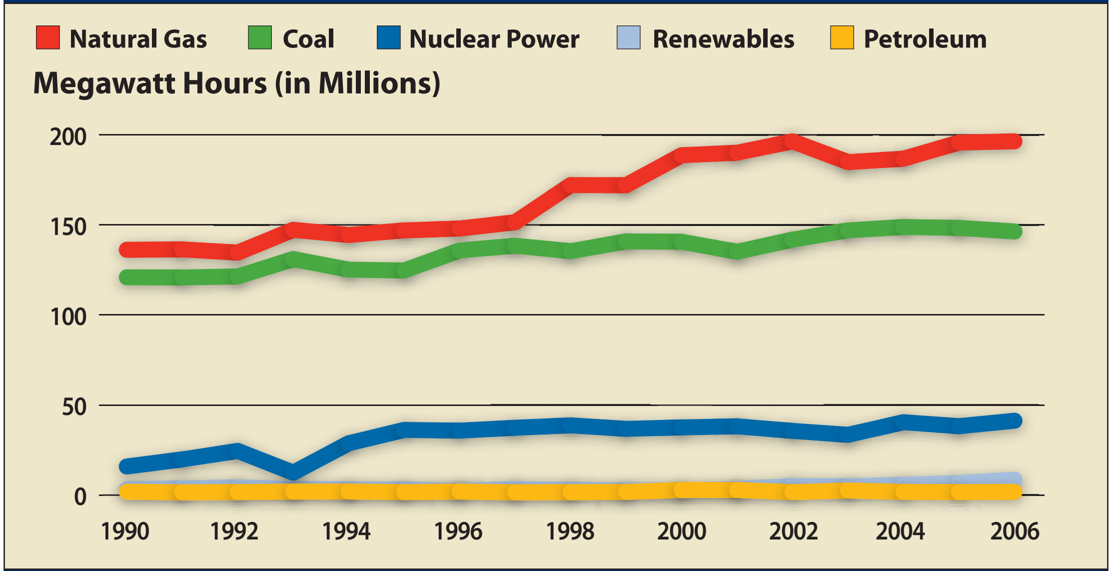
Texas Transportation Energy Consumption by Source



Source: U.S. Energy Information Administration.

Exhibit 2-16

Electric Power Industry Generation by Source



Source: U.S. Energy Information Administration.

electricity, as well as uranium deposits that can be used as fuel in generating nuclear power. Finally, Texas has an abundance of many types of renewable fuels and leads the nation in installed wind energy capacity.

Oil and Gas Production

Oil and gas production has been the cornerstone of the Texas energy industry since the Spindletop oilfield near Beaumont came in with a "gusher" on January 10, 1901. In the early 1900s, Texas produced just 1.3 percent of the nation's oil, and only 0.1 percent of its natural gas. This changed dramatically over the next half-century, however, and by 1952, Texas produced 45 percent of U.S. oil and 52 percent of its natural gas.[14] In 2006, Texas remained the nation's largest producer of oil and gas (excluding federal offshore areas), accounting for 21.3 percent and 27.8 percent of total U.S. production, respectively.[15]

Texas leads the states in fossil fuel reserves, with nearly a quarter of all U.S. oil reserves and nearly 30 percent of the country's natural gas.

Texas also leads the states in fossil fuel reserves, with nearly a quarter of all U.S. oil reserves and nearly 30 percent of the country's natural gas. (These statistics omit oil and natural gas production in federal offshore areas in the Gulf of Mexico and near California, which produce about a quarter of the nation's crude oil.)[16]

Texas also is the national leader in refining capacity. The state has 23 refineries capable of refining 4.6 million barrels of oil per day, more than a quarter (27 percent) of all U.S. refining capacity. The Houston area has the nation's largest concentration of refineries. It is home to the nation's largest refinery, in Baytown, and the originating point for the nation's largest refined product pipeline.[17]

Nevertheless, Texas oil and gas production has matured. U.S. and Texas crude oil production both have declined steadily since their peak in the early 1970s, leaving the nation increasingly reliant on imports of oil (**Exhibit 2-17**). Texas' natural gas production has remained relatively constant over the past two decades (**Exhibit 2-18**). Recent, dramatic increases in oil and gas prices have spurred exploration and drilling activity in Texas, particularly for natural gas. Natural gas production rose by 4.5 percent in 2006, yet U.S. crude oil production continues to decline.[18]

Coal and Nuclear Production

Texas has abundant deposits of lignite coal and some bituminous coal deposits. Lignite, the lowest grade of coal, is mined in Texas, but most of the state's coal-fired power plants burn higher-grade, lower-sulfur Powder River Basin coal, brought in by train from Wyoming, because it has higher energy content and lower emissions than lignite.

South Texas also is home to uranium mines and enriched uranium is used to fuel Texas' two nuclear power plants. The South Texas Project, jointly owned by NRG Energy, CPS Energy and Austin Energy, has two nuclear reactors with a combined rating of 2,500 megawatts; two new units will add an additional 2,700 megawatts when a planned expansion is complete.[19] Luminant's Comanche Peak facility has two reactors with a combined rating of 2,300 megawatts.[20] Luminant also plans to add two additional reactors at Comanche Peak.[21]

Renewable Energy Production

Texas leads the nation in renewable energy potential with a large amount of wind generation capacity and a high level of solar radiation capable of supporting a high level of solar power generation.[22] Texas now has the most wind generation capacity in the country, accounting for 27 percent of the national total.[23] Texas' current wind energy production is enough to power about 1 million homes in the state.[24] Unfortunately, the intermittent nature of wind energy means that it cannot be relied upon as a primary source of electricity and must be supplemented by more reliable sources, such as coal, natural gas or nuclear power plants.

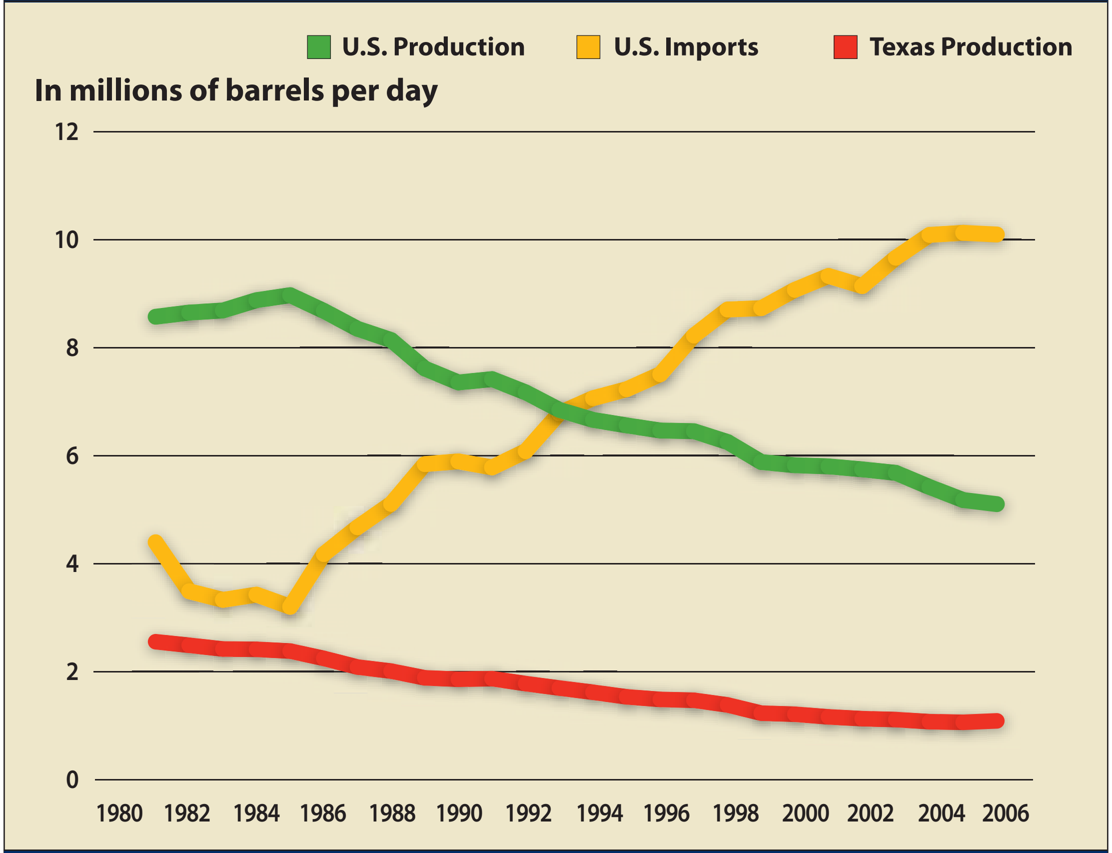
Texas is also the largest producer of biodiesel transportation fuel in the U.S., capable of producing more than 100 million gallons annually, with another 87 million gallons of capacity under construction. In 2007, Texas made 72.9 million gallons of biodiesel.[25]

ENERGY SPENDING

Given Texas' large population and many energy-intensive industries, it is no surprise that Texas businesses and consumers spend more money on energy than those in any other state. And with the cost of energy on the rise, total spending on energy has increased in recent years. Adjusted for inflation, Texas energy expenditures in 2005 were at an all-

Exhibit 2-17

U.S. and Texas Crude Oil Production and U.S. Imports



Source: U.S. Energy Information Administration.

time high. In 2005, Texans spent $114 billion on energy, accounting for nearly 11 percent of all U.S. energy expenditures. This measure nearly doubled the $61 billion (in 2005 dollars) spent in 1998, a period of much lower energy prices.[26]

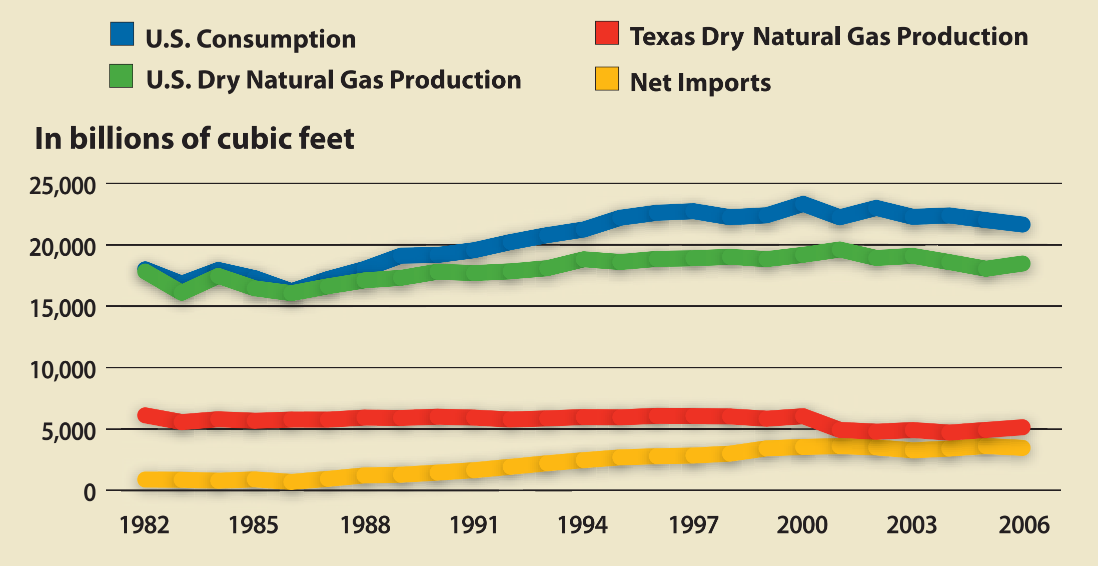
Per capita energy expenditures in Texas increased by 51 percent between 2002 and 2005, as energy prices rose. Energy expenditures in Texas roughly parallel the U.S., yet Texas per capita energy expenditures were 42 percent higher compared to the U.S in 2005 (**Exhibit 2-19**).

As a share of gross state product, Texas' energy expenditures have declined steadily over the past two decades, despite recent increases. In 2005, Texas' expenditures as a share of gross state product were 11.6 percent, down from its peak of 17.5 percent in 1981. The U.S. expenditure share was 8.4 percent in 2005 (**Exhibit 2-20**).

Though complete data are not yet available, it is clear that energy spending has continued to increase since 2005. Oil prices have set new records, exceeding $110 a barrel in April 2008. Prices for other fuels have been on the rise as well. This means it is likely that energy spending per capita and as a share of gross product have continued their recent climbs.

Exhibit 2-18

U.S. and Texas Natural Gas Production and U.S. Consumption and Imports



Source: U.S. Energy Information Administration.

ENVIRONMENTAL IMPACTS

Energy production and consumption obviously can have an effect on our environment, including air and water quality and land use. Government action to limit negative impacts can affect the cost of energy by making various fuels more expensive.

Major Federal Regulations

Congress approved two major public health and environmental protection laws in the 1970s. The Clean Air Act of 1970 authorized the U.S. Environmental Protection Agency (EPA) to establish National Ambient Air Quality Standards (NAAQS) that each state was required to adopt by 1975.[27] The Federal Water Pollution Control Act of 1972, commonly known as the Clean Water Act, authorized water quality programs, imposed federal effluent limits and state water quality standards and required permits for the discharge of pollutants into navigable waters.[28]

These two laws have had indirect but significant effects on energy production because the standards they impose affect discharges from power plants, refineries, mines, wells and other energy enterprises.

Clean Air Act

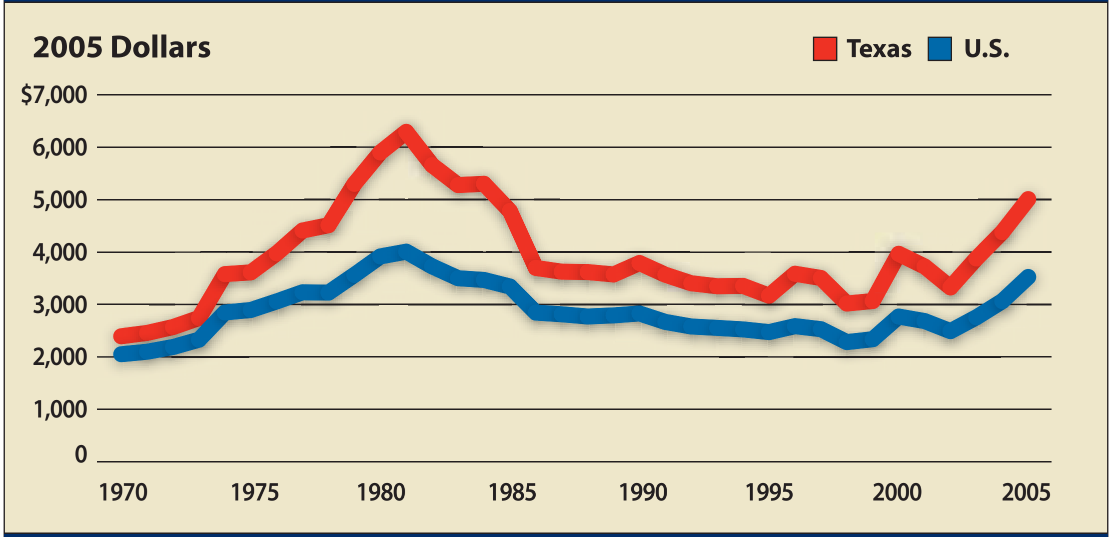
The NAAQS measure six outdoor air pollutants:

- ground-level ozone/smog (O_3)
- particulate matter (PM)
- lead (Pb)
- nitrogen dioxide (NO_2) and other nitrogen oxides (NO_X)
- carbon monoxide (CO)
- sulfur dioxide (SO_2) and other sulfuric oxides (SO_X)[29]

The Clean Air Act of 1970 created performance standards for new sources of emissions. All new

EXHIBIT 2-19

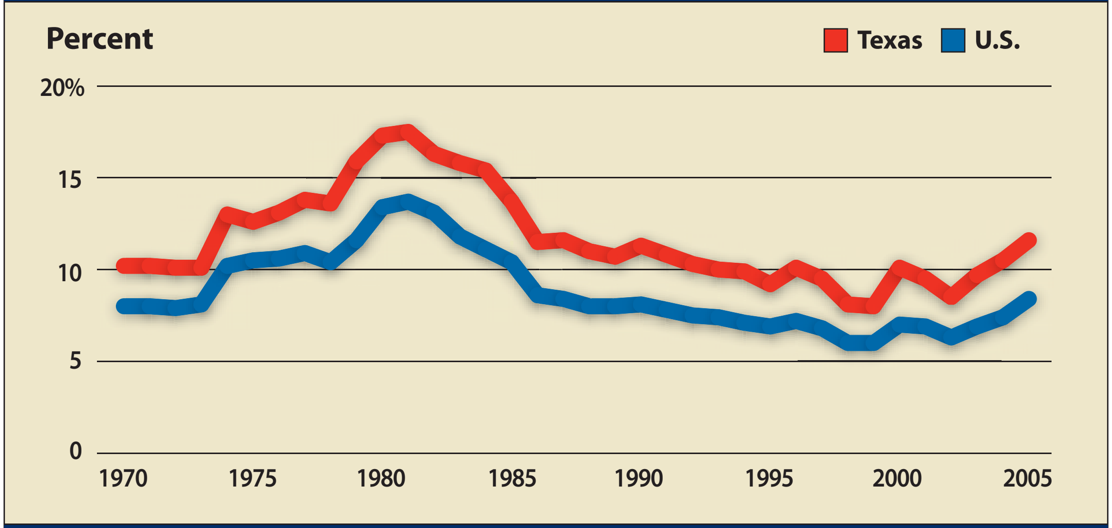
Real Per Capita Energy Expenditures



Source: U.S. Energy Information Administration.

EXHIBIT 2-20

Energy Expenditures as Share of Gross Product, U.S. and Texas



Sources: U.S. Energy Information Administration and U.S. Bureau of Economic Analysis.

plants and major additions to existing plants must meet higher emissions controls. Each state is required to submit a State Implementation Plan (SIP) to EPA to outline how it intends to meet federal air quality standards.

Areas that have cleaner air than EPA's standards are called "attainment areas;" areas that do not meet the standards are called "nonattainment areas."

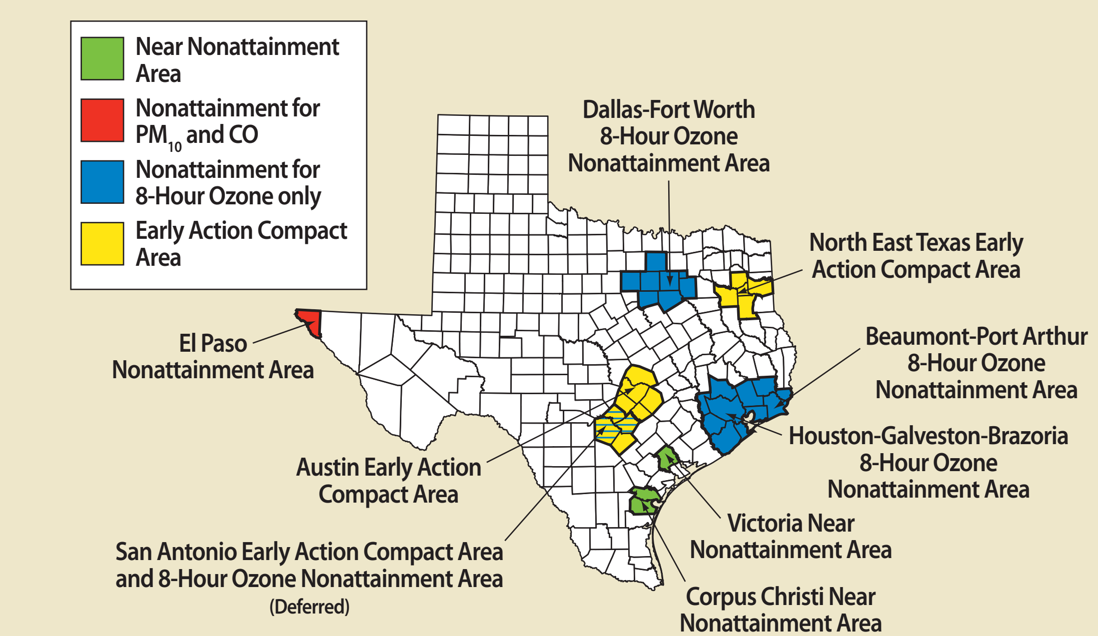
Texas has several geographical areas that violate EPA standards for ozone, particulate matter and carbon monoxide (**Exhibit 2-21**). EPA calculates ozone limits based on an eight-hour average of no more than 0.075 parts per million (ppm) of ozone.[30] Ground-level ozone — the primary component of smog — is created when volatile organic compounds (VOCs) and nitrous oxides react in the presence of sunlight and hot weather. Internal combustion engines, power plants and industrial plants emit these substances.

At this writing, Texas is not meeting federal clean air standards for carbon monoxide and particulate matter in El Paso or for ground-level ozone in Houston-Galveston-Brazoria, Dallas–Fort Worth, San Antonio and Beaumont–Port Arthur. Three Texas areas, Austin, San Antonio and Northeast Texas, have been designated as Early Action Compact Areas, which are voluntary eight-hour air quality plans for areas that are in danger of exceeding the eight-hour standard. If Texas fails to comply with Clean Air Act requirements, it could lose billions in federal highway funding.[31] The state recently asked EPA for an extension of time to meet federal standards.

Under 1990 amendments to the Clean Air Act, EPA must impose financial sanctions if states have not submitted or implemented adequate plans to meet the air quality standards. Note that it is not the failure to meet the air quality standards, but failing to plan to meet the standards that triggers the sanctions. The Clean Air Act leaves the states

EXHIBIT 2-21

Texas' Nonattainment and Near Nonattainment Areas



Source: Texas Commission on Environmental Quality.

responsible for determining what measures should be implemented to meet air quality standards.

In March 2008, as part of its mandatory five-year review of the Clean Air Act, EPA lowered the eight-hour ozone limit from 0.08 parts per million to 0.075 parts per million. Industry representatives and some state officials opposed any tightening of the ozone standard, citing the estimated $7.6 to $8.8 billion cost to affected industries to meet the new standard.[32]

The consequences of the lower ozone standard for Texas could be significant. The new standard is likely to substantially increase the number of nonattainment counties above the current 17, and regions that were already in nonattainment under the old standard could face additional restrictions under the lower standard. Other areas that were not yet in nonattainment or had recently achieved attainment could fall into nonattainment and face new restrictions.[33] Regions affected by the new rule likely will include Dallas-Fort Worth, Houston-Galveston-Brazoria, Beaumont-Port Arthur, El Paso, Northeast Texas, Austin, and San Antonio.

State and local officials point out that much of the pollution afflicting many Texas counties does not originate locally but instead blows in from the east from refineries, power plants and other industrial activity. Some of these critics argue that it is unfair for Texas cities and counties to be punished given Texas' unique characteristics such as its busy port in Houston, its extensive refinery operations, its border with Mexico and its international entry points filled with idling vehicles.[34] Other critics argue that these challenges should be addressed by state or federal government through more stringent restrictions on emissions from vehicles, power plants and other industrial activities that affect air quality in areas that are downwind.[35]

Whereas current federal regulations deal primarily with pollutants contributing to ozone and other public health threats, much of the current debate concerning energy and the environment is focused on greenhouse gas emissions, which most climate scientists believe contribute to global climate change. The emissions of some greenhouse gases, such as nitrous oxide, are restricted under the Clean Air Act, though not because of their greenhouse gas effects. And some greenhouse emissions, such as carbon dioxide, are not regulated at all.

In April 2007, the U.S. Supreme Court ruled that EPA has the authority to regulate greenhouse gas emissions.[36] Although the Court found that EPA was required to regulate greenhouse gases unless it provided a scientific reason not to do so, the agency has not yet taken action to regulate carbon emissions. In April 2008 a coalition of states, cities and environmental groups sued to require EPA to publish an agency analysis that found that greenhouse gas emissions endanger humans and contribute to climate change, an action that could lead to the adoption of rules regulating greenhouse gases. Federal legislation establishing a framework for regulating and reducing greenhouse gas emissions has also been filed in the U.S. House and Senate.[37]

Thus far, the most prominent legislation on greenhouse gas emissions (such as carbon emissions) introduced in the U.S. Congress is Senate Bill 2191, introduced by Senators Lieberman and Warner in October 2007. As filed, S. 2191 would establish an emissions "cap and trade" system intended to reduce U.S. carbon emissions to 2005 levels by 2012, 15 percent below 2005 levels by 2020, and 70 percent below 2005 levels by 2050. As of this writing, the bill had passed committee and was awaiting action by the full Senate.

Cap and trade systems typically limit emissions to a specific level, issue emissions allowances in some manner and allow the subsequent owners of those allowances to sell them on a market. Entities that acquire more allowances than they use can sell the surplus to entities that need more allowances.

Emissions allowances can be given to industries based, for example, on historical emissions, or they can be sold, typically via an auction. S. 2191 would give some allowances away and auction others, but over time would increase the share of total allowances that are auctioned.

As the nation's leading consumer of energy, due in part to its large industrial sector, Texas could face a significant economic impact from any policy that caps greenhouse gas emissions. The National Association of Manufacturers and the American Council for Capital Formation, for example, re-

If the federal government imposes limits on emissions of greenhouse gases such as carbon dioxide, it will inevitably shape the decisions made by Texas business, investors and policymakers as they develop the energy infrastructure.

leased an analysis of S. 2191 in March 2008. Their analysis concluded that Texas would see reductions in gross state product and household income, along with higher gasoline and electricity prices, if the bill were passed in its current form.

If the federal government imposes limits on emissions of greenhouse gases such as carbon dioxide, it will inevitably shape the decisions made by Texas business, investors and policymakers as they develop the energy infrastructure.

Clean Water Act

Under the federal Clean Water Act, states must establish standards describing the ways that water bodies can be used. The Texas Surface Water Quality Standards define four general categories of water use: aquatic life use, contact recreation, public water supply and fish consumption.

States generally have focused on controlling "point sources" of pollution, or pollution that can be traced to a specific location. Point-source pollution is the most serious cause of water pollution, and can be controlled by treating wastewater before discharging it into lakes or rivers. According to TCEQ, about 59 percent of the water bodies in Texas were "impaired" — not meeting the state's quality standards — in 2006.[38]

WATER AND ENERGY

Water policy intersects with energy policy in numerous ways.

Water policy intersects with energy policy in numerous ways. Water is used directly to generate electricity through hydroelectric power, and to cool thermoelectric power plants, enhance oil recovery, refine oil and biofuels, irrigate corn and other sources of biofuel and aid in the extraction of coal and other natural resources.

A distinction should be made, however, between water *withdrawals* and water *consumption*. Power plants with "open-loop" cooling systems require very large water withdrawals, but almost all of this water is returned to its source. Most power plants constructed since the 1970s use "closed-loop" cooling systems. These plants require much less water, although most of what they use is lost through evaporation.[39]

Water is required to produce electricity, and electricity is required to pump and transport water. Improved water conservation and efficiency will lead to lower energy demand, just as improved energy conservation and efficiency will lead to lessened demand for water resources.

Another important issue is the impact that energy production has on *water quality*. Without proper controls, energy production has the potential to affect water quality. Waste streams flowing from mining runoff can affect water supplies; air pollution from power plants can lead to acid rain; aquifers can be contaminated by oil and gas exploration and production; and the irrigation of biofuel crops can lead to pesticide runoff. State and federal environmental regulations exist to protect water quality, and proper mitigation activities by utilities, mining companies, agricultural producers, and other interests can minimize many of these harmful effects.

Finally, evaporation due to surface water storage in reservoirs is an important consideration in evaluating hydroelectric power projects. The U.S. Department of Energy estimates that evaporative losses associated with hydropower are approximately 3.8 billion gallons per day.[40]

GOVERNMENT AND THE ENERGY INDUSTRY

As should be clear from the above discussion of environmental regulations, government action can influence the development of energy resources. Federal, state and local governments can affect the development of any industry, directing private investors away from resources in which they might otherwise invest. Similarly, government action can drive investment *toward* resources that might otherwise be ignored. In other words, government action can distort markets.

Such government action can take a variety of forms: regulation, such as the Clean Air Act discussed earlier in this chapter; taxation, which makes the cost of a product or service more expensive; or subsidies, which can encourage investment in and development of resources, products or services.

Regulation and taxation can be used to limit negative spillover effects — "negative externalities" — that result from a given activity. Negative externalities impose costs on society that are not borne by the producers or consumers of a product or service. Pollution is a classic example of a negative externality whose costs often are borne by society at large instead of by the producers of that pollution. The Clean Air Act, in turn, is an example of regulation intended to limit the impact of pollution by forcing polluters to pay for equipment to reduce emissions.

Regulation and taxation are government actions that typically discourage a given activity. Subsidies, on the other hand, can encourage the private sector to engage in some activity by using tax dollars to make such investments more attractive. Recent examples of energy industry growth strongly influenced by government subsidies include the production of corn-based ethanol and wind-generated electricity. Chapter 28 of this report details the value of federal, state and local financial subsidies to the energy industry.

Energy, then, is an industry in which the government has traditionally exerted influence through regulation, taxes and subsidies. In Texas, for example, the oil and gas industry has benefited from subsidies, is subject to a mature set of regulations and has contributed a significant portion of state revenues through the taxes it pays. And a recent surge in renewable energy resources in Texas, particularly wind, has benefited from subsidies such as property tax value limitations as well as regulations requiring power companies to use renewable energy sources for a certain amount of their total electricity generation.

Furthermore, the mere *prospect* of government action can influence private investment decisions. A comparison between recent developments in the coal and wind industries is instructive in this regard. The wind industry, as noted above, has grown rapidly in Texas in recent years. In addition to federal, state and local subsidies that encourage investment in the industry and the improving cost-competitiveness of wind-generated electricity, investor anticipation of new federal regulations to limit carbon emissions has encouraged private investment in emissions-free wind farms.

Conversely, many investors may be hesitant to invest in new coal plants, as any regulations limiting carbon emissions are likely to raise the cost of coal-generated electricity. To cite just one example, three major investment banks — Citigroup, J.P. Morgan Chase and Morgan Stanley — recently announced that they believe Congress will enact carbon restrictions within a few years, and that the banks will begin requiring new power plants seeking financing to show that they will be able to generate profits with such emissions caps in place.[41]

Government policy also can have unintended consequences — impacts beyond what the policy was intended to achieve. A recent, oft-cited example of this is government policy to encourage corn-based ethanol production. Ethanol production, as discussed in Chapter 13 of this report, has boomed in recent years, indicating that government policy has achieved its goal. As Chapter 13 also notes, however, the policies intended to encourage the use of ethanol have had dramatic impacts in other areas. Rising corn prices resulting from strong ethanol demand have raised prices in other markets, indirectly increasing prices for other agricultural products, including crops whose supply has decreased as farmers replace them with higher-priced corn. It also raised feed costs for cattle ranchers as well as poultry and pork producers, thereby raising meat prices.

Texas-based Pilgrim's Pride, Inc. eliminated 1,100 jobs after closing a chicken processing plant in Silver City, North Carolina and 6 of its 13 distribution centers. The company cited record high prices for corn and soybean meal, as well as an oversupply of chicken, as reasons for the job cuts.[42]

These are only a few examples illustrating how policy plays a key role in the energy industry. This report draws no conclusions about the policies lawmakers should pursue. Instead, it is intended to provide them with the factual information they need to make informed decisions as they carefully weigh the costs and benefits of policies to achieve the state's energy goals.

OUTLOOK FOR TEXAS

Energy fuels economic development, and Texas' demand for energy will continue growing for the foreseeable future. Meeting this demand will require a diverse array of existing and new resources and technologies, combined with improved energy efficiency.

In the following chapters, we will explore the availability, costs and benefits of various fuel sources to meet our growing demands. We also discuss

Energy fuels economic development, and Texas' demand for energy will continue growing for the foreseeable future.

the major uses of energy in Texas and the current mix of fuels employed for those uses, along with a discussion of efficiency. Finally, we take a ground-breaking look at the extent of current government involvement in the energy sector through a detailed analysis of subsidies across energy sources.

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CHAPTER 3

Overview: Non-Renewable Fuels

INTRODUCTION

Oil, natural gas, coal and uranium — the most common fuels in the world — are considered to be non-renewable, due to the eons it took to create them and mankind's inability to synthesize similar fuels readily. All but uranium are called "fossil fuels" because of their genesis in decaying plant and animal matter. Together, oil, natural gas and coal account for about 85 percent of the world's energy supply, a share that has changed little over recent decades. Nuclear power now provides 6.3 percent, a six-fold increase from 1973 levels.[1]

In 2005, petroleum products (including oils, gasoline and other liquid fuels, but not natural gas) provided 40.6 percent of the 100.3 quadrillion British Thermal Units (Btu), or "quads," consumed in the U.S. Coal and natural gas each provided more than 22 percent of the Btu consumed nationwide; nuclear energy provided 8 percent; and hydropower and biomass provided less than 3 percent each.[2]

The Texas oil and gas industry has bolstered the state economy for a century. Oil and gas deposits are widely distributed throughout the state and offshore. Deposits of coal and uranium (which, when processed, produces nuclear power) are found in Texas, but not in quantities comparable to those of oil and gas. Combined, these fuels produce all but a small fraction of the state's electricity; gasoline and diesel refined from oil likewise account for all but a small fraction of the state's transportation fuels.

HYDROCARBONS

Oil, natural gas, coal and liquefied petroleum gases (LPGs) are called "hydrocarbons" because of their chemical structure, which is based on hydrogen and carbon atoms. Under heat and pressure, these elements bond and create chains of molecules in almost infinite combinations, each with unique properties. For example, the long "carbon chain" molecules that create crude oil can be heated and "cracked" in the refining process. (The longer the chain, the broader the variety of refined products it can produce.) The result is a variety of shorter molecule chains that give us waxes, liquids and gases such as paraffin, diesel, gasoline, kerosene, propane, butane and methane (natural gas), among others.

Petroleum deposits, for the most part, formed at the bottom of ancient seabeds to become semi-solid, liquid and gaseous compounds. These deposits are now found as deep as tens of thousands of feet below the earth's surface. As such, petroleum deposits generally can be extracted economically only by drilling. The exception is tar or oil sands, found in Canada and elsewhere in the world, which are near the surface and can be mined.[3]

Today, petroleum products and their derivatives supply almost all of the world's transportation fuels, chemicals and plastics.

COAL

Coal is a combustible rock of varying hardness, moisture and mineral content. Coal deposits, called "seams," must be excavated; commercial deposits generally are found either just below the surface or underground at depths up to 1,000 feet, although mine depths of more than 2,000 feet are not uncommon.[4]

Coal was widely used first as jewelry, then as fuel, by the Chinese six millennia ago and by the Romans in Britain four millennia later.[5] Today, coal is the world's most common heating fuel. China, with the third-largest proven reserves in the world, is unique among developing countries in that coal is its preferred fuel for both heating and home cooking.[6]

Oil, gas, coal and uranium combined produce all but a small fraction of the state's electricity.

URANIUM

Uranium is a mineral found throughout the world. Commercial concentrations of uranium ore are fairly widespread, including several in South Texas.

In its natural state, uranium is an ore that must be extracted via underground mining, open-pit mining or in-situ leach (ISL) mining. Open-pit and underground mining mechanically remove the uranium ore from on or below ground, break it up and send it to a mill where the uranium is removed.

ISL mining, also called solution mining, pumps a leach solution (commonly sulfuric acid or a weak alkaline solution, depending on the type of rock) through the ground to separate uranium from the source rock, and then extracts the uranium-bearing fluid from the formation. ISL causes little surface disturbance or waste rock. The source rock must be permeable to the leach solution, however, and should be located in a geologic formation that prevents groundwater contamination.

Domestic supplies of coal, natural gas, crude oil and natural gas plant liquids accounted for about 78 percent of all 2006 U.S. domestic energy production

FROM SOURCE TO CONSUMPTION

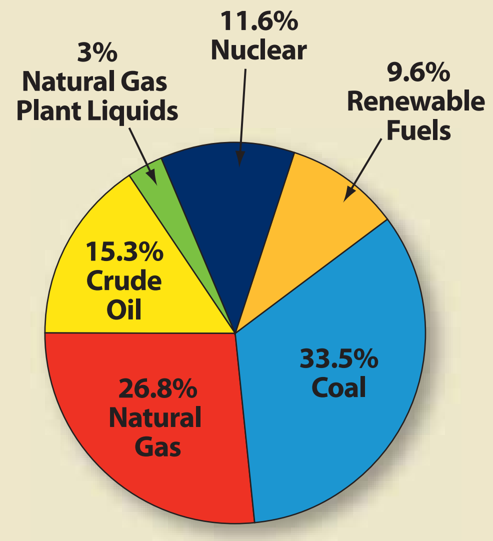
Domestic supplies of coal, natural gas, crude oil and natural gas plant liquids (hydrocarbons and water that precipitate out of natural gas) contributed 56 quadrillion Btu (quads), accounting for about 78 percent of all 2006 U.S. domestic energy production (**Exhibit 3-1**). (Throughout this report, Btus will be used to compare the heat value in fuels that are otherwise measured by different units of volume. Once a fuel is burned to generate electricity, that electricity will be measured by watts.)

Imported petroleum and nuclear sources added a combined 37 quads or 36 percent to the total supply. Fossil fuel and nuclear sources combined represented 93 percent of the total U.S. energy supply of 104.8 quads in 2006 (**Exhibit 3-2**).

Of the total 99.9 quads the U.S. consumed in 2006, residential customers used 21 percent, commercial customers 18 percent and industrial customers 32 percent. The remaining 28 percent was used for transportation.[7]

EXHIBIT 3-1

Domestic Energy Production, 2006 (in Quadrillion Btu)

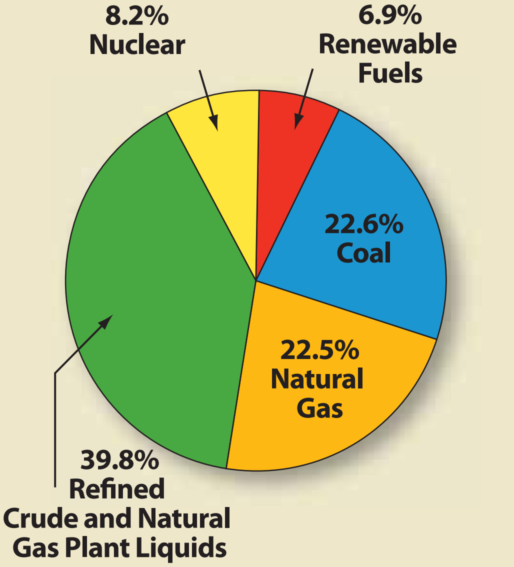


Note: Numbers may not total due to rounding.

Source: U.S. Energy Information Administration.

EXHIBIT 3-2

Domestic and Imported Energy Sources, 2006



Note: Numbers may not total due to rounding.

Source: U.S. Energy Information Administration.

Electricity Production: U.S. vs. Texas

In both the U.S. and Texas, fossil fuels are by far the largest source of energy used to generate electricity, followed at some distance by nuclear power. But Texas and the rest of the U.S. differ greatly on their reliance on specific fossil fuels.

For example, coal-fired generators produced roughly half of the nation's electricity from 1995 to 2006 (**Exhibit 3-3**).

Although the nation's total electricity generation (as measured in megawatt-hours, or MWhs) increased by 21 percent from 1995 to 2006, coal's share of that production declined by about 2 percent, from 51 to 49 percent of the total. Nuclear remained steady at about 20 percent. The share attributable to natural gas rose by about 5 percent over the period, from 14.8 percent in 1995 to 20 percent in 2006. Fuel oils and liquefied petroleum gases, or LPG, remained at a relatively steady 3 percent share until 2006, when they dropped to 1.6 percent.[8]

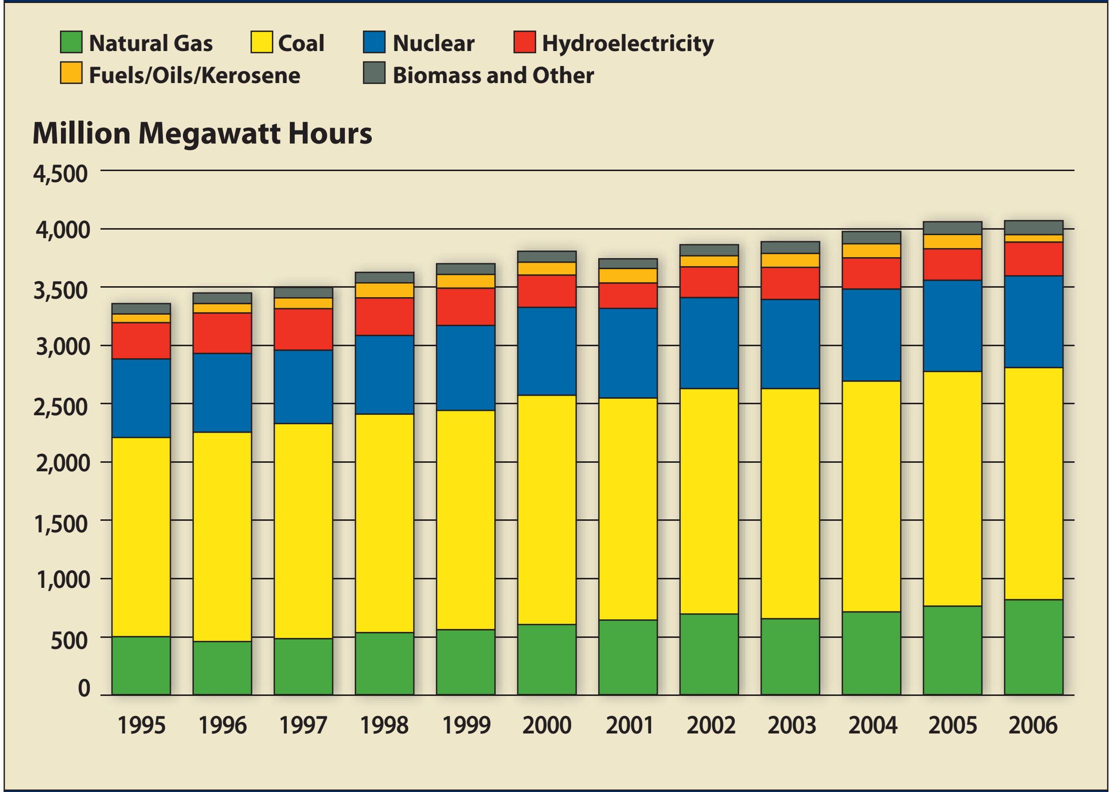
The story in Texas, however, is quite different (**Exhibit 3-4**). Due to the state's population growth, Texas electricity generation rose by about 26 percent from 1995 to 2006, 5 percent more than the national increase. Natural gas was the state's most common electricity-producing fuel from 1995 to 2006, and its share rose over the period, from a low of 45 percent in 1996 and 1997 to a high of 51 percent in 2001. In 2006, natural gas accounted for 49 percent of all Texas electricity generation.

Coal was second but, following the national trend, saw its share of electricity generation decline by about 3 percent, from 39.3 percent in 1995 to 36.5 percent in 2006. Nuclear power's share remained

Natural gas is the state's most common electricity-producing fuel.

Exhibit 3-3

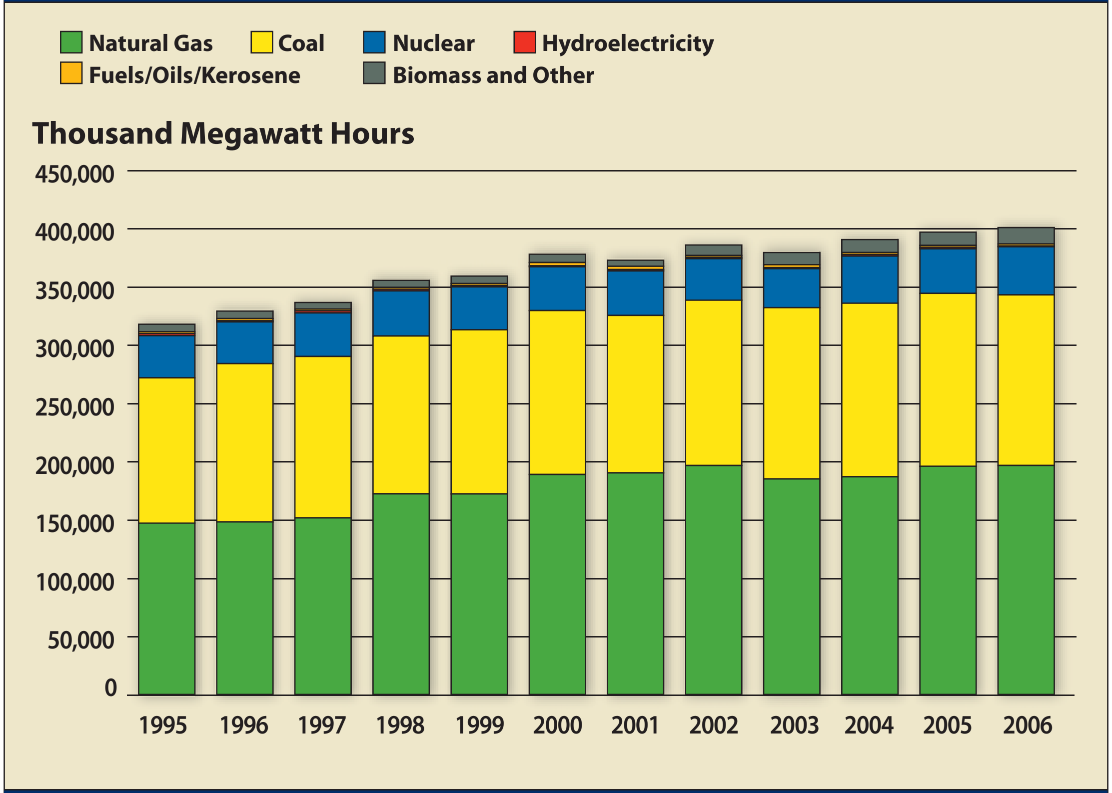
U.S. Net Electricity Production by Fuel Source



Source: U.S. Energy Information Administration.

Exhibit 3-4

Texas Net Electricity Production by Fuel Source



Source: U.S. Energy Information Administration.

relatively steady at about 10 percent, as did the fuel oils/LPG share, at about 0.5 percent.[9]

For more information on electricity, see Chapter 27.

Direct Use

Fossil fuels also are used in homes and businesses to provide heat. In 2004, Texans used about 641.2 trillion Btu of direct-use energy to heat homes and another 558.4 trillion Btu to heat commercial buildings.

In the same year, according to EIA, 49 percent of Texas' 8 million-plus homes were heated by natural gas or LPG (primarily propane); 49 percent were heated by electricity; and the remaining 2 percent of homes were heated by other sources such as wood and solar and geothermal energy.[10]

For more information on direct use, see Chapter 25.

Transportation

In 2005 (most recent data available for both the U.S. and Texas), Americans used 28.3 quadrillion Btu of fuel to transport people or goods from one place to another (**Exhibit 3-5**).[11]

For more information on transportation fuels, see Chapter 26.

Fuel Consumption

Many factors affect fuel consumption. For example, the wide difference between the share of electricity produced by natural gas nationwide (18 percent) and in Texas (almost 50 percent) is largely a matter of climate, supply and infrastructure. Northern areas of the country import vast

Exhibit 3-5

U.S. and Texas Transportation Fuel Sources, 2005 (Trillions of Btu)

Fuel Source	U.S. Amount of Fuel Used	Percent	Texas Amount of Fuel Used	Percent
Petroleum Products	27,301.6	96.5%	2,640.9	96.8%
Natural Gas*	626.3	2.2	85.4	3.1
Ethanol**	342.0	1.2	2.4	0.1***
Electricity	25.7	0.1	0.3	
Total	**28,295.6**	**100.0%**	**2,729**	**100.0%**

* Natural gas used in the transportation sector is consumed in the operation of pipelines, primarily in compressors, and gas consumed as vehicle fuel.
** On the original EIA document, ethanol is listed twice: once as blended into motor gasoline and also separately, to display the use of renewable energy by the transportation sector.
*** Ethanol and electricity used for transportation in Texas together account for 0.1 percent of all transportation fuel used in the state.
Source: U.S. Energy Information Administration.

Northern areas of the country import vast quantities of natural gas from the Gulf Coast and Canada, but more commonly use it for home heating rather than electricity generation.

quantities of natural gas from the Gulf Coast and Canada, but more commonly use it for home heating rather than electricity generation. Texas, with a warmer climate, prolific supplies and an extensive pipeline infrastructure, uses natural gas to heat homes, generate electricity and run the massive petrochemical complex on the Texas Gulf Coast. The remainder is shipped by pipeline to the rest of the country.

Coal use is also affected by many factors. In northern areas, coal is the centuries-old traditional fossil fuel, while natural gas is a relative latecomer. Because high transportation costs naturally encourage an area to consume local coal, northern areas burn high-grade, cleaner-burning coal supplies from Appalachia and Wyoming, while Texas uses a combination of Wyoming coal and local, lower-grade supplies with lower heat value and higher emissions.

Texas Economic Impact

Non-renewable fuels, particularly oil and gas, have been the mainstays of the Texas economy throughout the 20th century and are still important today. The two fuels are so intertwined from production through consumption that federal and state governments combine their data on the two, which is why this chapter discusses oil and gas as a single entity.

The oil and gas industry remains a significant part of the Texas economy, but its relative importance has declined over the past 30 years. Texas crude oil and natural gas production peaked in 1972. In that year, the oil and gas industry represented more than 14 percent of Texas' gross state product (GSP). Its share of GSP continued to rise, largely due to increasing oil prices, to a peak of more than 26 percent of GSP in 1981. In 2006, the industry's share of GSP was 15.7 percent, up from its lowest point of 7.4 percent in 1999.[12]

Employment and Wages

During the 1970s and early 1980s, the health of the Texas economy largely depended on the price of oil. By 1981, oil prices reached $38 per barrel (the equivalent of nearly $87 in 2007). In that year, Texas employment in oil and gas extraction and oilfield machinery manufacturing totaled 366,200 jobs, or 6 percent of all nonfarm employment in the state. By July 1986, however, oil prices dropped to less than $12 per barrel ($21 in 2007 dollars), sending Texas into a 17-month recession. By 1987, Texas had lost 175,000 jobs in oil and gas extraction and oilfield machinery manufacturing.

In the past two decades, Texas' reliance on the oil and gas industry has decreased as the state has transitioned to a more service-oriented economy. Industries such as manufacturing, trade and services, transportation, communications, finance, insurance and real estate all have increased their share of the state's output. The overall result is a state economy that increasingly mirrors the national economy and is less dependent on energy prices.[13]

In 2006, the oil and gas industry employed more than 312,000 Texans, or 3.1 percent of the state's nonfarm jobs. That was slightly higher than 2000 levels, when oil and gas employment accounted for less than 3 percent, but considerably lower than its 4.3 percent share in 1990.[14]

Wages in the state oil and gas industry totaled $30.6 billion in 2006, accounting for 6.9 percent of all nonfarm wages.

The industry's contribution to the Texas GSP has risen every year since 2003, when it was $85.6 billion or 10.3 percent of the total. In 2004, the oil and gas share of GSP rose to $118.4 billion (13.1 percent of the total); in 2005, it was $142.2 billion (14.4 percent); in 2006, $159.3 billion and 14.9 percent, respectively.[15] (See Chapters 4 and 5 for more information.)

Coal production contributed 2,241 mining jobs to the Texas economy in 2006.[16] Other coal-related jobs may exist in other sectors, such as electricity generation, that are not included in these data. Wages totaled an estimated $167.6 million. (See Chapter 7 for more information.)

The state's two nuclear reactors — Luminant's Comanche Peak near Glen Rose and the South Texas Project (STP) in Matagorda County — employ a combined 2,150 persons, not including contractors. Total payroll for the two plants is approximately $196 million annually. (See Chapter 8 for more information.)

STATE TAXES AND REVENUES

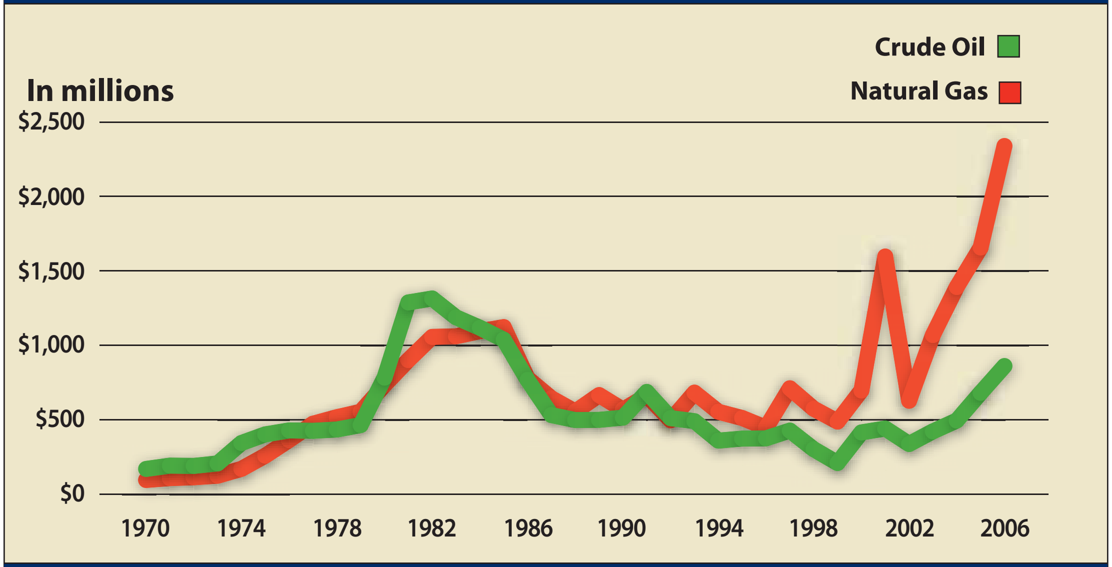
Texas has several sources of tax revenue related to oil and gas, including severance taxes and motor fuels taxes.

Severance taxes include the oil production tax and the natural gas tax, both paid by producers based on the market price of each commodity. Until recently, revenue from both taxes had been declining steadily since the early 1980s (**Exhibit 3-6**). Due to higher oil and gas prices and an increase in production, however, severance tax collections jumped by 37 percent in 2006, to $3.2 billion. In 2006, severance taxes accounted for 9.1 percent of total state revenue, up from just 3 percent in 1999. Oil accounted for almost 2.5 percent and natural gas accounted for 6.6 percent (**Exhibit 3-7**).

The oil and gas industry remains a significant part of the Texas economy.

EXHIBIT 3-6

Oil and Gas Severance Tax Revenue



Source: Texas Comptroller of Public Accounts.

Motor fuels taxes include consumption levies on gasoline, diesel fuel and liquefied petroleum gas. Both the diesel and gasoline taxes have been levied at a rate of 20 cents per gallon since 1991. In 2006, motor fuels taxes totaled nearly $3 billion in revenue, or nearly 9 percent of all state tax revenue (**Exhibit 3-8**).

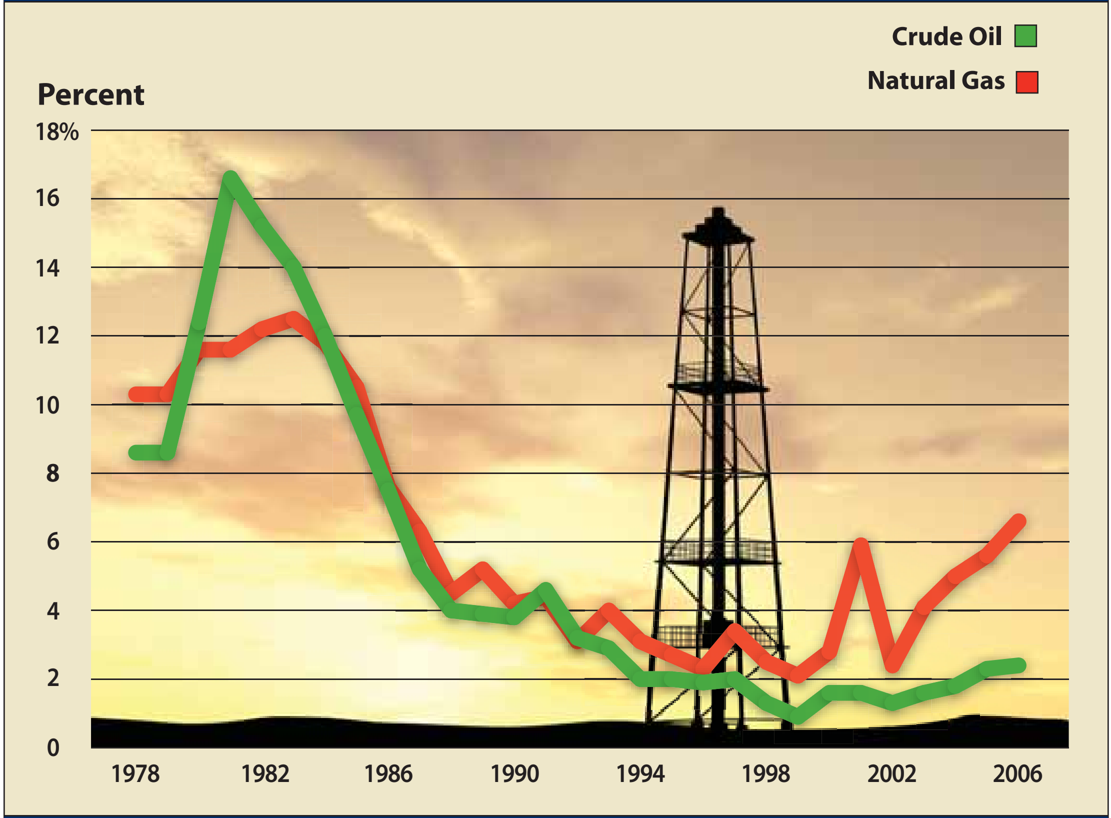
Coal and uranium production and use contribute to federal, state and local tax revenues through income taxes, state franchise taxes, property taxes and indirectly through taxes paid by coal and nuclear power plant owners. No data are available, however, to identify or quantify revenues attributable to these energy sources.

OUTLOOK FOR TEXAS

Texas leads the U.S. in the production and consumption of non-renewable fuels and the electricity generated from them. The U.S., in turn, leads the world. Our reliance on these fuels presents both challenges and choices for the future. The challenges will come in trying to provide a growing state with more energy; the choices will come in deciding how to accomplish that task. Because these fuels are so important to our lives and our economy, we must choose carefully for ourselves and for the generations to come.

EXHIBIT 3-7

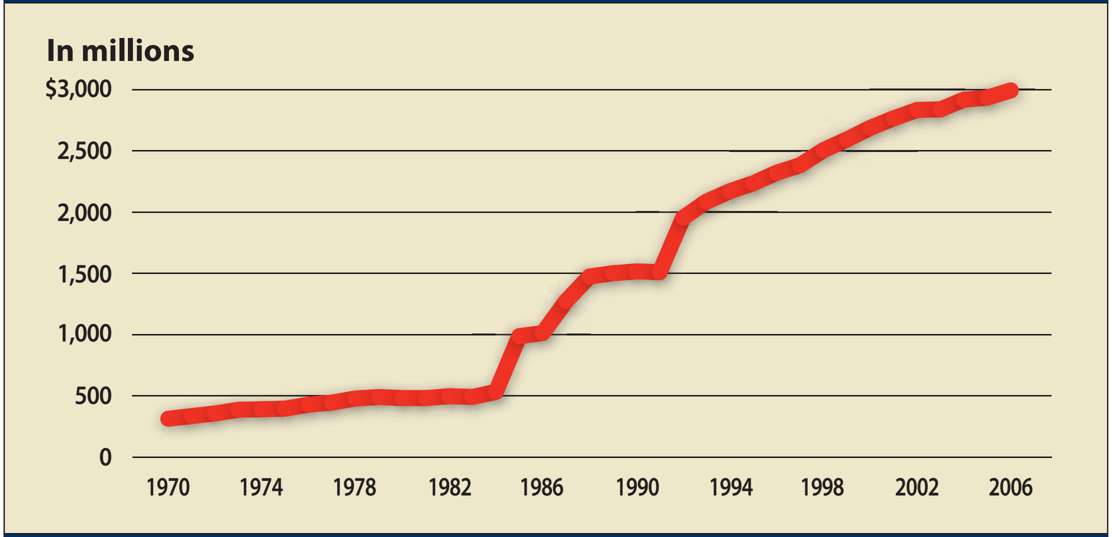
Oil and Gas Industry Tax Revenue as a Percentage of Texas Total Tax Revenue



Source: Texas Comptroller of Public Accounts.

Exhibit 3-8

Texas Motor Fuel Tax Revenue



Source: Texas Comptroller of Public Accounts.

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[1] International Energy Agency, *Key World Energy Statistics* (Paris, France, 2007), p. 6, available in pdf format from http://www.iea.org/Textbase/publications/free_new_Desc.asp?PUBS_ID=1199. (Last visited April 21, 2008.)

[2] U.S. Energy Information Administration, “Energy Consumption Estimates by Source, 2005,” http://www.eia.doe.gov/emeu/states/sep_sum/plain_html/sum_btu_tot.html. (Last visited April 21, 2008.) Petroleum categories included asphalt and road oil, aviation gasoline, distillate fuel, jet fuel, kerosene, liquefied petroleum gases (LPGs), lubricants, motor gasoline, residual fuel and other. The other fossil fuels, natural gas and coal, were counted separately.

[3] U.S. Bureau of Land Management, Oil Shale & Tar Sands Programmatic EIS Information Center, “About Tar Sands,” http://www.ostseis.anl.gov/guide/tarsands/index.cfm. (Last visited April 21, 2008.)

[4] United Mine Workers of America, *Underground Coal Mining: Types of Underground Coal Mines*, http://www.umwa.org/who/underground/types.php. (Last visited April 21, 2008.) Also, see Colorado Geological Survey, *Colorado Coal Directory 2005* http://geosurvey.state.co.us/Default.aspx?tabid=479. (Last visited April 21, 2008.) Colorado reported that its deepest mine in 2005, the West Elk Mine, was 2,300 feet deep.

[5] Freese, Barbara, *Coal: A Human History* (New York: Penguin Books, 2003), pp. 15-16 (Britain) and pp. 204-205 (China).

[6] International Energy Agency, *World Energy Outlook 2006, Chapter on Energy for Cooking in Developing Countries*, p. 435, http://www.worldenergyoutlook.org/2006.asp. (Last visited April 21, 2008.)

[7] An excellent chart detailing the sources and uses of energy may be found at U.S. Energy Information Administration, *Annual Energy Review*, “Energy Flow, 2006” http://www.eia.doe.gov/emeu/aer/diagram1.html. (Last visited April 21, 2008.)

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[10] U.S. Energy Information Administration, “State Energy Profiles, Texas,” http://www.eia.doe.gov/overview_hd.html. (Last visited April 21, 2008.)

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[12] Texas Comptroller of Public Accounts, Oil&Gas EmpWages&GSPJAN2008.xls, Austin, Texas, March 6, 2008. (Internal data with supplementary data from U.S. Bureau of Economic Analysis.)

[13] Federal Reserve Bank of Dallas, “The Effect of High Oil Prices on Today’s Texas Economy,” *Southwest*

Economy (September/October 2004), http://www.dallasfed.org/research/swe/2004/swe0405a.html. (Last visited April 21, 2008.)

[14] Texas Comptroller calculation based on data obtained from Texas Workforce Commission.

[15] Texas Comptroller of Public Accounts, Oil&Gas EmpWages&GSPJAN2008.xls, Austin, Texas, March 6, 2008. (Internal data with supplementary data from U.S. Bureau of Economic Analysis.)

[16] Texas Comptroller of Public Accounts calculation based on data obtained from Texas Workforce Commission.

CHAPTER 4
Crude Oil

INTRODUCTION

We live in what has been called the Petroleum Age. This hydrocarbon-rich mixture of crude oil and gases runs our factories, our cars, heats some homes and has provided Americans with an unprecedented standard of living since its discovery in America in 1859.

Petroleum is an extremely versatile substance; refining it creates everything from asphalt and gasoline to lighter fluids and natural gas, along with a variety of essential elements such as sulphur and nitrogen. Petroleum products are also vital ingredients ("feedstocks") in the manufacture of medicines, chemicals and plastics.

Crude oil and other petroleum products found under Texas soil have been a major component of the Texas economy, in recent decades accounting for 10 to 25 percent of the Gross State Product. The combined oil and natural gas industry in 2006 employed 3.1 percent of the state's workforce and paid that workforce $30.6 billion — 6.9 percent of all wages.[1]

Texas consistently has led the nation in petroleum production since the early 20th century. Currently, Texas also leads the nation in the consumption of petroleum products for many reasons, including the state's reliance on electricity generated by natural gas, a petroleum product, for air conditioning and for its energy-intensive refineries and petrochemical plants.

History

People have used petroleum for thousands of years, for a variety of purposes. More than 4,000 years ago, natural seeps of a tar-like asphalt called bitumen were used to fortify walls and towers in ancient Babylon and Jericho. Ancient Persians used petroleum for medicine and light.

Fourth-century Chinese were the first to drill wells to collect oil and use it to fire boilers, evaporate brine and produce salt. In 1543, a Spanish expedition found oil floating on the surface of the water along the Texas coast and used it to caulk their boats.[2]

The Petroleum Age began with the 1854 discovery of a new process to make kerosene from heavy crude oil.[3] In August 1859 on Oil Creek near Titusville, Pennsylvania, Edwin L. Drake drilled down 69 feet and struck oil, creating the nation's first oil well.[4] Oil quickly proved to be a cheap, abundant and reliable feedstock for the manufacture of kerosene. Its use increased dramatically throughout the country, sparking an economic boom.

While coal continued to fuel industrial expansion in Europe and America, kerosene made from rock oil, the "new light," rapidly replaced kerosene made from coal as a source of home heating and light. By the time of the introduction of the internal combustion engine in the early 20th century, the petroleum economy was well established.

Texas consistently has led the nation in petroleum production since the early 20th century.

Uses

Because of its chemical structure — long hydrocarbon molecules that can be "cracked" or recombined into shorter molecules with different characteristics — crude oil can be refined into everything from tar, gasoline, diesel and jet fuel to heating oil and natural gas. It is also an ingredient, or feedstock, for the manufacture of chemicals, fertilizer, plastic, synthetic fibers, rubber and even such everyday products such as petroleum jelly, ink, crayons, bubble gum, dishwashing liquids and deodorant.

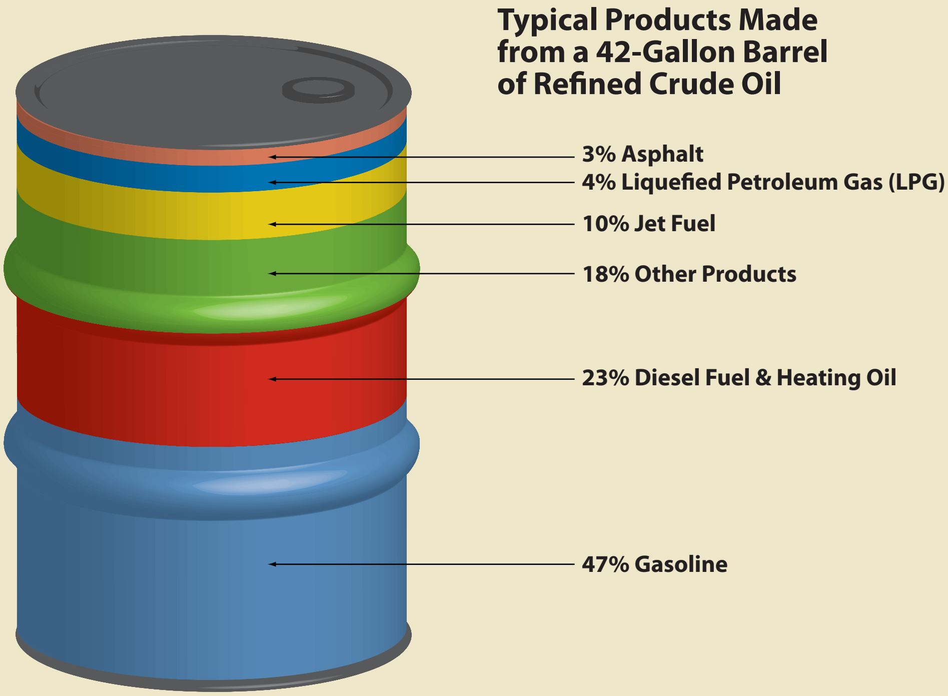
A 42-gallon barrel of crude oil will yield 44.6 gallons of refined products; the difference is what producers call "refinery gain." The greatest portion of a refined barrel of crude oil typically becomes fuel for transportation (**Exhibit 4-1**).

Depending on the season and oil quality, refiners adjust the proportion of fuels produced. For

Gasoline accounts for roughly 47 percent of all refinery products.

Exhibit 4-1

Products Made from a Barrel of Crude Oil



Source: U.S. Department of Energy.

instance, refiners generally make more heating oil in the fall to prepare for winter markets, which can mean a slight cutback in gasoline production. In the spring, refiners reverse this allocation to produce more gasoline for the summer driving season.

Common Refined Products

Gasoline accounts for roughly 44 percent of all refinery products. Gasoline is not a single hydrocarbon, but may be a blend of several. In areas with air quality problems, ethanol or other additives may be added to gasoline to reduce emissions. (Ethanol is a biofuel that adds oxygen to gasoline — making it an "oxygenate" — so that it burns with fewer emissions; see Chapter 13 of this volume.) Gasoline also can occur naturally within crude oil, although this product is more unstable and volatile than refined gasoline.[5]

Diesel fuel and heating oil are "distillates," fuels distilled in refineries and blended with light oils. They are similar, although diesel has a lower sulphur content. Both fuels are available in three grades depending on the intended use. The highest grade of diesel (with the lightest hydrocarbons) fuels buses; the middle grade fuels railroad locomotives, trucks and automobiles; and the lowest grade fuels off-road vehicles such as agricultural and construction equipment. Diesel and heating oil account for about 23 percent of refinery products. Diesel has more energy per gallon than gasoline and is less volatile, but it also produces more emissions than gasoline.

Heating oil accounts for about 5 percent of refinery products. High-grade heating oil is used in portable outdoor stoves and heaters. Mid-grade heating oil fires medium-capacity residential or commercial burners. Low-grade heating oil is used in industrial and commercial burners.[6]

Jet fuel, also called aviation gasoline, is kerosene blended to specifications for general and military aircraft. These specifications include a low freezing point (to keep fuel flowing at high altitudes), low combustibility (to help make handling safer and airplane crashes more survivable) and high energy content with low weight (to allow planes to gain and hold altitude).[7] Jet fuel accounts for 9 percent of refinery products.

Heavy fuel oil, also known as residual fuel oil or "resid," is used primarily for power, heat and electricity generation. The U.S. military uses resid to run steam-powered vessels. Resid accounts for 4 percent of refinery products.

Liquified petroleum gases (LPGs) are gases refined from crude oil or natural gas, liquefied under pressure for easy transportation. The term includes ethane, ethylene, propane, propylene, butane, butylenes, isobutane and isobutylene. LPGs account for 4 percent of refinery products (see Chapter 6 of this report).

The remaining 17 percent of crude oil products are a wide variety of gases, liquids and semi-solids. Among the more common products, *still gas*, also known as refinery gas, is a generic term for any gas produced by refining crude oil. Still gases include methane, ethane, butane and propane. Although containing the same constituent elements as LPGs, still gas is used to fuel refineries and as a chemical feedstock. *Road oil* is any heavy petroleum oil used to stabilize paved roads. *Asphalt* is a thick tar used to pave roads and to make roofing materials and floor coverings.

The heaviest product, *petroleum coke*, is almost pure carbon and is the product that remains after all other hydrocarbons have been removed. Coke with low sulphur content is used as fuel for industries and power plants. Coke with high sulphur content is used as a catalyst in refineries.[8]

CRUDE OIL IN TEXAS

Texas' first oil well began producing in 1866, at Melrose in Nacogdoches County. The area became home to Texas' first commercial oil field, first pipeline and first effort to refine crude oil.

On January 10, 1901, an oil well on a small hill called Spindletop near Beaumont created a worldwide sensation when it came in with such explosive force that it blew six tons of drill pipe, mud, rocks and crude oil several hundred feet into the air. The geyser of oil continued for nine days, becoming the world's first "gusher."[9]

Within a few months, 214 wells on Spindletop hill owned by 100 different companies were producing up to 100,000 barrels of oil a day — more than all the rest of the world's oil production combined.[10] Within a year, Spindletop wells were producing 17.5 million barrels annually.

In October 1930, a vast oil field opened in East Texas. Overnight, Kilgore, Longview and Tyler became oil towns. The East Texas field was the largest and most prolific oil reservoir ever found onshore in the continental U.S. Spanning 140,000 acres of piney woods and sandy soil, the 30,340 wells drilled in the field so far have produced more than 5.4 billion barrels of oil.[11]

Along with Spindletop and the East Texas field, other prolific and well-known Texas oil fields were discovered: the Yates, McCamey, Kermit and Kelly-Snyder fields in the Permian Basin of West Texas; the Austin Chalk in Central and South Texas; and the Tomball and Anahuac fields on the Gulf Coast, to name only a few.[12]

Economic Impact

As mentioned throughout this report, both the federal and state governments consolidate economic data for oil and natural gas industries because of the high degree of overlap between the two. In 2006, more than 312,000 Texans, or 3.1 percent of the state work force, were employed in the oil and natural gas industry, which accounted for $159.3 billion or 14.9 percent of Texas' gross state product (GSP). For comparison, in 2003 the industry contributed $85.6 billion to GSP, 10.3 percent of the state GSP.

Likewise, oil and gas industry wages have risen substantially in recent years. In 2006, wages totaled $30.6 billion, or about 6.9 percent of all wages in Texas. In Texas in 2003, oil and gas

In 2006, more than 312,000 Texans, or 3.1 percent of the state work force, were employed in the oil and natural gas industry.

industry wages were $20.9 billion or 5.8 percent of all wages.

Historically, the oil and natural gas industry have accounted for approximately 10 percent to 25 percent of the state's GSP, a trend that roughly tracks the price of oil (**Exhibit 4-2**). (The price indicated in the exhibit is based on the taxable value of oil from in-state production, in dollars adjusted for inflation.)

Historically, the oil and natural gas industry have accounted for approximately 10 percent to 25 percent of the state's GSP, a trend that roughly tracks the price of oil.

Refining and petrochemical industries combined represented 31 percent of all oil and gas employment in 2006, or about 1 percent of all nonfarm employment in Texas. Likewise, refining and petrochemical industries accounted for 28.5 percent of all oil and gas wages and 27.5 percent of oil and gas GSP. When compared to the state, these two industries accounted for 2 percent of all state wages and 4.1 percent of GSP.[13]

The federal and Texas state governments impose several major taxes on oil and gas production and consumption, in addition to receiving royalties, rentals and bonuses from the leasing of federally- or state-owned mineral ownership. The federal and state gasoline taxes support transportation initiatives such as highway infrastructure and mass transit.

Texas imposes severance taxes on the value of oil and gas produced in the state, which has been a major and relatively stable source of revenue until the last two decades. Portions of these tax revenues are rebated back to producers under economic incentive programs. (For more information on oil and gas taxes, incentives and subsidies, see Chapter 28 of this report.)

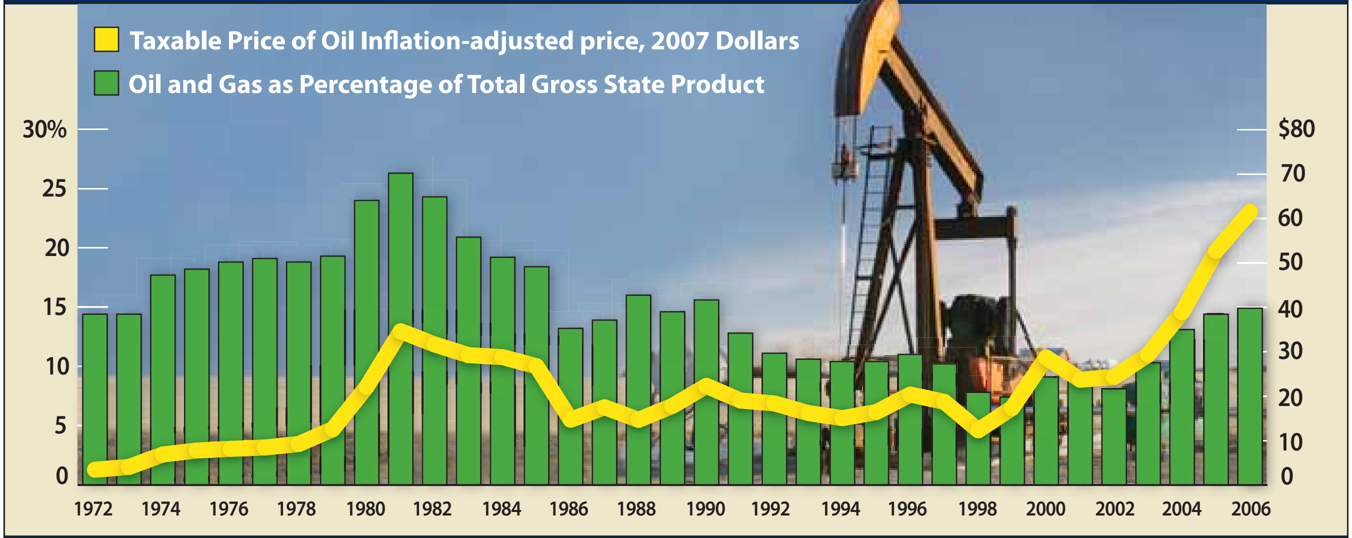
Consumption

Demand for petroleum products in the U.S. remains strong, but it can be mitigated by conservation and efficiency improvements. For example, in 2005, each of the estimated 296 million people in the U.S. used an average of almost three gallons of petroleum every day. In 1978, the average American used 3.5 gallons per day.[14]

In 2006, crude oil imports totaled 10.1 million barrels per day (MBD), two-thirds of the

Exhibit 4-2

Texas Oil and Gas Industry Percentage of Gross State Product and Taxable Price of Oil (2007 dollars)



Sources: U.S. Bureau of Economic Analysis and Texas Comptroller of Public Accounts.

total U.S. supply of 15.2 MBD, according to the Energy Information Administration (EIA) of the U.S. Department of Energy (DOE). After several additions of other petroleum products by refiners and fuel blenders, total petroleum consumption came to 20.6 MBD for 2006.

The transportation sector used almost 14 MBD, or 68 percent, of all petroleum resources, mainly for fuels. Industry used 25 percent or 5.1 MBD. Residential, commercial and electric power use of petroleum products accounted for a combined 1.5 MBD or 7 percent (**Exhibit 4-3**).[15]

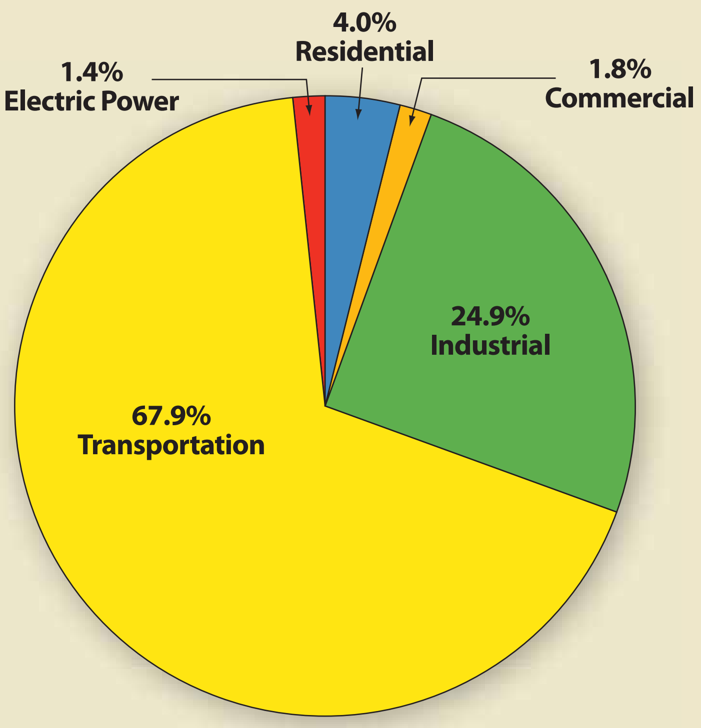
In 2006, motor gasoline accounted for 45 percent of all fuels consumed in the U.S. Distillate fuel oils, used primarily for heating, represented 20 percent; LPGs, 10 percent; jet fuel, 8 percent; and residual fuel oil, used to run refineries, accounted for 3 percent (**Exhibit 4-4**).

To compare the energy value of different fuels, EIA reports each fuel's use in British thermal units (Btu), the amount of heat each fuel produces, whether it is sold by weight, volume or quality. In 2005, petroleum products (including oils, gasoline and other liquid fuels, but not natural gas) provided 41 percent of the 100.4 quadrillion Btu consumed in the U.S.

In the same year in Texas, petroleum products alone accounted for 49 percent of the state's almost 12 quadrillion Btu (or "quads") of energy consumption, an amount almost half as much as the consumption of the second-ranked state, California.[16] Texas led all states in both

Exhibit 4-3

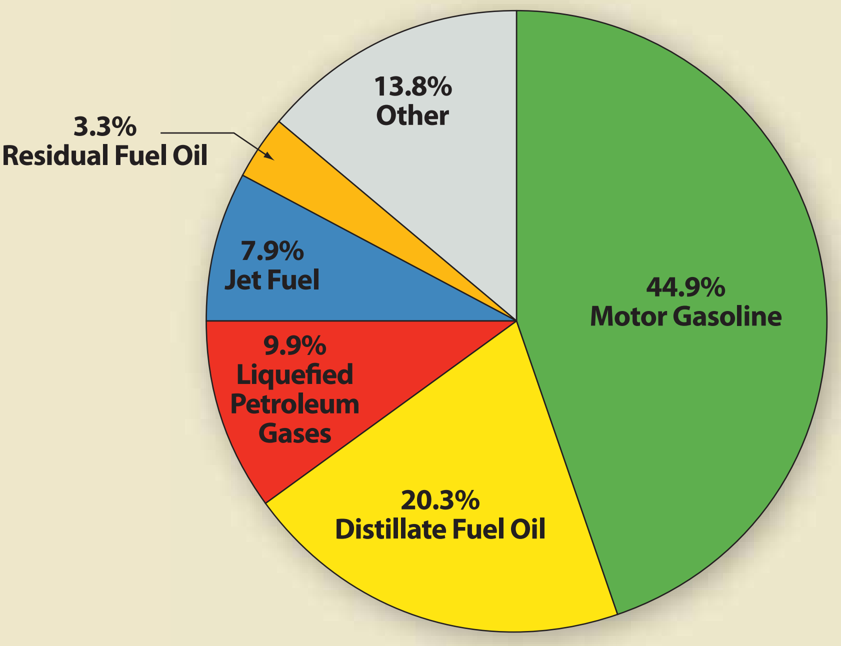
U.S. Petroleum Consumption by Sector, 2006 (Total 20.6 Million Barrels per Day)



Sources: U.S. Energy Information Administration and Texas Comptroller of Public Accounts.

Exhibit 4-4

U.S. Petroleum Consumption, 2006 (Total 20.6 Million Barrels per Day)



Note: Numbers may not total due to rounding.

Sources: U.S. Energy Information Administration and Texas Comptroller of Public Accounts.

Texas is the largest chemical producer in the country, with 14 percent of the nation's chemical output and more than 200 chemical plants.

petroleum and all energy consumption in 2005 (**Exhibit 4-5**).

Texas' lead in consumption is largely due to the state's vast, energy-intensive petrochemical industry and the state's hot climate. Texas is the largest chemical producer in the country, with 14 percent of the nation's value of chemical output and more than 200 chemical plants.[17] The state uses more LPG than all other states combined, again largely because of the petrochemical industry.

Texas' numerous refineries and chemical plants use the very petroleum products they are refining as fuel to run them. In 2005, the total energy consumption of Texas' industrial sector was more than two and a half times higher than that of second-place Louisiana's — 5.8 quads, compared to 2.3 quads.[18]

In Texas and the U.S., oil products provide nearly all vehicular fuel.[19]

Oil also supplies a major portion of the nation's home heating fuel. Currently, in the Northeastern U.S., 6.2 million households (78 percent) burn fuel oils for heating. For the U.S. as a whole, the number is 8.0 million households.[20]

Oil products also fuel some of the nation's electricity generators, although in proportions dwarfed by coal and natural gas. In 2006, 0.4 percent of the electricity generated in Texas came from petroleum-powered generating facilities.[21] Nationally, oil is responsible for just 1.7 percent of the electricity generation.

Production

Texas produced 397.2 million barrels of crude oil in 2006, 21.3 percent of total U.S. production.[22]

Exhibit 4-5

Top Ten Petroleum-Consuming States, 2005 (Trillion Btu)

State	Petroleum Only Total	Percent of U.S. Total	All Energy Sources Total	Percent of U.S. Total
Texas	5,671.1	13.9%	11,558.3	11.5%
California	3,869.6	9.5	8,359.8	8.3
Florida	2,163.2	5.3	4,563.3	4.5
New York	1,849.4	4.5	4,179.5	4.2
Louisiana	1,587.4	3.9	3,613.0	3.6
Pennsylvania	1,535.4	3.8	4,050.2	4.0
Illinois	1,486.1	3.6	4,121.5	4.1
Ohio	1,366.5	3.4	4,081.6	4.1
New Jersey	1,331.7	3.3	2,728.6	2.7
Georgia	1,159.1	2.8	3,173.0	3.2

Source: U.S. Energy Information Administration.

Texas is currently the world leader in CO_2 enhanced oil recovery, with more than 50 projects under way in West Texas.

Crude oil most commonly is found in underground reservoirs and is obtained by drilling. Some alternative sources of oil, however, like the tar sands of Alberta, Canada, are mined near the surface. Other alternative sources, now feasible because of improved but expensive drilling methods, are found in certain rock formations previously thought to be too difficult from which to produce, such as oil shales and coalbeds.

Drilling the Well

To retrieve oil and gas, a rig with a rotating bit drills a hole six to 10 inches wide into the earth. Steel pipe called "casing" is cemented in the hole to line it. As the drill bit slowly grinds downward, drilling fluid called "mud" is pumped down the inside of the drill pipe to help break up the rock, maintain downward pressure and clean, cool and lubricate the bit. To complete the well, the casing in the production zone is perforated with small holes, allowing oil and gas to flow from the surrounding rock up into the pipe.

Exhibit 4-6 provides a schematic of a typical oil rig. **Exhibit 4-7** provides more detail on the underground portion of the well.

In all oil and gas fields, the hydrocarbons are found in small (microscopic to less than BB-sized) holes distributed though the reservoir-rock interval. Fracturing that rock and applying downward pressure are two of the most common retrieval methods. Typically, even the best production methods have produced only one-third of the oil in place.[23]

Producers routinely use "enhanced oil recovery," or EOR to retrieve the remaining oil or gas in place. EOR involves injecting fluids or gases into the reservoir to make the oil more mobile and more likely to flow to producing wells. Water, carbon dioxide (CO_2), soap-like substances and steam are the most common EOR fluids.[24]

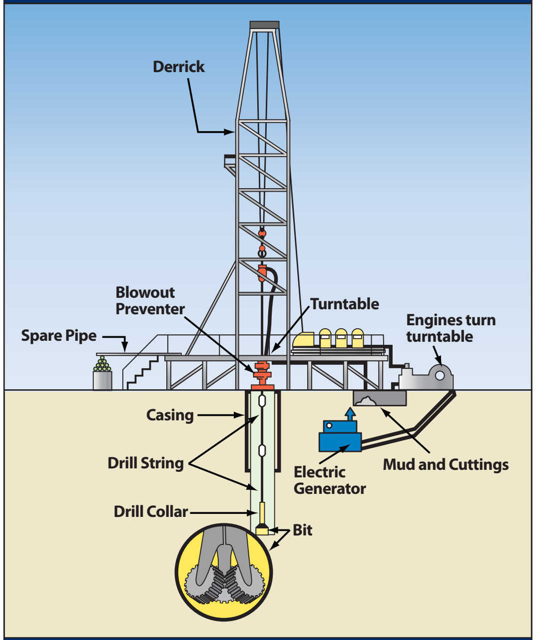
Carbon Dioxide EOR

Texas is currently the world leader in CO_2 EOR, with more than 50 projects under way in West Texas. An extensive CO_2 pipeline network in the western U.S. carries the gas from natural sources in Colorado and New Mexico to West Texas. This system is capable of carrying one to four billion cubic feet (Bcf) of CO_2 daily.

West Texas fields now produce more than 100,000 barrels of oil per day via carbon dioxide EOR. Further expansion is limited by a lack of available CO_2 supplies. The most likely candidate for these

Exhibit 4-6

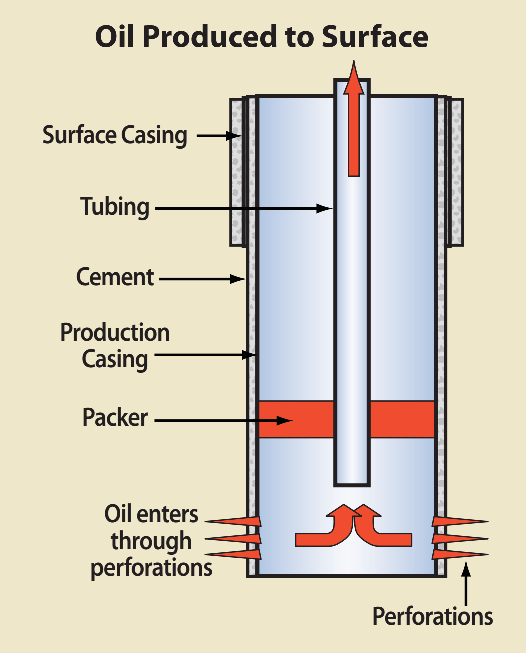
A Typical Oil Rig



Source: Dukes Wood Oil Museum.

Exhibit 4-7

The Well



Source: Oil and Gas Blog.

supplies is from industrial carbon-capture efforts such as FutureGen.[25] (See Chapter 7 for more information on FutureGen.)

Post-Production

When the well is complete and producing, it is topped off with a pumpjack or a cluster of valves known as a "Christmas tree." These valves regulate pressure and control flows. An outlet valve from the Christmas tree is connected to a distribution network of storage tanks and pipelines that supply the crude oil to refineries.

According to Baker Hughes, a Texas corporation specializing in oil drilling equipment, Texas had an average of 377 rotary rigs — the standard drilling rig in use today — operating between 1987 and 2007. The rig count fluctuated significantly during that period, however, from an average low of 227 in 1999 to 748 in 2007, the latter figure representing 45.4 percent of all oil rigs operating in the U.S. in that year (**Exhibit 4-8**).[26]

In 2007, Baker Hughes reported that U.S. drilling activity had reached a 21-year high, with 1,798 rigs in operation. Onshore rigs and rigs in Texas accounted for most of the increase.[27]

Exhibit 4-9 shows the locations of Texas' highest-producing oil and gas fields and oil wells, respectively. Today, about 79 percent of the state's oil wells are classified as marginal or "stripper" wells, which produce fewer than 10 barrels per day.[28] This low recovery rate per well is one indication of the advanced maturity of Texas oil production.

Offshore Production

Texas oil also is produced offshore in the Gulf of Mexico. As of 2006, offshore oil reserves in Texas' portion of the Gulf totaled 158 million barrels, from both state and federal areas.[29] Much of the Gulf's proven reserves lie beneath federal waters off the Louisiana shore. About 3.7 billion barrels of oil now exist in federal offshore reserves in the Gulf (**Exhibit 4-10**).

Proven oil and gas reserves are an important indicator of the nation's energy future. These reserves are estimates of oil or gas in the ground deemed to be both economically and operationally recoverable.[30] Since 1996, proven reserves from water deeper than 200 meters (656 feet, or 0.12

miles) have exceeded those in shallower water and now account for more than 81 percent of all Gulf of Mexico reserves.[31] Recent large discoveries in ultra-deep (greater than 5,000 feet) water offshore Texas are not yet included in these data.[32]

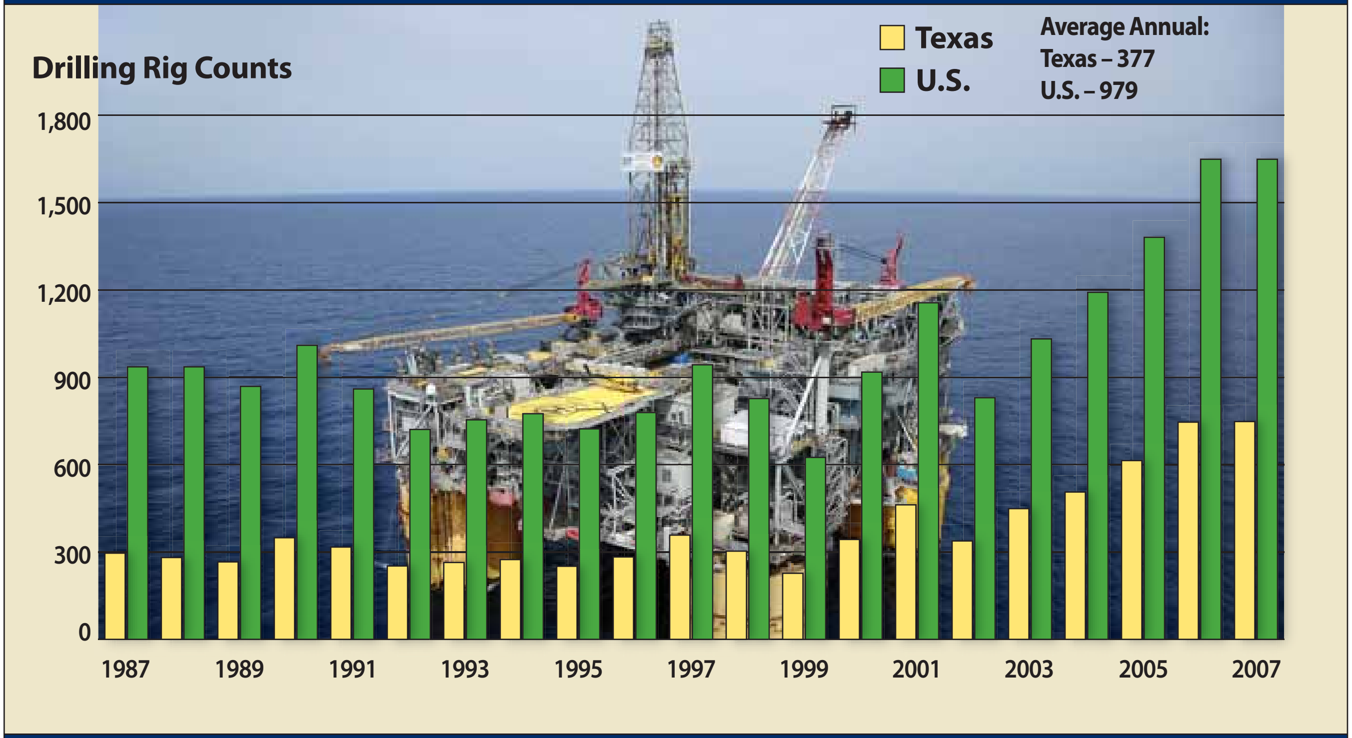
Texas has an unusual relationship with the federal government concerning its offshore lands. When Texas entered the Union in 1845 by treaty, it retained ownership of more than 4 million acres of offshore lands out to the "three marine league" line — about 10.3 statute miles, or 9 nautical miles.[33] Only Texas and Florida (along its Gulf coast only) own these "submerged lands" out to 10.3 miles; all other states retain ownership only as far as three nautical miles. (A nautical mile is a measure of latitude equivalent to 1.15 miles.)[34]

In the 1970s, a dispute arose between Texas and the federal government over how to divide the bonuses, rents, royalties and other revenues of wells in areas of the Gulf where state and federal ownership appeared to overlap. In 1984, a federal district court determined that these tracts were co-owned, resulting in a 50/50 split over the revenues in dispute.[36] Federal law passed in 1986 in response to the decision awarded Texas $382 million in past bonuses, rents, royalties and other revenues and allowed a 27 percent share of future income.[37] In fiscal 2006, Texas collected $13.4 million in these revenues; in fiscal 2007, Texas collected $15.9 million.[38]

One ton of carbon dioxide or CO_2 at normal atmospheric pressure and 77 degrees Fahrenheit occupies 556.2 cubic meters or 19,642 cubic feet. Twenty tons would fit inside the Senate chamber in the Texas Capitol. Each gallon of conventional gasoline, when combusted, produces almost 172 cubic feet of CO_2, an area with a height, width and depth of 5.6 feet.[35]

EXHIBIT 4-8

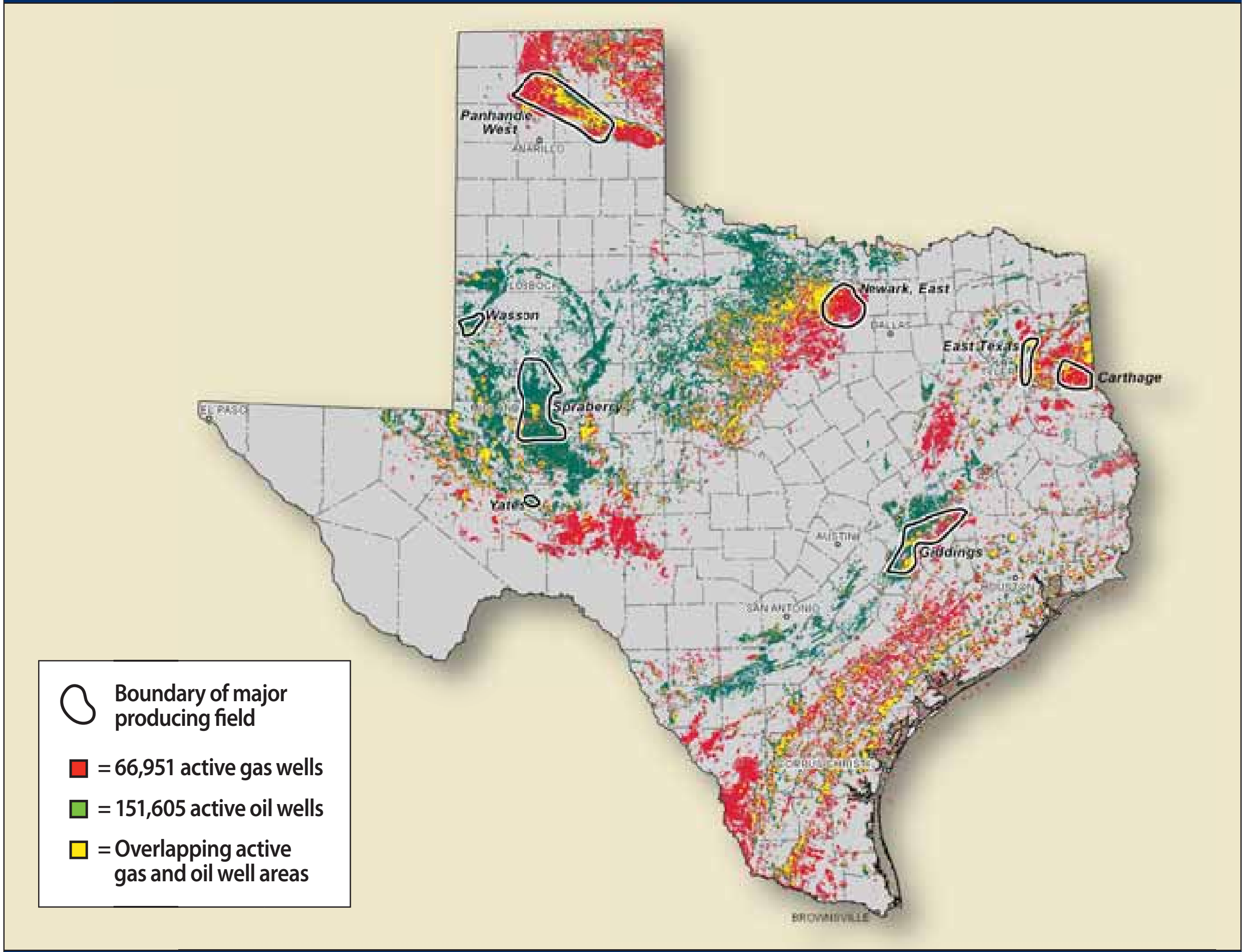
Average Annual Drilling Rig Counts for Texas and the U.S.



Sources: Baker Hughes Inc and Texas Comptroller of Public Accounts.

Exhibit 4-9

Oil and Gas Map of Texas



Source: University of Texas at Austin.

The first CO_2-flood project in the world began in West Texas in the 1970s, in the Kelly-Snyder field in Scurry County. Kelly-Snyder, one of the largest fields in the U.S., has produced to date 1.3 billion barrels of oil from the Canyon Reef formation since its discovery in 1948.[39]

In the 1970s, many operators and producers in the Kelly-Snyder field realized that EOR was becoming necessary, but knew it would be expensive and possibly fruitless if each approached it alone. The operators formed SACROC, the Scurry Area Canyon Reef Operating Committee, to oversee reservoir-wide EOR operations, and began injecting CO_2. As a result, anticipated total production increased by 5 to 12 percent.[40] More than 13 million tons of CO_2 is injected into SACROC wells annually, with about half of that withdrawn and recycled. Since CO_2 injections began in 1972, SACROC has stored more than 55 million tons of CO_2. By comparison, a 500 megawatt coal-fired power plant produces three to four million tons of CO_2 annually.[41]

Exhibit 4-10

Federal Proven Crude Oil Reserves in Gulf of Mexico (Million Barrels)

Year	Total Proven Reserves	Percentage of Crude Oil Proven Reserves from Waters More than 200 Meters Deep
1992	1,835	30.4%
1993	2,072	39.8
1994	2,127	41.2
1995	2,518	49.3
1996	2,567	51.1
1997	2,949	57.0
1998	2,793	57.7
1999	2,744	59.3
2000	3,174	63.7
2001	4,288	74.8
2002	4,444	75.9
2003	4,554	79.6
2004	4,144	79.2
2005	4,042	81.0
2006	3,655	81.6

Source: U.S. Energy Information Administration.

Texas is home to 23 petroleum refineries, including half of the 12 most productive refineries in the U.S.

Reserve estimates for Texas' state-owned offshore reserves are very small compared to reserves further offshore, in federal waters (**Exhibit 4-11**). The relatively shallow state offshore fields are considered to be "mature" by experts; that is, their production is declining, and new discoveries are smaller and more quickly depleted. But the industry is seeking deeper production, primarily of natural gas in state waters based on new three-dimensional (3-D) seismic survey results.[42]

Refining

Texas is home to 23 petroleum refineries, including half of the 12 most productive refineries in the U.S.[43] Texas has more than a fourth of all U.S. oil refining capacity, more than any other state.[44] The nation's largest refinery, owned by ExxonMobil, is located in Baytown, Texas. This refinery, originally built in 1919, has a distillation capacity of 562,500 barrels per day (b/d).[45] Texas as a whole has a daily refining capacity of 4.7 million barrels (**Exhibit 4-12**).[46]

In addition to leading the U.S. in refining capacity, Texas also leads the U.S. in daily refinery production (**Exhibit 4-13**).

Refineries require extensive federal and state environmental review, which may explain in part why no new refineries have been built from the ground up in the U.S. since 1976. One proposed refinery near Yuma, Arizona recently received final approval from state and federal authorities after a seven-year process.[47] Cost is another factor. The International Energy Agency estimated in 2003 that refineries cost $10,000 per barrel of daily capacity.[48] The new Yuma refinery will cost an estimated $2 billion to build.[49]

While new refineries have not been built, expansions of existing refineries are a common occurrence. Just recently, on December 10, 2007, in Port Arthur, Texas, a partnership of Royal Dutch Shell and Saudi Aramco broke ground on a 325,000 b/d refinery expansion that will increase the existing refinery's throughput capacity to 600,000 b/d by 2010, replacing Exxon's Baytown refinery as the largest refinery in the world.[50] In February 2008, Total S.A. of France announced a 50,000 b/d expansion of its Port Arthur refinery. At the same time, Valero Energy of San Antonio announced plans to expand its Port Arthur refinery.

Exhibit 4-11

Texas Proven Crude Oil Reserves (Million Barrels)

Year	Texas Onshore Reserves	Texas Gulf of Mexico FEDERAL Offshore Lands	Texas Gulf of Mexico STATE Offshore Lands
1986	7,152	101	2
1987	7,112	88	8
1988	7,043	78	7
1989	6,966	69	6
1990	7,106	71	6
1991	6,797	60	7
1992	6,441	192	5
1993	6,171	192	4
1994	5,847	205	4
1995	5,743	249	8
1996	5,736	210	8
1997	5,687	362	4
1998	4,927	310	1
1999	5,339	302	3
2000	5,273	423	5
2001	4,944	411	6
2002	5,015	356	6
2003	4,583	303	7
2004	4,613	225	9
2005	4,919	190	5
2006	4,871	155	3

Sources: U.S. Energy Information Administration and Texas Comptroller of Public Accounts.

Exhibit 4-12

Top 15 U.S. States and Territories, Total Refining Capacity, 2006 (Barrels per Day)

State	Total Operable Refining Capacity	Percent of U.S. Capacity
Texas	4,685,526	26.0%
Louisiana	2,971,183	16.5
California	2,037,188	11.3
Illinois	903,600	5.0
Pennsylvania	773,000	4.3
New Jersey	655,000	3.6
Washington	623,850	3.5
Ohio	510,120	2.8
Virgin Islands	500,000	2.8
Oklahoma	490,700	2.7
Indiana	433,000	2.4
Alaska	375,000	2.1
Mississippi	364,000	2.0
Minnesota	349,300	1.9
Kansas	300,700	1.7
U.S. Total	**18,021,392**	

Sources: U.S. Energy Information Administration and Texas Comptroller of Public Accounts.

Preparing Petroleum Products for Market

Oil is refined in three basic steps: separation, conversion and treatment. Refineries remove impurities in crude oil such as sulphur, nitrogen and metals. Refined and distilled oil yields three major types of products: fuels, finished non-fuel products and chemical industry feedstocks.

After crude oil is removed from the ground, it is sent to refineries by pipeline, ship or barge. According to EIA data for 2006, U.S. refineries and blenders produced more than 6.5 billion barrels of petroleum products from 6.2 billion barrels of crude oil, natural gas and other hydrocarbons and gases.[51] (Blenders are companies that do not refine oil products but prepare them for the marketplace by, for instance, adding oxygenates to gasoline.) Crude oil accounted for 90 percent or 5.6 billion barrels of the hydrocarbons used by refineries and blenders.

Gasoline accounted for more than 46 percent, or 3 billion gallons, of the products made by refiners and blenders in 2006; distillate fuel oil amounted to less than half of that share, at 22.6 percent or 1.5 billion gallons. **Exhibit 4-14** illustrates a refinery's typical processes.

Once refined, the products make their way from onshore "tank farms" to pipelines, storage terminals near urban areas and finally to trucks for

Exhibit 4-13

U.S. Crude Oil and Petroleum Products Refinery Net Production (Thousand Barrels per Day)

	2005 Production	2005 Percent of U.S.	2006 Production	2006 Percent of U.S.	2007 Production	2007 Percent of U.S.
U.S.	15,579	100.0%	14,996	100.0%	14,731	100.0%
East Coast	1,711	11.0	1,482	9.9	1,434	9.7
Midwest	3,140	20.2	3,150	21.0	3,032	20.6
Gulf Coast	8,120	52.1	7,818	52.1	7,812	53.0
Texas Inland	620	4.0	629	4.2	578	3.9
Texas Gulf Coast	4,113	26.4	3,674	24.5	3,610	24.5
Louisiana Gulf Coast	3,110	20.0	3,228	21.5	3,335	22.6
North Louisiana, Arkansas	189	1.2	199	1.3	188	1.3
New Mexico	89	0.6	87	0.6	101	0.7
Rocky Mountain	590	3.8	585	3.9	567	3.8
West Coast	2,018	13.0	1,961	13.1	1,885	12.8

Sources: U.S. Energy Information Administration and Texas Comptroller of Public Accounts.

delivery to individual consumers, which could be residential homes, gasoline stations, electric power generation facilities or petrochemical plants.

Availability

Texas' crude oil reserves represent almost one-fourth of total U.S. reserves. Alaska, other Gulf states, Oklahoma, Wyoming, New Mexico, California and federal offshore areas provide most of the remainder.[52] Although Texas' oil reserves are found throughout the state, its largest remaining reserves are concentrated in the Permian Basin of West Texas, which contains 21 of the nation's 100 most productive oil fields.[53]

Texas oil production peaked in 1972, at more than 3.4 million barrels per day. Since then, production has declined steadily and now represents less than a third of its 1972 peak. **Exhibit 4-15** shows Texas' oil production from 1981 through 2006.

While Texas' crude oil reserves and production have declined, the state still leads the nation in its average daily crude oil production (**Exhibit 4-16**).

Both the U.S. and Texas depend on foreign countries for petroleum. U.S. net imports of foreign oil represented 59.9 percent of the petroleum it consumed in 2006.[54] The U.S. leads the world in petroleum imports (**Exhibit 4-17**).

COSTS AND BENEFITS

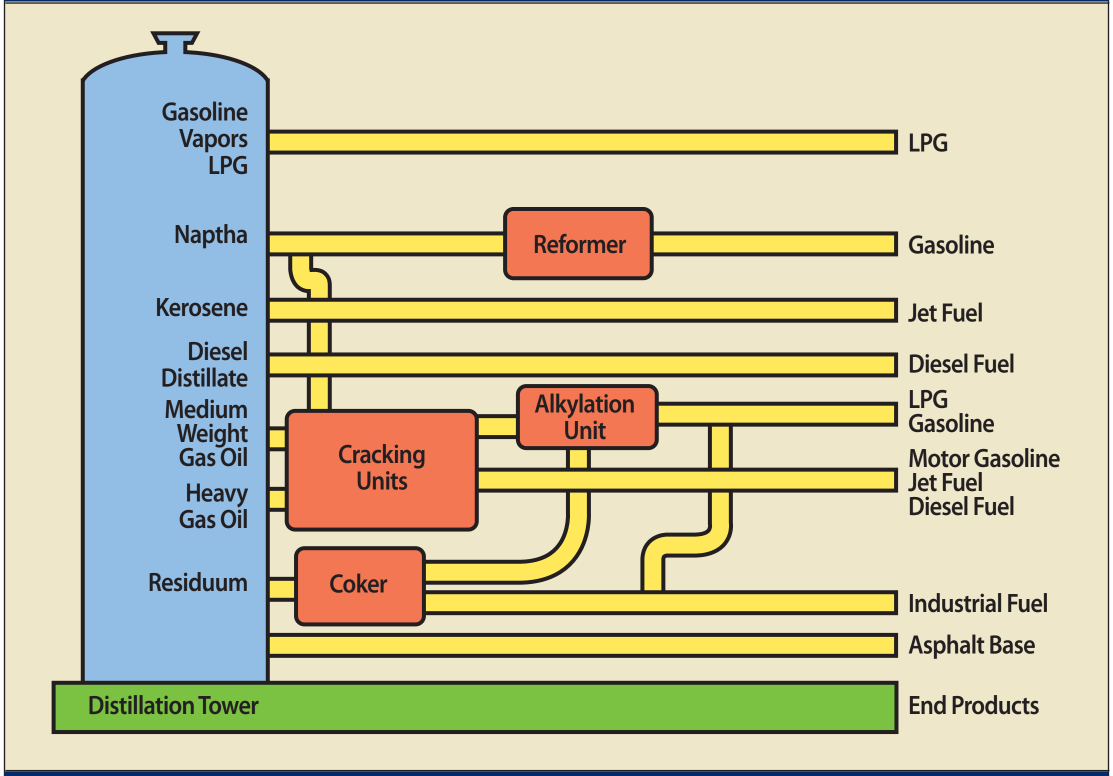
The cost of finding and producing petroleum depends on many factors, particularly the type and complexity of the geological surveys needed to locate it; the location of the target reservoir (and particularly, whether it is onshore or offshore); and the depth of the well. According to EIA, in 2004 the U.S. average oil and gas well drilling depth for all exploratory and development wells was 5,838 feet; the average nominal cost of drilling those wells was about $1.7 million, or $292.57 per foot.[55]

Deep-water drilling is considerably more expensive than drilling the average well on land. Houston-based Transocean, the world's largest offshore drilling contractor, has 19 ultra-deepwater rigs capable of drilling in water depths of at least 7,500 feet. The current contract rate to lease one of these rigs ranges between $183,000 and $600,000 per day.[56]

While company drilling cost data are highly proprietary, some information gleaned from

EXHIBIT 4-14

Petroleum Refining: Basic Processes and Products



Source: U.S. Department of Energy.

public sources confirms that record oil prices and finite supplies of drilling equipment are driving up costs. A July 2007 article in *The Wall Street Journal* stated that "Renting a state-of-the-art floating drilling rig in 2001 cost about $200,000 a day; the same rig now fetches more than $500,000 a day."[57] EIA reports that offshore operating costs increased by a third in 2006.[58]

But similar price increases have affected onshore drilling in West and South Texas. In 2006, drilling equipment costs for typical 4,000 foot and 8,000 foot oil wells in West Texas were $1.4 million and $2.3 million, respectively, representing 41.2 percent and 33 percent increases since 2000. The additional cost of EOR on holes of these depths was $8.8 million and $17.9 million, respectively, representing price increases of 39.8 percent and 36.7 percent since 2000 (**Exhibit 4-18**).[59]

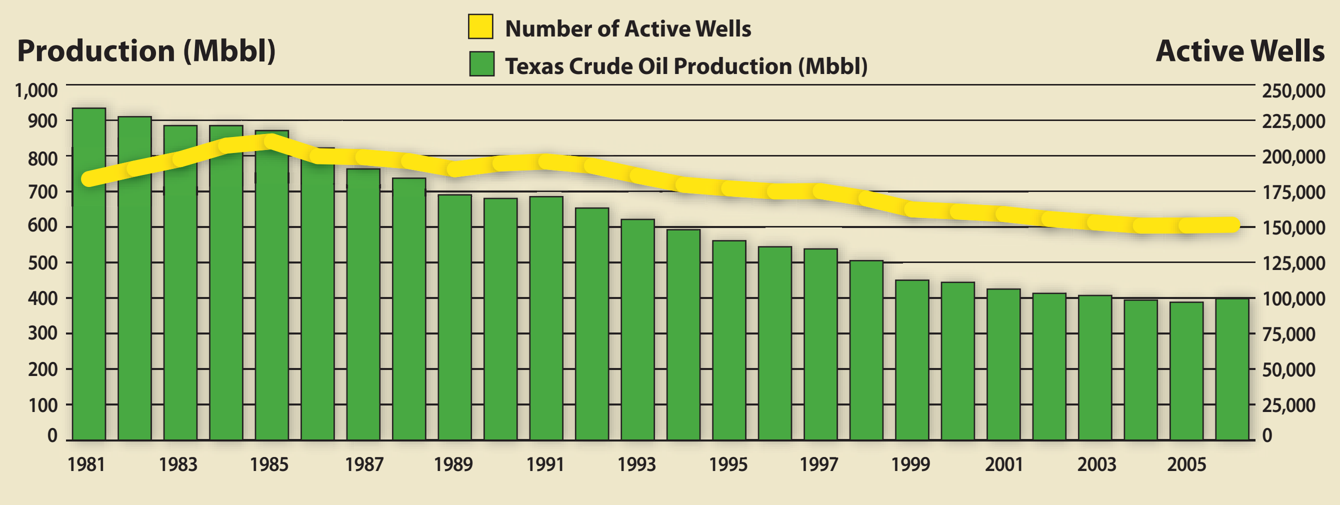
As **Exhibit 4-18** indicates, the story in South Texas is similar. Typical 4,000-foot oil wells now cost nearly $1.5 million for equipment and $332,700 in annual operating costs, 47 percent and 53.4 percent more than in 2000, respectively. Typical 8,000-foot oil wells cost almost $1.9 million in equipment and $416,300 in annual operating costs, 49.4 percent and 54.2 percent more than in 2000. EIA data do not include EOR costs in South Texas.

Cost to Consumers

Sharp increases in the price of a barrel of oil and a gallon of gasoline have dominated recent headlines. Crude oil futures topped $100 per barrel in early 2008 for the first time, eventually exceeding the

EXHIBIT 4-15

Texas Crude Oil Production and Active Wells, 1981-2006



Sources: U.S. Energy Information Administration and Texas Railroad Commission.

all-time inflation-adjusted high price of $103.76 set in April 1980.[60]

In June 2005, the national average retail price of gasoline was $2.16 per gallon. By June 2007, it had risen to $3.05, dropped to $2.80 in September 2007 and was up to $3.24 by March 2008.[61] EIA gives many reasons for these increases, including: strong world economic growth, usually indicating increasing consumption of petroleum products, especially in China and India; the declining value of the dollar, which is used to price oil on the world markets; geopolitical risks; production and refining bottlenecks; and OPEC decisions.[62]

The market price of oil is determined at a few producing areas in the country where pipelines converge before setting off for distant markets. One of those places is Cushing, Oklahoma, where the U.S. benchmark crude oil, West Texas Intermediate (WTI), is priced for futures contracts at the New York Mercantile Exchange. WTI is a "light, sweet" crude because of its low density (making it "light") and low sulphur content (making it "sweet").[63]

WTI developed as a benchmark commodity because it dominates U.S. production. WTI can be refined into high-value products such as gasoline, diesel and jet fuel more easily and less expensively than can heavy, "sour" crudes such as some from the Middle East and Venezuela.[64]

The cost structure of gasoline includes distributing and marketing costs, refining costs and profits, federal and state taxes and the cost of crude oil. In March 2008, the cost of crude oil accounted for 72 percent of the cost of a gallon of gasoline; federal and state taxes accounted for 13 percent; refining costs and profits accounted for 8 percent; and distribution and marketing accounted for 8 percent of the cost (**Exhibit 4-19**).[65]

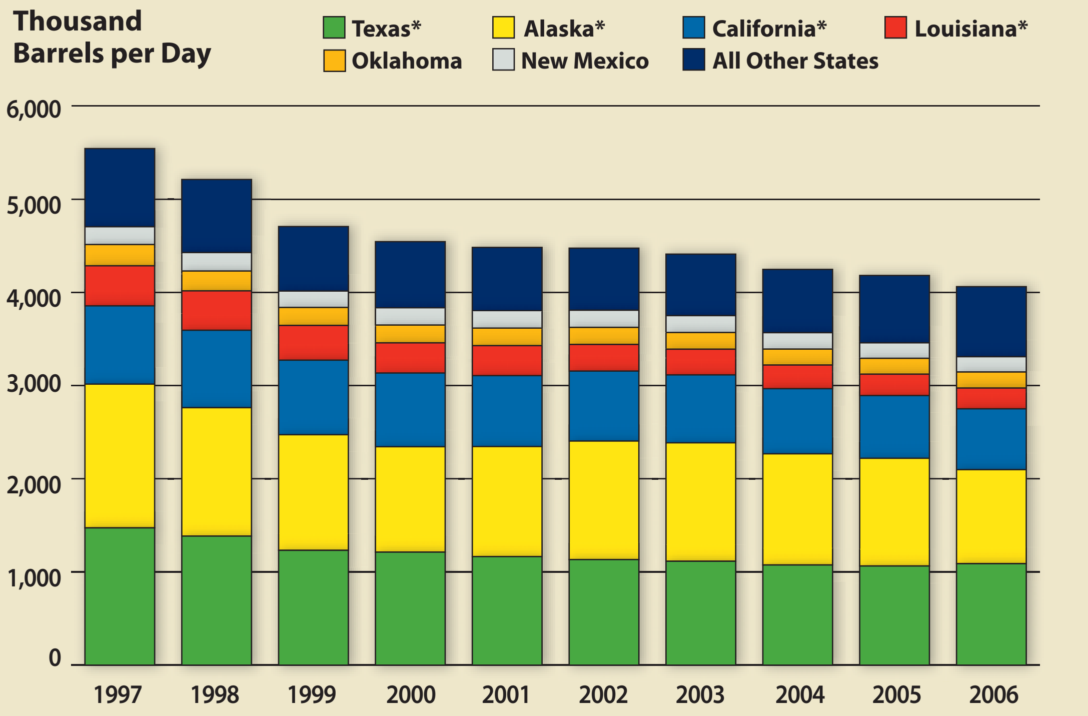
Environmental Impact

The production, refining, transportation, storage and consumption of petroleum and its byproducts, if not expertly handled, entail some environmental risk. The most toxic compounds found in crude oil and many refined products are aromatic hydrocarbons, also known as volatile organic compounds or VOCs. These hydrocarbons mix with the lower levels of the atmosphere and, when heated by the sun, create ground-level ozone, a major component of smog and a greenhouse gas.[66]

While oil spills from tankers can be dramatic and deadly to wildlife, the fact is that more oil seeps out

Exhibit 4-16

U.S. Crude Oil Production by State



*Includes state offshore production.

Source: U.S. Energy Information Administration.

Exhibit 4-17

Top Oil-Importing Countries (Thousand Barrels per Day)

2006 Rank	Country	2006 Net Imports	2005 Rank	2004 Rank	2000 Rank	Net Change 2000-2006
1	United States	12,357	1	1	1	16.1%
2	Japan	5,031	2	2	2	-6.5
3	China	3,356	3	3	7	136.7
4	Germany	2,514	4	4	3	-4.2
5	Korea, South	2,156	5	5	4	1.7
6	France	1,890	6	6	5	-1.3
7	India	1,718	7	8	9	26.6
8	Italy	1,568	8	7	6	-8.9
9	Spain	1,562	9	9	8	10.7
10	Taiwan	940	10	10	10	7.8

These data include crude oil, lease condensates, natural gas liquids, other liquids and refinery gain.
Sources: U.S. Energy Information Administration and Texas Comptroller of Public Accounts.

Exhibit 4-18

Equipment Lease Costs and Annual Operating Costs in South and West Texas

South Texas 4,000-Foot Wells

	2000	2001	2002	2003	2004	2005	2006	Percent Change Since 2000
Lease Equipment Costs	$994,400	$1,014,600	$1,025,800	$1,051,100	$1,269,400	$1,361,700	$1,461,800	47.0%
Annual Operating Costs	$216,900	$224,500	$226,300	$262,800	$281,300	$308,900	$332,700	53.4%

South Texas 8,000-Foot Wells

	2000	2001	2002	2003	2004	2005	2006	Percent Change Since 2000
Lease Equipment Costs	$1,250,300	$1,268,400	$1,277,300	$1,307,300	$1,635,500	$1,749,500	$1,867,900	49.4%
Annual Operating Costs	$269,900	$281,100	$279,000	$328,400	$351,900	$391,600	$416,300	54.2%

West Texas 4,000-Foot Wells

	2000	2001	2002	2003	2004	2005	2006	Percent Change Since 2000
Lease Equipment Costs	$1,018,700	$1,059,300	$1,055,000	$1,065,700	$1,259,800	$1,351,900	$1,438,800	41.2%
Annual Operating Costs	$160,800	$168,400	$154,600	$178,100	$186,900	$214,400	$223,500	39.0%
Enhanced Oil Recovery	$424,700	$447,200	$439,700	$470,900	$472,200	$516,300	$593,700	39.8%

West Texas 8,000-Foot Wells

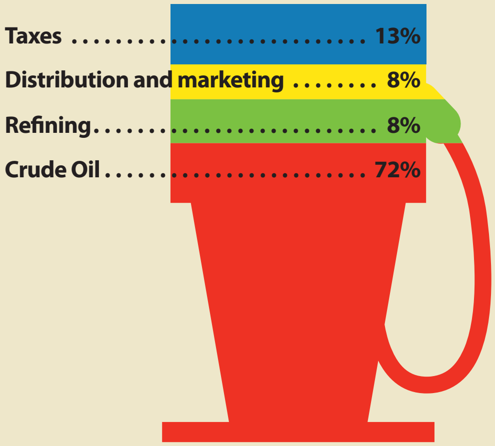
	2000	2001	2002	2003	2004	2005	2006	Percent Change Since 2000
Lease Equipment Costs	$1,765,500	$1,775,000	$1,771,900	$1,781,400	$2,087,100	$2,221,300	$2,348,700	33.0%
Annual Operating Costs	$220,700	$232,700	$213,400	$248,300	$262,700	$309,700	$326,200	47.8%
Enhanced Oil Recovery	$605,800	$635,600	$615,500	$665,700	$662,000	$723,100	$827,900	36.7%

Sources: U.S. Energy Information Administration and Texas Comptroller of Public Accounts.

Exhibit 4-19

Cost Structure of Gasoline

What We Pay For in a Gallon of Regular Gasoline (March 2008)
Retail Price: $3.24 a Gallon



Note: Numbers may not total due to rounding.

Source: U.S. Energy Information Administration.

of the earth naturally, generally from subsea sources, than from manmade ("anthropogenic") spills. The National Academy of Sciences reported in 2003 that more than 60 percent — some 47 million gallons — of crude oil released in North American waters every year comes from natural seepage.[67]

Exploring and drilling for crude oil can disturb the surrounding land and ecosystems, although the impact is generally temporary. Most of the nation's untapped reserves are located offshore; these wells pose a unique set of environmental risks because of the risk of spillage or leakage into surrounding waters.

Many hazardous materials used in drilling must be disposed of after a well is complete. Given that oil and gas reservoirs are found in strata representing the remnants of ancient salt seas, salt water is a frequent drilling byproduct. The Railroad Commission of Texas (RRC) requires producers to use injection wells to force this salt water into deep formations to keep it from mixing with fresh water.

Pipelines used to transport crude oil can leak and pollute the environment. Old, unplugged wells also pose a threat to groundwater, as do the above- and below-ground tanks generally used to store oil and refined oil products. New technologies can reduce but not eliminate these environmental risks.

Refineries face particularly difficult disposal problems because of the number and volume of hazardous substances and chemical byproducts involved in their operations. Petroleum refineries are a major source of toxic air pollutants such as benzene, toluene, ethyl benzene and xylene (the so-called BTEX compounds.) They also are major sources of federal Clean Air Act (CAA) "criteria" air pollutants — that is, those subject to federal regulation — including particulate matter, nitrogen oxides (NO_X), carbon monoxide (CO), hydrogen sulfide (H_2S) and sulfur dioxide (SO_2). Refineries also release hydrocarbons such as methane and light volatile fuels and oils.[68]

In addition, oil refining produces wastewater sludge and solid waste that can contain metals such as arsenic, mercury and other toxic compounds, all of which require special handling, treatment and disposal. Treatment of these wastes includes burning, treatment both on- and off-site, land filling, chemical fixation and neutralization.

The combustion of hydrocarbons creates carbon dioxide, a greenhouse gas. Methane, the lightest hydrocarbon that can be produced by the decay or decomposition of any biological material, is another common greenhouse gas.

Crude oil production and refining also can result in some water consumption, requiring up to 2,500 gallons per million Btu of energy produced, depending on production methods.

Other Risks

The highly flammable nature of petroleum products, particularly when dispersed in the air, carries a risk of fire or explosion. Furthermore, as Hurricanes Katrina and Rita in 2005 showed, extreme weather poses a serious risk for the entire petroleum industry along the Gulf of Mexico, with potential environmental and economic effects.

Other hurdles for the Texas oil and gas sector include an insufficient number of technically educated workers to meet demand. Nationally, employment in this sector dropped by 55 percent between 1982 and 2003. In Texas, oil and gas extraction employment fell by 12.9 percent between 1990 and 2007, a loss of 11,260 jobs.[69] Those who remained in the workforce — the older, most experienced geologists, engineers and drilling crews — have few younger, educated workers to replace them, thus introducing the risk of a labor shortage that could extend supply outages and lead to higher maintenance costs. One producers' trade association estimates that less than 15 percent of the oil and gas work force is under 35 years of age; 10 percent is aged 65 or older. By comparison, 60 percent of a typical technology company's workforce is under 35 years of age with few employees over the age of 60.[70]

Furthermore, the CAA makes it difficult for refiners in areas such as Houston, which is not in compliance with CAA air quality standards, to build new refining capacity. In 2005, industry representatives identified state and local tax structures that rely on property and capital-intensive businesses as placing a limit on new development and expansion.[71] For these reasons and many others, no new refinery has been built in the U.S. since 1976.[72]

Energy and National Security Debate

Despite the fact that the U.S. is still its own largest supplier of total energy, the current policy dialogue has linked the idea of energy independence from foreign suppliers with our national security interests.

Many experts, however, including those with the National Petroleum Council (NPC) and the Center for Strategic and International Studies (CSIS), caution against making this connection absolute. A 2007 NPC study said:

> "Energy independence" should not be confused with strengthening energy security. The concept of energy independence is not realistic in the foreseeable future, whereas U.S. energy security can be enhanced by moderating demand, expanding and diversifying domestic energy supplies, and strengthening global energy trade and investment. There can be no U.S. energy security without global energy security.[73]

An oil expert with CSIS testified before Congress in March 2006 that:

> The oil market is a truly global market. Reducing America's oil consumption can potentially have a dampening effect on prices, but it will not completely insulate us from supply or price volatility. We frequently speak about "politically unstable" sources of oil supplies around the globe, but the largest protracted losses of global oil and gas output in both 2004 and 2005 were the result of hurricanes in the U.S. Gulf of Mexico.[74]

The security of Middle Eastern oil supplies often is expressed as the nation's greatest concern, but it is worth noting that in 2007, the U.S. imported more oil from Canada alone (2,337,000 barrels per day) than it did from Persian Gulf countries (2,305,000 barrels per day).[75]

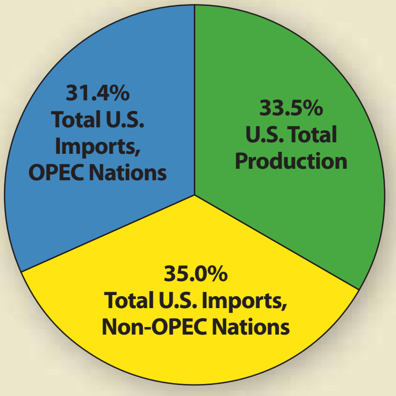
In addition, domestic production supplies one-third of all the oil consumed in the U.S. (**Exhibit 4-20**).

Exhibit 4-21 depicts the U.S.' 10 largest sources of foreign crude oil imports in 2007 by nation and what the U.S. imports from the rest of the world. Total imports that year were 4,394,600,000 barrels.

In fact, U.S. imports from OPEC nations as a share of all imports have declined since 1997. The share of U.S. imports attributable to OPEC was highest in the cartel's founding year, 1960, at 72.4 percent. (It should be noted that overall U.S. oil imports were only a small portion of total oil sup-

EXHIBIT 4-20

U.S. Crude Oil Supply by Source, 2006



Source: U.S. Energy Information Administration.

In 2007, the U.S. imported more oil from Canada alone than it did from Persian Gulf countries.

ply until the mid-1970s.) In 2007, with imports providing two-thirds of the U.S. oil supply, OPEC accounted for 44.5 percent of all U.S. imports and 28.9 percent of all U.S. supplies.[76]

State and Federal Oversight

Most federal agencies have some oversight over aspects of the oil exploration, production, refining and transportation industries, which generally comes with the enforcement of a wide spectrum of federal environmental, health, safety, emergency response and homeland security laws. Likewise, most states and some local jurisdictions either regulate the industries directly under authority delegated by a federal agency or by statute, or have a site-specific interest, such as the siting of a tank farm.

In addition to governmental oversight, some areas have organizations to help industries cope with disasters. For example, in the 1950s, petrochemical companies and local governments located along the Houston Ship Channel formed a non-profit mutual aid organization, agreeing to help each other fight fires, provide rescue and emergency medical assistance and handle hazardous material spills. The organization has also provided training.[77]

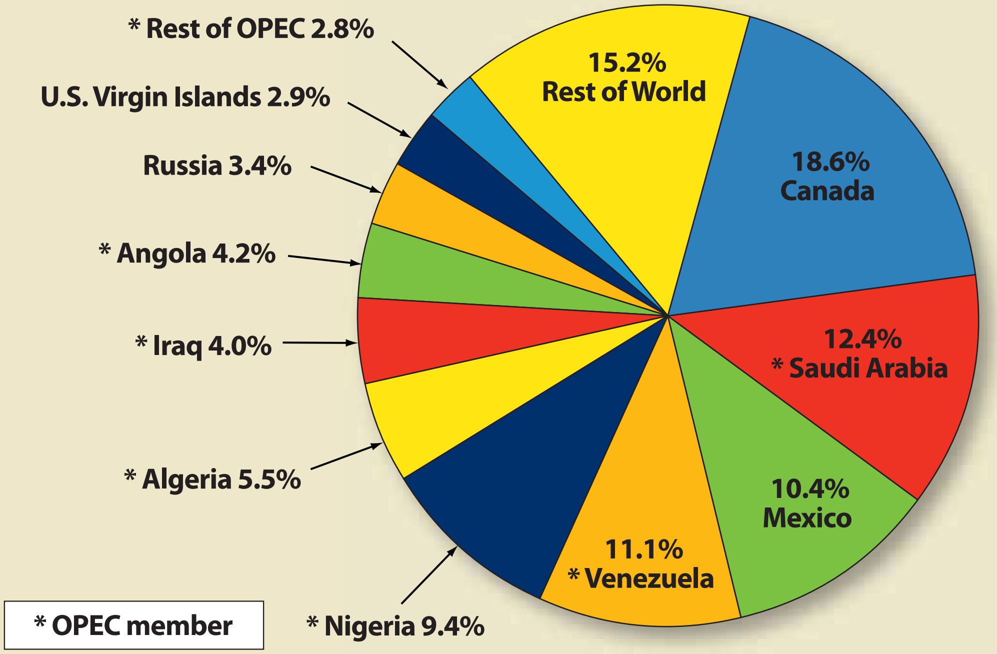
The U.S. Environmental Protection Agency (EPA) is entrusted with protecting human health and safeguarding the natural environment. In addition to enforcing the CAA, EPA specifically enforces the federal Clean Water Act, the Oil Pollution Act, the Comprehensive Environmental Response, Compensation & Liability Act and the Superfund Amendments and Reauthorization Act, which focus on cleaning up hazardous waste sites.

EPA has delegated the responsibility for issuing permits and monitoring and enforcing compliance to the states. Programs not delegated to the states are managed through EPA's 10 regional offices across the nation.

When national standards are not met, EPA can issue sanctions and take other steps to assist the states in reaching the desired levels of environmental quality.

EXHIBIT 4-21

Sources of U.S. Oil Imports, 2007



Source: U.S. Energy Information Administration.

Federal/Private Partnership for Enhanced Oil Recovery

The Wilmington field, running roughly southeast to northwest through the Los Angeles Basin, is the third-largest oilfield in the contiguous U.S. and has been in operation for 73 years.[78] This oilfield had seen a steady decline in oil production over the years, and many considered it to be depleted.

In 1995, DOE and a private company began a partnership to employ new EOR methods to revitalize the field. Specifically, the project has developed:

- new three-dimensional computer modeling to find better ways to inject steam, hot water and other treated water into the production zone, thus heating its thick crude and driving it toward production wells without causing surface subsidence, a common problem in the area;
- a new well completion technique using alkaline steam instead of sand to dissolve the oil-bearing rock, cutting capital costs by 25 percent;
- a new commercial technology to remove deadly hydrogen sulfide (H_2S) gases from steam emissions, reducing the cost of this process by 50 percent; and
- a new steam generator that can burn a variety of low-quality waste gases created by the operation.

The project formally ended on March 31, 2007. The new technologies developed in the project ultimately could add 525 million barrels of additional oil production at Wilmington field. The private company that implemented the DOE-supported technologies has experienced its most successful drilling in 25 years at the Wilmington oil field. In fact, its best wells were drilled in an area that had been abandoned as depleted.[79]

EPA also may seek the assistance of state agencies in its own efforts to protect the environment.

In Texas, EPA has delegated enforcement duties for many regulatory and environmental permits and standards to RRC and the Texas Commission on Environmental Quality (TCEQ). Generally, TCEQ has jurisdiction to enforce all major federal environmental laws except those applying to oil and gas production, which fall under RRC's authority.

The federal Occupational Safety and Health Administration (OSHA) oversees the working environment in nearly all phases of crude oil exploration and production. The U.S. Department of Transportation oversees not just overland petroleum transportation, but also pipeline safety. The Coast Guard enforces federal pollution and safety laws regulations on navigable waters. The U.S. Army Corps of Engineers issues permits for any construction in either federal waters or wetlands. The Federal Energy Regulatory Commission has rate-setting oversight for interstate oil pipelines and market oversight for interstate gas pipelines.

Subsidies and Taxes

Chapter 3 of this report discusses major taxes related to the oil and gas industries, including severance and motor fuels taxes, which together accounted for about 18 percent of state tax revenue in 2006. Chapter 28 contains information on subsidies for the oil and gas industries.

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OTHER STATES AND COUNTRIES

Major initiatives and innovations in the oil industry concern developing and enhancing the cost-effectiveness of secondary or enhanced oil recovery. Such technologies have become a major concern because of the world's dwindling oil reserves.

One example of these initiatives is a recently completed, DOE-funded project in a small portion of the Wilmington oil field in the heart of Long Beach, California.

Many U.S. companies and the U.S. government are actively investigating alternative sources of oil and gas, which includes "tight" sands (those with low permeability for hydrocarbons), oil sands, coalbed methane and oil-bearing shale rock. For example, DOE's National Energy Technology Laboratory is actively researching the potential of oil shales in Utah, Colorado and Wyoming; tar and oil sands in Utah, Alaska, Alabama, Texas and California; coal-to-liquid technologies that create a synthetic gas or "syngas" from coal that ultimately forms ultra-clean diesel and jet fuels; "heavy oil" in California, Alaska and Wyoming that requires heat, solvents or both to move underground; and, as mentioned previously, carbon dioxide enhanced oil recovery.[80]

One concern regarding crude oil supplies is China's modernization and its increasing consumption of petroleum.

One concern regarding crude oil supplies is China's modernization and its increasing consumption of petroleum. **Exhibit 4-22** shows the top 15 petroleum-consuming countries in 2006.

In addition to increasing consumption in China, oil-producing countries such as Saudi Arabia and Iran are increasing their oil consumption rapidly while other Asian and European countries are reducing theirs.

OUTLOOK FOR TEXAS

Texas has been a major producer and consumer of petroleum products and will continue to be for the foreseeable future. The outlook for Texas, however, is inextricably linked to national and global supply and demand for oil.

Companies throughout the industry are pushing technological limits to develop oil and gas fields offshore in ever-deepening waters. Most recently, in 2006, Chevron and its partners set a drilling depth record in the Gulf of Mexico, reaching strata 34,189 feet or 6.5 miles deep in 3,500 feet of water.[81] The federal Minerals Management Service reported in August 2007 that a record number of drilling ships — 15 — were work-

EXHIBIT 4-22

Top Petroleum-Consuming Countries, 2006
(Thousand Barrels per Day)

Rank	Country	Consumption	2005 Rank	2004 Rank	2000 Rank	Net Change in Consumption 2000-2006
1	United States	20,687	1	1	1	5.0%
2	China	7,273	2	2	3	51.7
3	Japan	5,159	3	3	2	-6.1
4	Russia	2,861	4	4	5	10.9
5	Germany	2,665	5	5	4	-3.9
6	India	2,587	6	6	8	21.6
7	Canada	2,264	7	7	10	11.7
8	Brazil	2,217	9	9	6	2.3
9	Korea, South	2,174	8	8	7	1.8
10	Saudi Arabia	2,139	11	12	14	39.2
11	Mexico	1,997	10	11	9	-1.9
12	France	1,961	12	10	11	-2.0
13	United Kingdom	1,830	13	13	13	4.0
14	Italy	1,732	14	14	12	-6.6
15	Iran	1,686	16	16	16	35.0

Sources: U.S. Energy Information Administration and Texas Comptroller of Public Accounts.

ing in Gulf of Mexico waters deeper than 5,000 feet.[82]

Has Oil Production Peaked?

Another current issue is the debate among academics, business leaders, economists and government officials as to whether the world has seen "peak oil" — that is, the absolute peak of oil production, followed by an irrevocable production decline. Daniel Yergin, author of the Pulitzer Prize-winning *The Prize: The Epic Quest for Oil, Money & Power*, has said that the more appropriate vision is that of an "undulating plateau," with the slope of decline much more gradual than that of the rapid increases of the 20th century, largely due to technological advances.[84] Others argue that economic models should begin reflecting a downturn in global oil production to better prepare for the future.[85]

A November 2007 article in the *Wall Street Journal* provides some insight into the debate.

> A growing number of oil-industry chieftains are endorsing an idea long deemed fringe: The world is approaching a practical limit to the number of barrels of crude oil that can be pumped every day. Some predict that, despite the world's fast-growing thirst for oil, producers could hit that ceiling as soon as 2012. This rough limit — which two senior industry officials recently pegged at about 100 million barrels a day — is well short of global demand projections over the next few decades. Current production is about 85 million barrels a day…. The new adherents — who range from senior Western oil-company executives to current and former officials of the major world exporting countries — …share a belief that a global production ceiling is coming for other reasons: restricted access to oil fields, spiraling costs and increasingly complex oil-field geology.[86]

Today, the U.S. economy is as reliant on oil and gas as ever. Alternative fuel development has risen and fallen with the price of oil, but has yet to increase its relative share of U.S. consumption. Unconventional sources of hydrocarbons — such as tar sands, oil shale and coalbed methane — are neither cheap nor easy to produce. Clearly, however, the better we become at finding and using petroleum economically, the more likely we are to hold our petroleum consumption to sustainable levels and foster the development of alternatives.

Other challenges exist in producing more of the hydrocarbons we have already discovered using EOR technologies. For Texas, with its mature producing fields, more EOR is a significant opportunity. The Bureau of Economic Geology (BEG) at UT-Austin estimates that an additional three billion barrels of Texas oil could be produced if sources of CO_2 can be provided for EOR.[83]

BEG announced recently that it will be coordinating research by seven major oil-related companies over three years to determine if nanomaterials — cutting-edge materials created in a lab on an infinitesimally small scale — have the potential to improve EOR. One possible application under review is injecting nanomaterials into oil and gas reservoirs where they could link together and serve as sensors to help petroleum engineers monitor oil and gas reservoirs.[87]

The federal government is funding research to determine if pumping carbon dioxide into mature oil and gas fields will increase yield and at the same time sequester CO_2, a known greenhouse gas.[88] And other researchers are working to find better materials to use to find, recover and use petroleum products.[89]

Oil and natural gas built modern Texas. Although production rates for both reached their peaks in the early 1970s, the industry still remains a major factor in the state's economy.

Texas' oil and natural gas production is expected to continue declining for the foreseeable future, but employment numbers and wages should remain steady or increase slightly through 2014.[90]

Texas will be a preeminent oil and gas producer for as long as the world relies on them. The development of alternative energy sources such as wind, solar and biomass is not likely to challenge Texas' preeminence; in fact, it stands to enhance Texas' position as an energy producer.

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CHAPTER 5

Natural Gas

INTRODUCTION

Natural gas is one of the most abundant energy sources in the world. Like oil, it is created by the decomposition of organic matter. The lightest of all hydrocarbons, natural gas is commonly found in underground formations either by itself; associated with or lying atop oil deposits; or dissolved in crude oil.

Once burned as an oilfield waste product, natural gas now supplies the U.S. with 22.5 percent of its energy, as measured by British thermal units (Btu).[1] Texas is the nation's largest producer and consumer of natural gas, providing one-fourth of U.S. supplies and consuming one-sixth, primarily in the industrial and electricity generation sectors.[2]

Natural gas imports via pipeline from Canada and Mexico, as well as liquefied natural gas (LNG) imports from overseas, now provide 19 percent of total U.S. supplies.[3] Texas is the entry point for up to two-thirds of Mexican gas imported by pipeline, with a capacity of 2,485 million cubic feet (MMcf) daily.[4]

Natural gas, along with crude oil, is a major economic boon to Texas. Combined, these two energy sources accounted for 14.9 percent or $159.3 billion of the 2006 Texas gross state product (GSP).

History

The practical use of natural gas dates back to the Chinese of 2,500 years ago, who used bamboo pipes to collect it from natural seeps and convey it to gas-fired evaporators, where it was used to boil ocean water for the salt. French explorers in the early 17th century found Native Americans around the Great Lakes burning gas from natural seeps for cooking. As inexpensive cast-iron pipe became available in the 19th century, natural gas derived from coal became a relatively common fuel for street lighting in some U.S. cities.[5]

As the technology to create seamless steel pipe and related equipment advanced, the size and length of pipelines increased, as did the volumes of gas that could be transported easily and safely over many miles. The first natural gas pipeline longer than 200 miles was built in 1925, from Louisiana to Texas.[6]

The first long-line interstate pipelines were built in the 1930s to ship crude oil, not natural gas, from Texas and Oklahoma to the Midwest. Because natural gas is created from the same materials by the same processes as oil, natural gas often is encountered in oil drilling. Before the mid-1940s, it was an unwanted byproduct and was simply flared (burned off) in the field. As concerns about field conservation grew, Texas banned flaring after World War II, so producers had to find markets for gas.[7]

During World War II, the War Production Board approved other long-line crude oil pipelines from Texas to the East Coast, to avoid the threat to oil tankers from Nazi submarines. After the war, the government allowed these pipelines to carry natural gas instead of crude oil, which they do to this day.[8] U.S. demand for natural gas rose rapidly thereafter. Residential demand grew 50-fold between 1906 and 1970.[9]

Today, natural gas has become extremely important as a concentrated, clean fuel for home heating and cooking and electrical power generation, and is sought after almost as much as oil.

Uses

Natural gas is in fact a generic name for several gases. The natural gas that is piped into our homes, business and electricity generation plants is primarily methane, an odorless, colorless, lighter-than-air gas.[10] When produced from an underground formation, natural gas commonly contains other compounds, including slightly heavier hydrocarbon gases such as propane and butane, water and sulphurous compounds, and is known as "wet gas" (**Exhibit 5-1**).

"Casinghead gas" is the gas that appears with crude oil, often dissolved in it; "gas well gas"

Texas is the nation's largest producer and consumer of natural gas, providing one-fourth of U.S. supplies and consuming one-sixth, primarily in the industrial and electricity generation sectors.

comes from gas-only formations; and "coal seam" or "coal bed" gas is found in coal formations. Natural gas is also a byproduct of refined crude oil. In addition, many fossil fuels and other carbon-containing materials, such as coal and coke, can be gasified to produce natural gas.

Natural gas is a proven, reliable and clean fuel that has provided Texas not only with abundant and relatively inexpensive energy supplies for more than a half-century, but also has provided the Texas economy with a reliable income.

According to the U.S. Department of Energy's Energy Information Administration (EIA), natural gas provided 33.9 percent of all Btu derived from domestically produced fossil fuels in 2006; 26.8 percent of the Btu from all fuels domestically produced, including nuclear and biofuels; and 22.5 percent of Btu derived from the total U.S. energy supply.[11]

Natural gas is a versatile fuel and very simple to use, as it can be burned or used either as feedstock for other products or to power fuel cells. It is the fuel of choice for most Texas electric utilities, which use it to boil water to produce steam, turn turbines and generate electricity. EIA reports that one cubic foot of natural gas at normal pipeline pressure and temperature produces about 1,031 Btu, roughly the same Btu content as 1.3 ounces of high-grade coal.[12]

NATURAL GAS IN TEXAS

Natural gas is a proven, reliable and clean fuel that has provided Texas not only with abundant and relatively inexpensive energy supplies for more than a half-century, but also has provided the Texas economy with a reliable income. In a world where other energy supplies have uncertain futures, natural gas remains a popular, dependable and, most importantly, domestically produced fuel.

EXHIBIT 5-1

Typical Composition of Natural Gas

Chemical Component	Chemical Composition	Proportion of Natural Gas
Methane	CH_4	70-90%
Ethane	C_2H_6	0-20
Propane	C_3H_8	
Butane	C_4H_{10}	
Carbon Dioxide	CO_2	0-8
Oxygen	O_2	0-0.2
Nitrogen	N_2	0-5
Hydrogen sulphide	H_2S	0-5
Rare gases*	Ar, He, Ne, Xe	trace

*Argon, helium, neon, xenon.

Source: Natural Gas Supply Association.

Economic Impact

As noted in earlier chapters, the federal and state governments combine oil and natural gas data for various statistics because of the high degree of overlap between the two. In 2006, more than 312,000 Texans, or 3.1 percent of the state work force, were employed in the oil and natural gas industry, which accounted for more than $159 billion or 14.9 percent of Texas' gross state product (GSP). Oil and gas industry wages totaled $30.6 billion in that year, or about 6.9 percent of all wages in Texas. Per employee, the industry contributed $511,000 to the GSP. This compares very favorably with the 2003 GSP per employee of $319,000.[13]

Historically, the oil and natural gas industry have accounted for approximately 10 percent to 25 percent of the state's GSP (**Exhibit 5-2**). (The price indicated in the exhibit is based on the taxable value of gas from in-state production, in dollars adjusted for inflation.) However, compared to the relatively close relationship between the real price of oil and the industry's contribution to the state's GSP (see **Exhibit 4-2** in Chapter 4), the real price of natural gas is slightly less volatile and does not appear to track GSP closely.

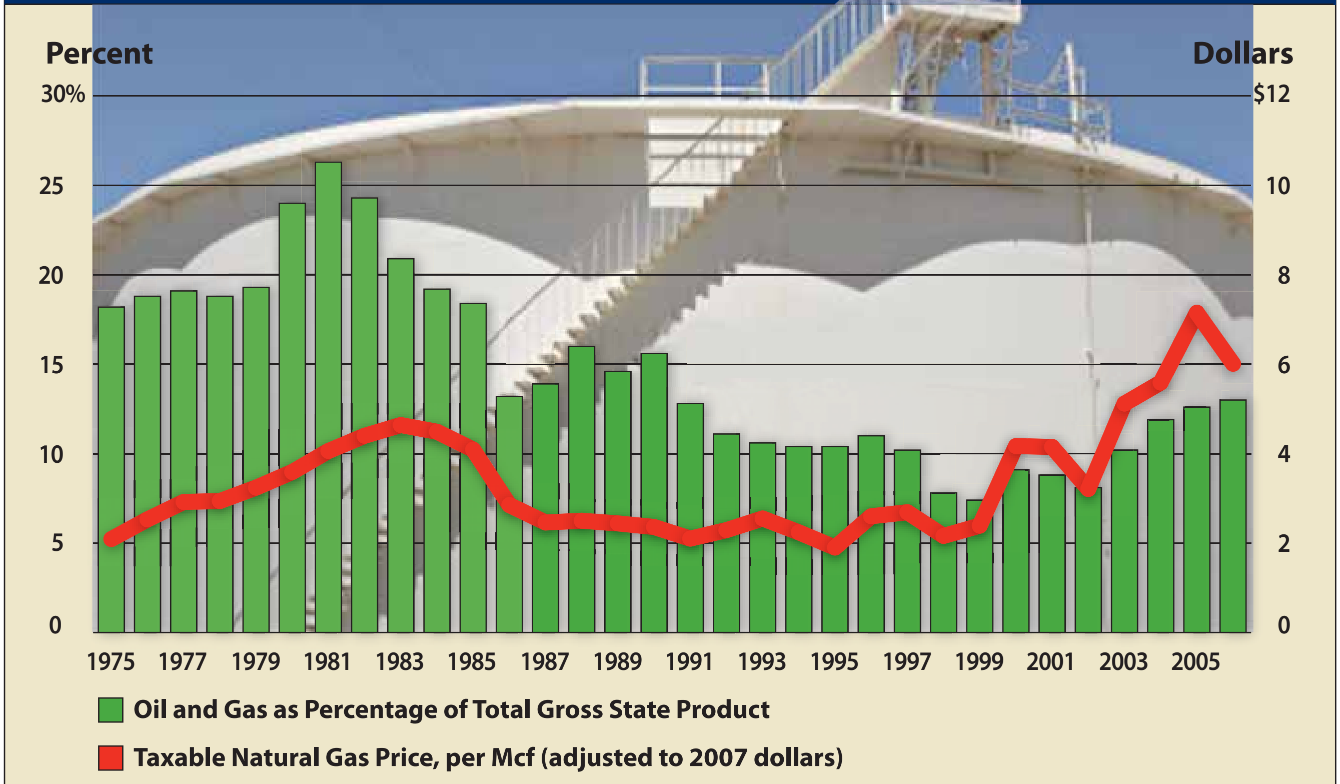
Consumption

According to the Electric Reliability Council of Texas (ERCOT), which operates the largest of Texas' four electric grids, natural gas could provide about 72 percent of its total electric generation capacity if used at maximum output every hour of every day. But because cheaper fuel alternatives often are used when available, and plants are often down for maintenance and repair, Texas electric generators used natural gas to produce 46.6 percent of the electricity on the ERCOT grid in 2006 — still making it the most common fuel for electricity generation in the state.[14] (For more on Texas electricity, see Chapter 27 of this report.)

The price of natural gas sold to electric power consumers in November 2007 was $6.58 per Mcf,

Exhibit 5-2

Oil and Gas Industry Gross State Product and Taxable Natural Gas Price



Sources: U.S. Bureau of Economic Analysis and Texas Comptroller of Public Accounts.

Note: BEA data supplementary only.

about 42 percent below the post-Katrina and Rita high price of $11.30 in October 2005.[15]

According to 2006 EIA statewide data, natural gas is used as the primary energy source in 48 operating Texas utility plants with a total of 144 generators. The "nameplate" (maximum) capacity of these generators is 17,350 megawatts (MW). Seven other Texas plants, with a total 10 generators and 3,787 MW of nameplate capacity, use natural gas as a backup fuel.

Thirty of these plants are in ERCOT; three are in the Southeastern Reliability Council (SERC) grid (in southeastern Texas); 13 are in the Southwest Power Pool (SPP) grid (covering the western and northern Panhandle and the Texarkana area); and two are in the Western Electric Coordinating Council (WECC) electricity grid (in far West Texas) (**Exhibit 5-3**).[16]

Private industrial plants also use natural gas to generate electricity for their own consumption. Some of these plants are owned by a wide variety of manufacturers and processors, such as Alcoa World Alumina, LLC, E. I. DuPont De Nemours & Co. and ExxonMobil.[17]

To reduce vehicle air emissions, the Texas Department of Transportation (TxDOT) uses natural gas and propane (a liquefied petroleum gas, or LPG) as fuel to power about 4,500 fleet vehicles and buses, which reduced its fiscal 2005 gasoline consumption by five million gallons, or 0.4 percent of the state's gasoline consumption that year.[18] In that year, all natural gas vehicles in Texas consumed

Exhibit 5-3

Natural Gas-Powered Generation in Texas, 2006, By Grid

	Total Plants	Total Generation Units	Utility-Owned Plants	Utility-Owned Generation Units	Natural Gas-Driven, Utility-Owned Generation Plants	Natural Gas-driven, Utility-Owned Generation Units
ERCOT	217	698	59	164	30	92
SERC	18	65	3	9	3	9
SPP	36	78	19	49	13	36
WECC	6	18	3	8	2	7
State Total	**277**	**859**	**84**	**230**	**48**	**144**

Sources: U.S. Energy Information Administration and Texas Comptroller of Public Accounts.

1,811 MMcf, less than one-tenth of 1 percent of the natural gas consumed in the state.[19] Since TxDOT's program began in 1993, it has replaced a total of 52 million gallons of gasoline with 52 million gallons of cleaner-burning alternative fuels.[20]

In addition to its merit as a fuel, natural gas is essential to the recovery of other hydrocarbons in underground formations. As a well is drilled into an oil accumulation pressurized by the weight of overlaying rock, the lighter gas expands in response to the release of pressure, forcing the oil downward in the formation and up the producing wells to the surface (**Exhibit 5-4**). For this reason, recovering all the natural gas in an oil field is not always a wise or economical idea. Other substances — water and injected non-hydrocarbon gas — can be used to artificially pressurize a formation, but often at substantial cost.

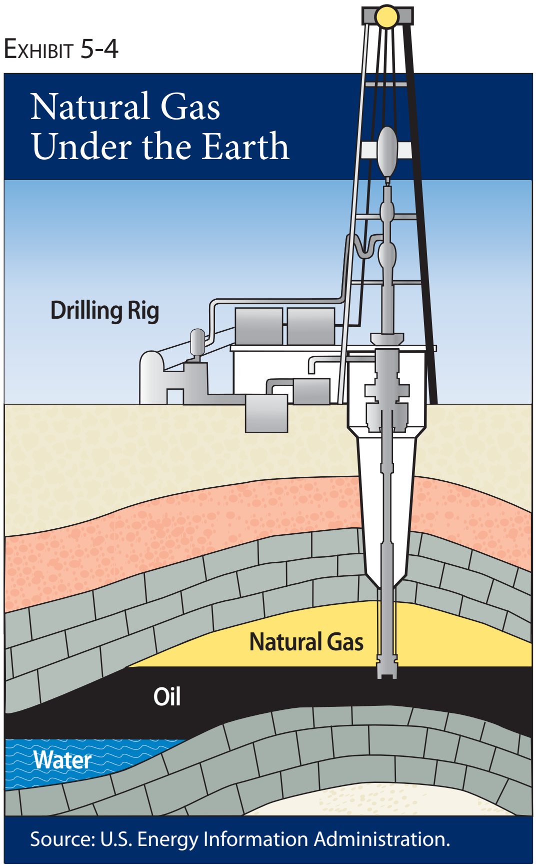
EIA data indicate that the U.S. consumed 21.7 trillion cubic feet of natural gas in 2006. Of that amount, 92.1 percent went to U.S. consumers; natural gas processors and pipelines used the remainder. Processors use natural gas to fuel the facilities that separate liquids from natural gas, while pipelines use natural gas to run the compressor engines that pressurize the gas, allowing it to travel hundreds of miles through the pipeline.

Of the consumer share, residential users accounted for 21.9 percent of gas supplies; commercial users consumed 14.2 percent; industrial users consumed 32.6 percent; and electric power generators used the remaining 31.2 percent.[21]

The industrial and electric power sectors dominate consumer natural gas demand in Texas, accounting for 90 percent of the state's use.

In 2006, Texas consumed more natural gas than any other state, or about 16 percent of total U.S. consumption. The industrial and electric power sectors dominate consumer natural gas demand in Texas, accounting for 90 percent of the state's use (**Exhibit 5-5**).[22]

Exhibit 5-4



Natural Gas Under the Earth

Source: U.S. Energy Information Administration.

Production

Natural gas is extracted through subsurface drilling. Natural gas does not require refining in the sense crude oil does, but it does require cleaning, due to the presence of other gases and liquids. These are removed at a gas processing plant where, as a safety measure, an odorant called mercaptan is added to the naturally odorless methane, giving it a distinctive rotten egg smell.

Four states — Texas, Louisiana, New Mexico and Oklahoma — and the Gulf of Mexico accounted for more than three-quarters of all natural gas produced in the U.S. until the late-1990s. In 2005, these four states plus Gulf production represented 68.4 percent of all U.S. production.[23] Texas natural gas production reached its peak in 1972, at more than 9.6 trillion cubic feet or more than 40 percent of all U.S. production.[24] In 2006, Texas produced more than 5.1 trillion cubic feet or 27.8 percent of all natural gas produced in the U.S., still more than any other state (**Exhibit 5-6**).[25]

Production in western states (California, Colorado, Montana, Nevada, Utah and Wyoming) has helped to make up for declining production from Texas, Louisiana, New Mexico and Oklahoma, while Alaskan production has remained steady (**Exhibit 5-7**).[26]

EXHIBIT 5-5

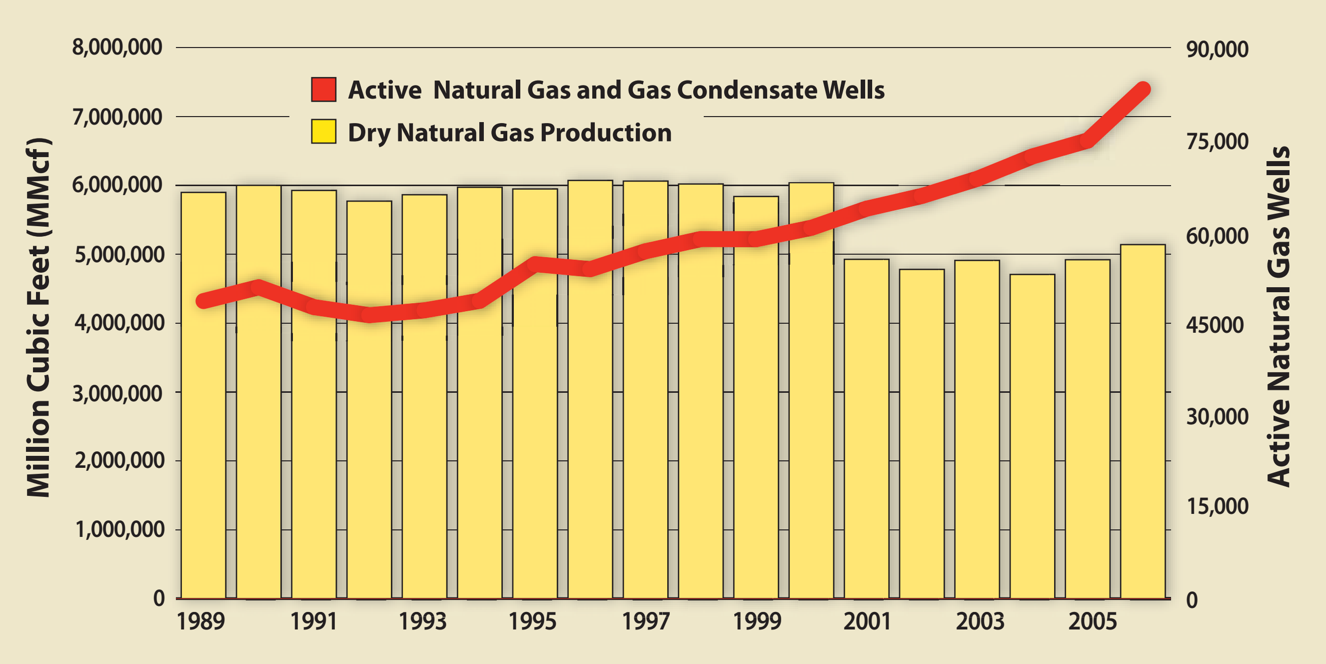
Texas Dry Natural Gas Consumption by End Use, 2006 (Millions of Cubic Feet [MMcf])

	2006 Total	Percent of Total
Residential	166,225	5.4%
Commercial	149,221	4.9
Industrial	1,288,510	42.0
Vehicle Fuel	1,972	<0.1
Electric Power	1,463,658	47.7
Total	**3,069,646**	

Sources: U.S. Energy Information Administration and Texas Comptroller of Public Accounts.

EXHIBIT 5-6

Texas Natural Gas Production and Active Wells



Source: U.S. Energy Information Administration.

In the 1980s, horizontal or “slant-hole” drilling came into widespread use in the prolific Austin Chalk (Giddings) gas fields east of Austin (**Exhibit 5-8**). This technique allows producers to drill vertically and then horizontally, to access multiple permeable zones associated with vertical geologic faults. In 1993, the chairman of Oryx Energy Co., at the time a major producer in the Austin Chalk, noted that the costs of drilling horizontal wells were about 50 percent higher than that for vertical wells, but the daily production was three to five times higher.[27] Gas production in the Austin Chalk formation was very high for several years, but has fallen slightly since.[28]

Today, horizontal drilling also is used in the Barnett Shale trend, extending south and west from Fort Worth over parts of 19 counties (**Exhibit 5-9**). The Barnett Shale is one of the most active natural gas production zones in the state and the nation. It contains more than 26 trillion cubic feet of natural gas locked up in a “tight” shale formation.[29] (A tight formation is one in which hydrocarbons are trapped in rock of particularly low permeability and low porosity.) Producers use large volumes of fresh water injected down hole to fracture or “frac” the shale and release the gas.

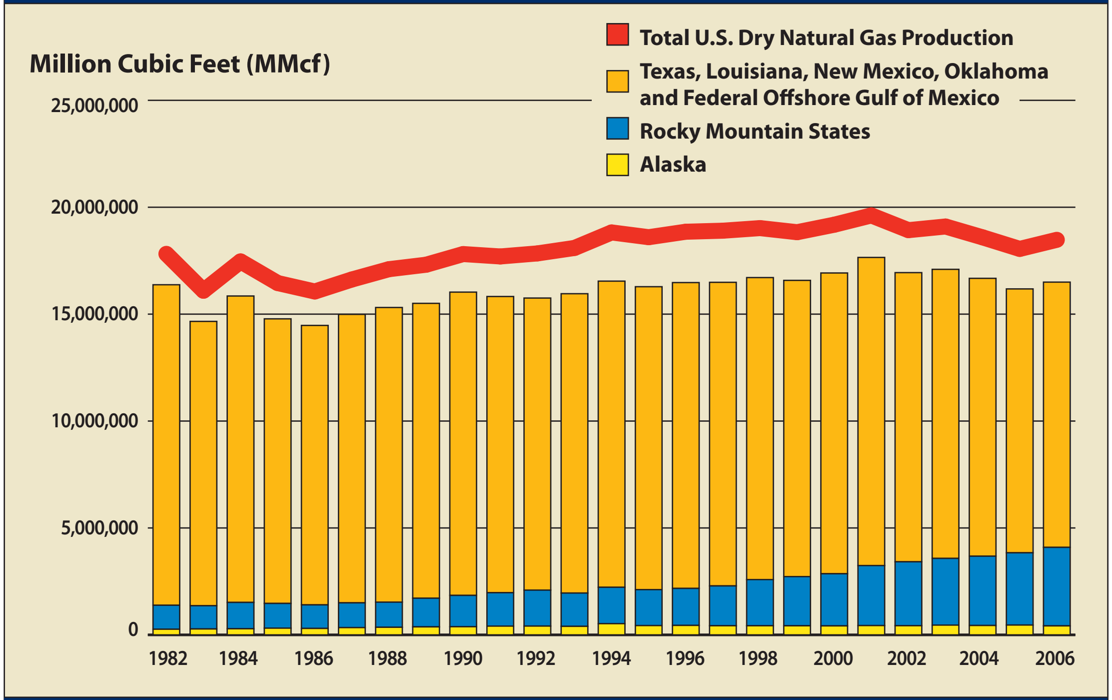
“Unconventional Gas”

The success of the Barnett Shale production zone has spurred efforts to produce gas in many other areas and geological formations that were previously considered unrecoverable or uneconomic. These “unconventional gas” sources include tight gas sands, shales and coalbeds. Producers have known about these unconventional resources for decades, but relatively low gas prices prevented their exploitation until recently. Unconventional gas production requires permeability enhancement of the reservoir rock, which is accomplished by “frac” techniques. Because of this requirement, each well may be more difficult and more expensive than regular drilling for conventional sources of gas. Only when natural gas prices are high does

The Barnett Shale is one of the most active natural gas production zones in the state and the nation.

Exhibit 5-7

U.S. Domestic Dry Natural Gas Production



Sources: U.S. Energy Information Administration and Texas Comptroller of Public Accounts.

Exhibit 5-8

Austin Chalk Trend Area

Source: Schlumberger Limited.

producing from unconventional sources become economically feasible.

Unconventional gas resources tend to cover large contiguous areas, however, creating economies of scale for operators who specialize in such drilling. Now that gas prices consistently are above $5-6 per Mcf, activity and production has increased dramatically. About 31 percent of current U.S. gas production comes from these unconventional resources. Many of the major unconventional gas fields in Texas (such as East Newark Barnett, Oak Hill Cotton Valley, Carthage Cotton Valley, Sawyer Canyon and Ozona Canyon) have significantly increased production in the past decade. Continued growth in unconventional gas production is expected in Texas and the U.S.[30]

Gathering and Distribution

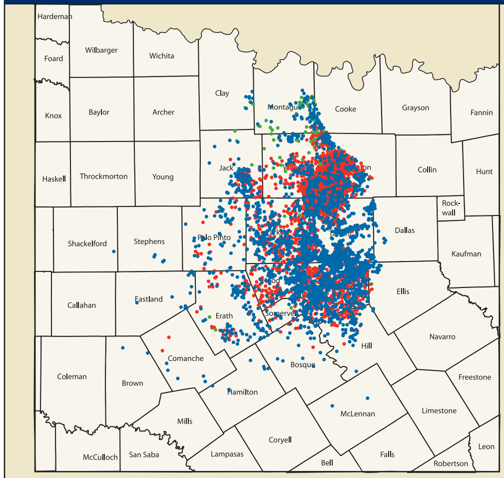
The first and smallest component of the pipeline system is a gathering line, generally less than eight inches in diameter, usually located in rural areas and operating under low pressure. Many states, including Texas, do not regulate these lines. Before the gas travels from the area of production, it is processed to remove liquids and non-hydrocarbon gases to become pipeline quality. It then is placed in ever-larger pipelines known as transmission lines, which can be up to 48 inches or more in diameter. These pipelines operate at higher pressures and if they cross state boundaries, become regulated by the Federal Energy Regulatory Commission (FERC).

As the gas nears its final points of sale, the pipeline diameters become smaller again, and are known as distribution lines. In energy parlance, interstate pipelines end at the "city gate," meaning at the pipeline terminus such as a utility or industrial facility, and the gas is sent to the end-user's "burner tip" through the utility's distribution lines.[31]

Some 215,000 miles of interstate pipelines deliver natural gas to every corner of the U.S., along with 87,000 miles of intrastate pipelines.

Exhibit 5-9

Operating Oil and Natural Gas Wells in the Barnett Shale



- 🔵 Drilling Permits
- 🔴 Producing Wells
- 🟢 Both Oil and Gas Producing Wells

Source: Railroad Commission of Texas.

Interstate Pipeline Construction

Constructing a new interstate pipeline or expanding an existing one is a lengthy and complex undertaking — and an expensive one, too. Although construction costs per mile are extremely variable and site-specific, the Interstate Natural Gas Association of America estimates that new pipeline construction costs are approaching $3 million per mile and trending upward.[32]

Most of Texas' interstate pipelines follow the Gulf Coast to the Mississippi River, then diverge northward to serve the Midwest and northeastward to serve the East Coast. West Texas oil and gas fields generally deliver to the West Coast.

Some 215,000 miles of interstate pipelines deliver natural gas to every corner of the U.S., along with 87,000 miles of intrastate pipelines. Texas leads all states in its number of pipeline miles (**Exhibit 5-10**).[33]

Thirty-one states derive more than 80 percent of their natural gas from interstate pipelines.[34]

The U.S. also imports significant quantities of natural gas — more than 4.2 trillion cubic feet (Tcf) in 2006. Canadian pipeline imports represented more than 85 percent of 2006 U.S. imports.[35]

Exhibit 5-11 summarizes the natural gas industry's production, transmission and distribution system.

Storage and Disposal

Large, commercial volumes of natural gas are usually stored in underground rock formations with an impermeable cap, such as caverns in salt domes or depleted oil and gas reservoirs, or in large aboveground tank facilities. In 2007, Texas had 35 natural gas storage sites—20 in depleted reservoirs around the state and 15 in underground salt caverns along its coast (**Exhibit 5-12**). In all, Texas' natural gas storage capacity was 683.5 billion cubic feet in August 2007, placing the state fourth in the nation behind Michigan, Illinois and Pennsylvania.[36]

Texas's natural gas storage facilities allow the state to store its natural gas production during the summer months, when national demand typically is lower, and then ramp up delivery quickly during the winter months, when markets across the country require natural gas for home heating.

Due to the growing use of natural gas for electricity generation, however, Texas has occasionally withdrawn natural gas from storage during the summer to help meet the state's peak electricity demands due to high air conditioning use. Although the volume fluctuates constantly, from September 2006 to August 2007 Texas underground facilities averaged 575.8 Bcf of natural gas in storage, or about 8 percent of the U.S. total.[37]

Availability

Natural gas is widely available in Texas and the U.S. as a whole, due to many on- and offshore gas fields and an extensive drilling and pipeline infrastructure.

Texas is the nation's leading producer of natural gas, and in 2006 produced 5.1 trillion cubic feet, nearly half again as much as the state consumed (3.4 trillion cubic feet) and 27.8 percent of total U.S. marketed production.[38] Today, the Barnett Shale (Newark East) field in Northeast Texas is the second-largest natural gas field in the continental

EXHIBIT 5-10

Estimated Pipeline Mileage in Continental U.S., 2007

🟥 Western Region	Pipeline Miles
Arizona	5,989
California	11,770
Idaho	1,567
Nevada	1,469
Oregon	1,823
Washington	2,072
Total	**24,690**

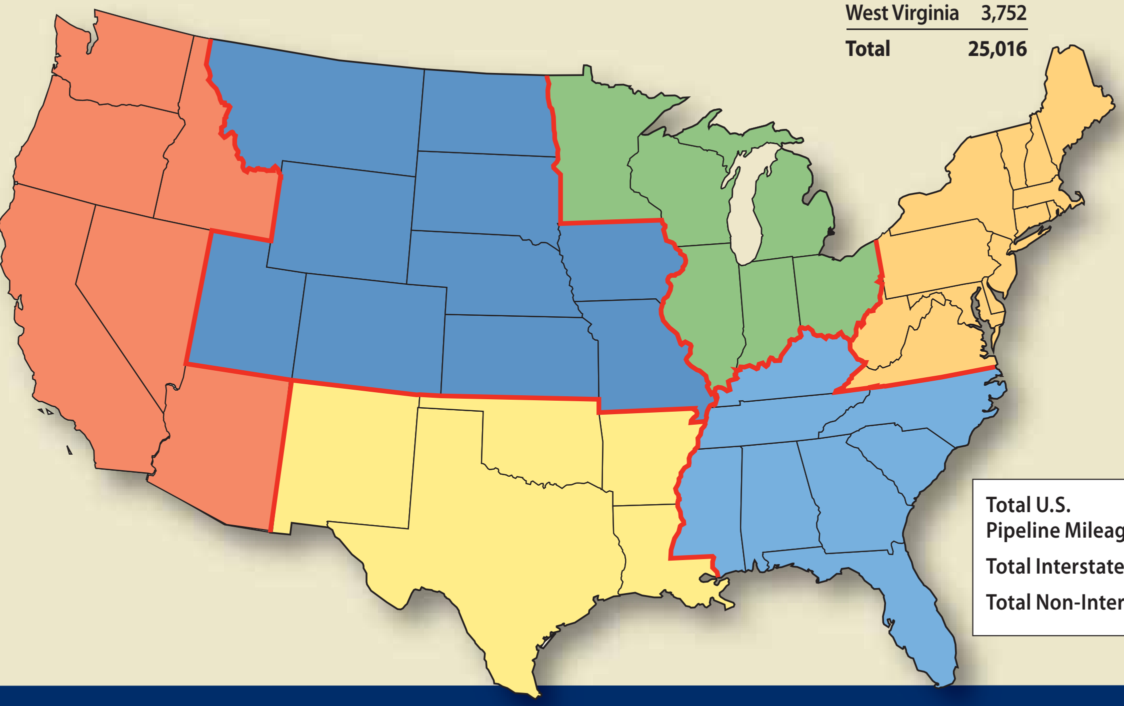
🟦 Central Region	Pipeline Miles
Colorado	7,465
Iowa	5,413
Kansas	15,286
Missouri	3,771
Montana	3,861
Nebraska	5,346
North Dakota	1,873
South Dakota	1,242
Utah	3,175
Wyoming	7,796
Total	**55,228**

🟩 Midwest Region	Pipeline Miles
Illinois	11,911
Indiana	4,704
Michigan	9,706
Minnesota	4,434
Ohio	7,666
Wisconsin	3,339
Total	**41,760**

🟦 Southeast Region	Pipeline Miles
Alabama	4,691
Florida	4,884
Georgia	3,483
Kentucky	6,824
Mississippi	9,484
North Carolina	2,484
South Carolina	2,265
Tennessee	4,273
Total	**38,388**

🟧 Northeast Region	Pipeline Miles
Connecticut	619
Delaware	273
Maine	607
Maryland/DC	972
Massachusetts	959
New Hampshire	291
New Jersey	1,516
New York	4,741
Pennsylvania	8,586
Rhode Island	100
Vermont	53
Virginia	2,547
West Virginia	3,752
Total	**25,016**

🟨 Southwest Region	Pipeline Miles
Arkansas	6,201
Louisiana	18,569
New Mexico	6,728
Oklahoma	18,509
Texas	57,519
Gulf of Mexico	9,357
Total	**116,883**



Total U.S. Pipeline Mileage	301,965
Total Interstate	214,623
Total Non-Interstate	87,342

Source: U.S. Energy Information Administration.

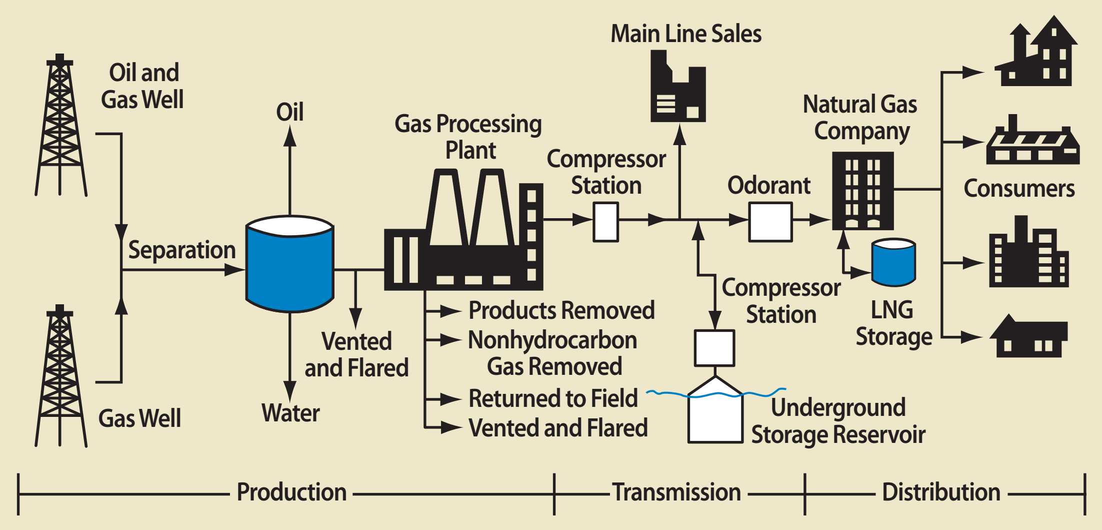
U.S., as ranked by 2005 gas production. Two other Texas fields are in the top ten — the Hugoton field stretching across the Panhandle into Oklahoma and Kansas is third, and the Carthage field in East Texas is seventh. The Giddings field in the Austin Chalk play is eighteenth.[39]

At the end of 2006, U.S. dry natural gas reserves totaled 211.1 trillion cubic feet. Federal reserves in the Gulf of Mexico were 14.5 Tcf; Texas state offshore reserves were 0.3 Tcf. Texas as a whole had 61.8 Tcf in dry natural gas reserves, a 42.1 percent increase since 2000. Texas reserves represented 29.2 percent of the total U.S. reserves.[40] To put this into perspective, total U.S. natural gas consumption in 2006 was 21.7 Tcf, down from a high of 23 Tcf in 2002.

Reserve estimates have been increasing in recent years, due primarily to the discovery of large reserves

EXHIBIT 5-11

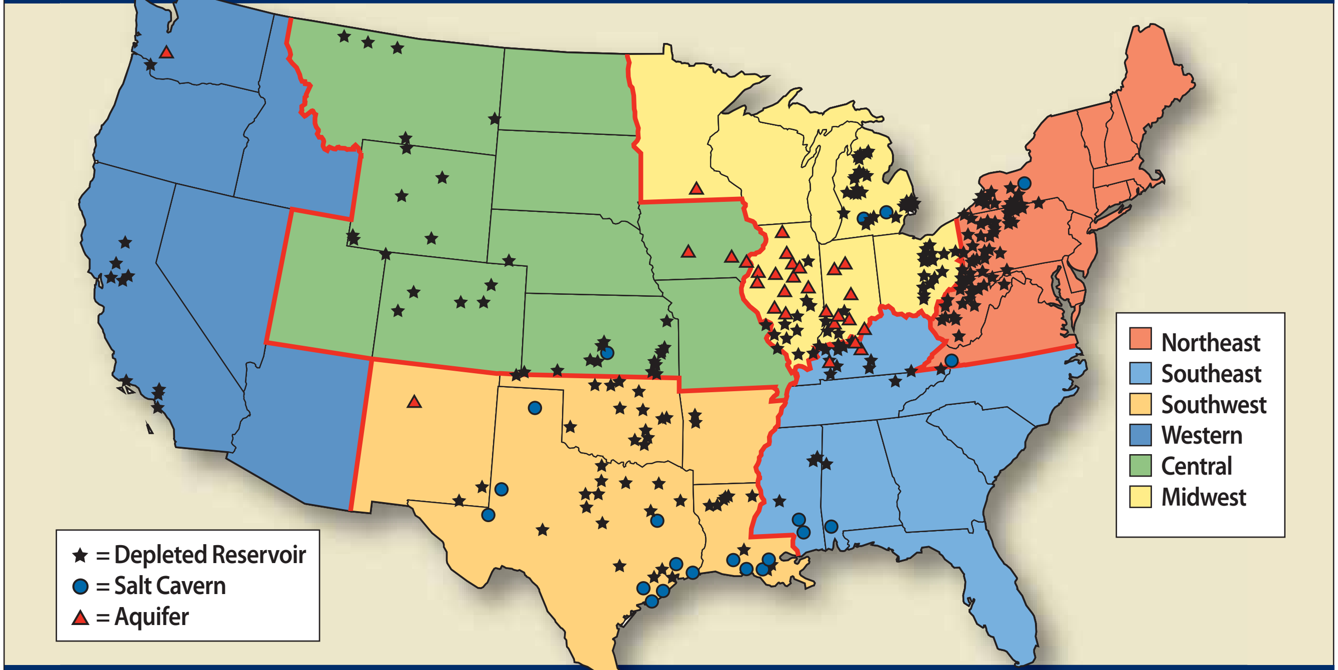
The Natural Gas Production, Transmission and Distribution System



Source: U.S. Energy Information Administration.

EXHIBIT 5-12

U.S. Natural Gas Storage Facilities as of August 2007



Source: U.S. Energy Information Administration.

of natural gas in the Gulf of Mexico. The most promising of these reserves, however, are located in areas of deep water — greater than 5,000 feet, or almost one mile — and are increasingly expensive to find and produce. (See Chapter 4 for more information on gulf exploration.)

Also, much of the U.S.'s offshore lands are off-limits to oil and gas exploration and production due to both congressional and presidential decree resulting from local environmental concerns. The American Petroleum Institute estimates that these lands could produce 656 Tcf of natural gas — more than three times existing reserves.[41]

Unconventional gas sources, though expensive to produce, are becoming more attractive and are an increasingly large percentage of total gas supply as gas prices remain near historical highs.[42] These prices, though, tend to depress consumption and therefore price.

COSTS AND BENEFITS

Natural gas is inextricably linked with crude oil in the ground and in the marketplace, even though oil is traded in a global market and natural gas is traded more often in a continental market such as that in North America. Because gas is often co-produced with oil, its price is related to the price of oil, whether that price is set on the floor of the New York Mercantile Exchange or in a board-room of the Organization of Petroleum Exporting Countries (OPEC), and it is subject to the same political and economic pressures facing crude oil, although on a somewhat lesser scale.

Natural gas prices have been highly volatile over the last few years, due in large part to production disruptions and outages caused by hurricanes Katrina and Rita in the Gulf of Mexico. In addition, prior to these storms, cold winters on the eastern and western coasts significantly depleted the amount of natural gas held in storage, further tightening the market.

The average production cost of natural gas is computed at each individual well and is based on its type, depth, type of recovery methods used and other factors. U.S. natural gas wellhead prices were $5.80 per thousand cubic feet (Mcf) in early 2005; by October, the price had nearly doubled, to $10.33 per Mcf. During 2006, prices declined from a high of $8.02 in January to $5.09 in October. In 2007, prices began at $5.92 per Mcf in January; rose slightly in anticipation of the summer cooling season to $6.98 per Mcf in May; and fell back to $5.90 in August. By November, prices rose again to $6.37 and in January 2008, were $6.99.[43]

Environmental Impact

Natural gas is a relatively clean fuel, leaving no ash residue and producing lower emissions of nitrous oxides (NO_X), sulfur oxides (SO_X) and carbon dioxide (CO_2) than coal. In Texas in 2006, natural gas-burning electric, commercial and industrial plants emitted 42.1 percent of the state's total NO_X gases, 0.1 percent of its SO_X gases and 40.4 percent of the state's CO_2 emissions (**Exhibit 5-13**).[44]

While natural gas is a significantly cleaner-burning fuel than coal, molecule for molecule in its unburned state it is also the most potent greenhouse gas (GHG), due to its high capacity for trapping heat radiating outward from the Earth.[45]

Other Risks

In a controlled state, natural gas is very safe. If released to the atmosphere, however, it is highly combustible until it dissipates. Because of its combustibility, the greatest physical risk involved with natural gas is a sudden, uncontrolled release, either from a well, storage facility or pipeline. The most common source of these releases is an unintended piercing of a natural gas line, often by a backhoe or other construction excavation equipment.

For this reason, both the federal and Texas governments have "one-call" systems to allow anyone digging near a pipeline to make one call to a central clearinghouse, which then sends information on the proposed dig to all local utilities. These utilities can send out crews to locate and mark underground facilities.

In addition, natural gas power plants use some water. Depending on the plant type, electricity generation from natural gas requires withdrawals of between zero and 5,863 gallons per million Btu of heat energy produced. This is the amount of water extracted from a water source; most of the water withdrawn is returned to that source.

Water consumption refers to the portion of those withdrawals that is actually used and no longer

Reserve estimates have been increasing in recent years, due primarily to the discovery of large reserves of natural gas in the Gulf of Mexico.

available. Electric generation using natural gas consumes between two and 56 gallons of water for each million Btu of heat energy produced.

State and Federal Oversight

Natural gas is subject to environmental regulations similar to those placed on oil, except that natural gas does not spill (it dissipates) and thus is not subject to laws such as the Oil Pollution Act of 1990 (passed in response to the *Exxon Valdez* spill).

In Texas, the U.S. Environmental Protection Agency (EPA) has delegated most of its authority over major federal environmental laws such as the Clean Air Act, Clean Water Act, Comprehensive Environmental Response, Compensation & Liability Act (CERCLA, also known as Superfund) and the Superfund Amendments and Reauthorization Act to the Texas Commission on Environmental Quality. The major exception is oil and gas exploration and production; the Railroad Commission of Texas (RRC) has EPA-delegated authority in the oil patch.

The only other significant distinction between oil and gas environmental regulation is due to overland pipeline construction, which is much more common in the natural gas industry. Before filing a pipeline construction proposal with FERC, applicants must determine the project's need by seeking approval from the pipeline's customers and rights of way from affected landowners. Pipeline companies who receive FERC approval for a project but are unable to negotiate either passage or price successfully with affected landowners have the right under federal law to condemn privately owned land to build the project (a power also known as eminent domain). Landowners must be fairly compensated, although what constitutes "fair" can be and occasionally is disputed in state or federal court.[46] Most pipelines and other utilities work to avoid exercising eminent domain because of the potential for dispute.

EXHIBIT 5-13

Texas Electric Utility, Commercial and Industrial Air Emissions, 2006

2006	CO_2 (Metric Tons)	SO_x (Metric Tons)	NO_x (Metric Tons)
Total U.S. Emissions	2,459,800,018	9,523,561	3,799,447
Total Texas Emissions	257,552,164	558,350	260,057
Percent of U.S.	*10.5%*	*5.9%*	*6.8%*
Coal in Texas	150,589,481	523,073	119,910
Percent of state	*58.5%*	*93.7%*	*46.1%*
Percent of U.S.	*6.1%*	*5.5%*	*3.2%*
Natural Gas in Texas	104,093,526	638	109,443
Percent of state	*40.4%*	*0.1%*	*42.1%*
Percent of U.S.	*4.2%*	*0.0%*	*2.9%*
Petroleum in Texas	2,869,153	28,819	7,530
Percent of state	*1.1%*	*5.2%*	*2.9%*
Percent of U.S.	*0.1%*	*0.3%*	*0.2%*

Source: U.S. Energy Information Administration and Comptroller of Public Accounts.

Liquefied Natural Gas

An increasing share of the nation's natural gas is coming from overseas, in the form of liquefied natural gas. LNG is formed by chilling natural gas to a liquid state at minus 260 degrees Fahrenheit; it then can be loaded on specially made cargo ships and transported to a growing number of U.S. LNG ports. The liquefaction process reduces the volume of natural gas by a factor of 610, making transoceanic transportation possible. Specially equipped tankers bring LNG to the U.S. from several countries, including Trinidad and Tobago, Algeria, Egypt, Nigeria, Oman and Qatar.[47]

LNG imports became popular during the 1970s U.S. energy crises. Algeria has supplied almost all of the nation's imported LNG ever since, although in widely varying amounts. In 1973, for instance, Algeria supplied a mere 3.4 billion cubic feet (Bcf); in 1979, it shipped 252.6 Bcf; and by 1995, the total had fallen to 18 Bcf. LNG prices were competitive with domestic natural gas when domestic supplies were low; as domestic production and pipeline imports increased, however, the higher-cost LNG quickly fell out of favor with consumers. Total LNG imports settled at levels well below 100 Bcf until 1999, when imports doubled in volume from 1998 to 163 Bcf and peaked at 652 Bcf in 2004.[48] Natural gas price spikes in late 2005 after hurricanes Katrina and Rita, coupled with increasing natural gas dependence for electric generation and a deregulation of large segments of the Texas electricity generation market brought LNG back into favor.

LNG can be unloaded at just five ports in the U.S. — three along the East Coast, one on the Louisiana coast and one in federal waters in the Gulf of Mexico — where it is returned to its gaseous state ("regassed") and placed in the pipeline system. Texas has no fully operational LNG terminals at this time but FERC has approved 21 new LNG terminals, including eight in Texas, that are in varying states of construction and operation. Freeport LNG Development LP in Freeport, Texas received its first LNG shipment in April 2008.[49]

The U.S. Coast Guard, which is authorized to approve terminals in federal waters, has approved four, two in the Gulf of Mexico and two offshore from Boston. These offshore terminals are floating platforms and storage facilities located a short distance from shore, with a substantial underwater pipeline from the platform to a connecting pipeline onshore. Terminals may be located offshore for many reasons, including cost, the lack of onshore space, the location of existing pipelines at sea and local opposition to the expansion of existing facilities.

Another 14 LNG import terminals have been proposed both on and offshore the continental U.S.[50]

While LNG imports appear once again to be a promising new source of energy that may be less expensive than other natural gas supplies, Asia and Europe are major importers of LNG. That fact, coupled with Asia's and Europe's preference for long-term contracts due to their dependence on LNG, tightens world supplies, leaving little for U.S. importers to buy on the spot, or daily, market. U.S. importers tend to buy LNG at spot, rather than perhaps lower contract prices, because the U.S. depends less on LNG than other countries and uses it primarily during temporary shortages. This can inhibit the U.S.'s flexibility in negotiations with producers. In addition, the liquefaction infrastructure of many of the exporting countries is not yet capable of supplying markets on all three continents.[51]

FERC reviews the proposal and may tentatively approve the project before conducting its own thorough analysis. FERC then will issue either a draft Environmental Impact Statement (EIS) or a less complex draft Environmental Assessment (EA) for relevant federal agencies and the public to review and comment upon. At the end of the review period, and after FERC finalizes the EIS or EA, it will issues a formal "certificate of convenience and necessity," or CCN.[52]

From that point on, the applicant must obtain the necessary environmental permits prior to construction. For example, if the pipeline crosses water or wetlands, the company must obtain a permit from the U.S. Army Corps of Engineers, the federal agency responsible for protecting U.S. waters and wetlands under the Rivers and Harbors Act of 1899 and the Clean Water Act.

Other permits also may be required, depending on the proposal. Most involve environmental quality, such as permits required by the Clean Air Act, Clean Water Act, the Coastal Zone Management Act and other legislation.[53]

State historical preservation officers (SHPOs), who protect cultural and archaeological resources, also must review and comment on the proposals.[54] In Texas, the SHPO is the Texas Historical Commission.

Once the pipeline applicant receives all permits, it can construct and operate the new pipeline.

The Office of Pipeline Safety in the U.S. Department of Transportation oversees post-construction pipeline safety issues.

Intrastate Pipeline Construction

Compared to the federal process, constructing an intrastate pipeline in Texas is relatively simple. RRC, which regulates the oil and gas industry, does not require a pipeline company operating as a RRC-designated public utility to receive a formal CCN from the state.

The public utility designation is very important, as it allows companies to construct pipelines of any size under general state law, with government oversight only if problems arise. Even so, some state agencies — including the General Land Office, Texas Department of Transportation, Texas Commission on Environmental Quality or the Texas Parks and Wildlife Department — may require intrastate pipelines to receive permits from them in specific instances, such as when the pipeline crosses waterways, roads or areas out of compliance with the Clean Air Act.

These designated utilities have eminent domain authority under general state law, if right-of-way negotiations with affected landowners break down. As with their interstate counterparts, intrastate pipeline companies tend to avoid using eminent domain.

For new intrastate pipeline construction, RRC requires the operator of an intrastate transmission pipeline of one mile or more to file a report at least 30 days prior to construction with the proposed originating and terminating points for the pipeline, counties to be traversed, size and type of pipe to be used, type of service, design pressure and length of the proposed line. New construction on natural gas distribution lines, or short-distance master meter systems, is exempt from this reporting requirement.[55]

If the pipeline is longer than five miles, RRC will send inspectors to ensure the integrity of the line's welded joints. RRC jurisdiction over the pipeline is limited to safety issues.

Government Regulation and Deregulation

Government policies have had a major influence on the natural gas industry's development. Wellhead gas prices — that is, the selling price of natural gas at the point of production, the wellhead — were unregulated until the 1950s, when the U.S. Supreme Court determined that the federal government must regulate prices to prevent companies owning both the gas and the pipeline from employing unfair practices.[56] The decision, however, did not require companies to separate their production, marketing and sales and transmission functions.

For the next 20 years, the Federal Power Commission (FPC) instituted a regulatory scheme allowing all interstate sellers of natural gas, as well as producers and pipelines, to set rates based on their "cost of service," plus a regulated return on capital.

This structure affected buyers and sellers quite differently. For natural gas customers, primarily large utilities called local distribution companies, the gas they bought at their "city gate" — the pipeline terminus — came at a single "bundled" price. This meant that the cost of gas, transportation and service guarantees were rolled up into one regulated price. Customers, for the most part, were unable to choose among gas suppliers or services.

For producers, a regulated pricing structure was enough of a disincentive to interstate commerce to spur natural gas shortages in the 1970s. But because the law did not restrict *intrastate* sales of natural gas, Texas saw half of its natural gas production dedicated to the home-state market, exacerbating shortages elsewhere.

The 1973 Arab oil embargo heightened Congress' fear of low oil and gas supplies, so it passed the Powerplant and Industrial Fuel Use Act of 1978, which discouraged the use of natural gas in favor of coal and renewable fuels, further depressing interstate natural gas prices and supplies. Relief came with the passage of the Natural Gas Policy Act of 1978 (NGPA), which relaxed — but did not remove — federal wellhead price controls. Congress intended the NGPA to create a national natural gas market, equalize supply and demand and allow market forces to determine wellhead prices.[57]

Now able to sell interstate natural gas at higher prices, Texas producers benefited substantially. Drilling and natural gas production increased, and the interstate pipeline system grew more robust. Competition for supplies increased and, combined with natural gas buyers' memory of shortages, provided enough motivation for buyers to negotiate high-cost, multi-year contracts for natural gas supplies. Predictably, consumer protests of high energy prices soon followed.

FERC, born of the same post-Oil Embargo era, was created as an independent agency to replace the FPC. FERC's mission was to regulate interstate natural gas, electricity and hydropower transmission and costs.

From the mid-1980s through the mid-1990s, FERC issued a series of orders gradually deregulating pipelines, first by allowing and then by requiring companies to create separate business units to buy, sell and transport gas.[58] As the companies separated into different units, rates were "unbundled," allowing customers to select from a menu of services offered by a now wide variety of businesses. These services could include guarantees from either the supplier or the pipeline, or both, that the customer would receive full supplies in times of shortage; paying a new middleman known as a "gatherer" to find and package natural gas supplies for shipment; or paying for and using gas held in storage.

These orders fundamentally altered the industry by introducing competition. The previously regulated and monopolistic pipeline system became exponentially more complex with deregulation.

For gas buyers, the point of sale moved from the city gate to the wellhead. Pipelines were no longer exclusive to particular companies or customers; they became "open access" transporters, much like interstate highways. Customers now could choose what gas they would buy; the suppliers from whom they would buy it; the services they required; and how and when gas would be delivered to them.

Subsidies and Taxes

Chapter 3 of this report discusses major taxes related to the oil and gas industries, including severance taxes, which accounted for a little more than 9 percent of state tax revenue in 2006. Chapter 28 contains information on subsidies for the oil and gas industries.

OTHER STATES AND COUNTRIES

As discussed above, unconventional sources of natural gas are being developed in many parts of the country, while producers are unable to access many promising federal offshore areas because of congressional and presidential orders.

LNG is once again emerging as a promising method to transport fuel to the U.S. from overseas. However, the U.S. is in competition for supplies with Asian and European countries that are growing dependent on LNG, while LNG-producing countries have limited export capabilities. Substantial investment in LNG production infrastructure will be required to increase LNG production significantly and balance the market.

OUTLOOK FOR TEXAS

The largest issue involving natural gas is supply. Supply pressures are being mitigated by continual innovation in the types of deposits pursued and growing LNG terminal capacity.

Natural gas production depends on pressure in the formation; with every cubic foot removed, the pressure is reduced. As a consequence, natural gas fields tend to become depleted quickly. Throughout the history of the industry in Texas, many fields have produced substantial amounts of gas for a short period and then lost pressure. Texas producers now pursue unconventional gas plays throughout the onshore part of the state, fracturing rock formations with sand-bearing liquids to expand the gas-producing areas underground. Horizontal drilling also can increase natural gas production in certain areas.

U.S. demand for natural gas is projected to grow by 0.5 percent annually through 2030. In view of declining domestic production, imports of natural gas will become increasingly important. LNG imports are expected to account for about 25 percent of the nation's supply of natural gas by 2030.[59]

LNG imports are expected to account for about 25 percent of the nation's supply of natural gas by 2030.

Natural gas is a proven, reliable and relatively clean and inexpensive energy source. Texas is a major producer and consumer, but without continued strong gas prices and continuing advancements in technology, natural gas producers may find it more difficult to keep producing adequate supplies. And natural gas prices are partly dependent on international oil prices, presenting another major challenge to U.S. energy independence.

EIA expects oil and natural gas production to continue declining for the foreseeable future, but industry employment and wages should continue to remain steady or increase slightly through 2035.[60]

In the meantime, new technology will allow us to produce from ever-deeper and more unconventional reserves. LNG imports are all but certain to become more important to the national energy portfolio, and new terminals under construction in Texas will increase employment and pipeline usage.

For the foreseeable future, natural gas will continue to serve Texas well both as fuel and as an important industry. Increasing concerns about either carbon dioxide emissions or the importation of natural gas from countries that may prove to give U.S. leaders foreign policy headaches could limit natural gas' growth as a fuel. Given natural gas' benefits, however, it should remain important throughout the century.

ENDNOTES

[1] U.S. Energy Information Administration, "Energy Flow, 2006," diagram in *Annual Energy Review 2006* (Washington, D.C., June 2007), http://www.eia.doe.gov/emeu/aer/diagram1.html. (Last visited April 25, 2008.) Natural gas provided 22.43 quadrillion British Thermal Units (Btu) of the 99.87 Btu consumed in the U.S., or 22.5 percent.

[2] U.S. Energy Information Administration, "State Energy Profiles: Texas," http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=TX. (Last visited April 25, 2008.)

[3] U.S. Energy Information Administration, "Basic Natural Gas Statistics," http://www.eia.doe.gov/neic/quickfacts/quickgas.html. (Last visited April 25, 2008.) U.S. consumption was 21.65 trillion cubic feet (Tcf) and imports were 4.19 Tcf or 19.3 percent.

[4] U.S. Energy Information Administration, "Locations of Natural Gas Import & Export Points, 2008," http://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/impex_list.html. (Last visited April 25, 2008.) This total is based on pipeline capacity, which may not correspond with actual volumes imported. Past the point of importation, data do not distinguish between that consumed in Texas and that dedicated for interstate commerce.

[5] Natural Gas Supply Association, "History," http://www.naturalgas.org/overview/history.asp. (Last visited April 25, 2008.)

[6] U.S. Energy Information Administration, "Energy in the United States: 1635-2000—Natural Gas," http://www.eia.doe.gov/emeu/aer/eh/natgas.html. (Last visited April 25, 2008.)

[7] Handbook of Texas Online, "Oil and Gas Industry," http://www.tshaonline.org/handbook/online/articles/OO/doogz_print.html. (Last visited April 25, 2008.)

[8] Handbook of Texas Online, "Big Inch and Little Big Inch," http://www.tshaonline.org/handbook/online/articles/BB/dob8_print.html. (Last visited April 25, 2008.)

[9] U.S. Energy Information Administration, "Energy in the United States: 1635-2000— Natural Gas."

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CHAPTER 6

Liquefied Petroleum Gas (LPG)

INTRODUCTION

Liquefied petroleum gas (LPG) is a term describing a group of hydrocarbon-based gases derived from crude oil and or natural gas. Natural gas purification produces about 55 percent of all LPG, while crude oil refining produces about 45 percent.

LPG is mostly propane, butane or a mix of the two. It also includes ethane, ethylene, propylene, butylene, isobutene and isobutylene; these are used primarily as chemical feedstocks rather than fuel.

LPG becomes a liquid at normal pressure and a temperature of -42° C, or at normal temperatures under a pressure of about eight atmospheres (standard units equivalent to ordinary atmospheric pressure at sea level and 0 degrees centigrade).

Separating the economic impact of LPG is problematic because it is derived from both oil and natural gas. A report commissioned by the propane industry estimated propane added $3.8 billion to the Texas economy in 2002.

History

In 1910, Dr. Walter Snelling, a chemist with the U.S. Bureau of Mines, discovered that propane was a component of liquefied gas. Soon afterward, he discovered a means to store and transport propane and butane. Snelling received a patent for LPG in 1913, which he then sold to Frank Phillips, founder of Phillips Petroleum Company.[1]

Initially, LPG was used to fuel metal-cutting torches, but by 1927, manufacturers were making gas cooking ranges fueled by LPG. Soon after World War II, propane was used as a transportation fuel in buses and cars.

Uses

LPG, primarily propane, is widely used as a fuel for heating and cooking in rural America and other areas where natural gas lines are unavailable. Its transportability and easy storage have boosted its popularity. Although relatively few urban residences depend upon large propane tanks for heating and cooking, smaller tanks for outdoor grills are extremely common throughout the nation.

Propane also is used to generate electricity through microturbines and combined heat and power (CHP) technology. Microturbines are very small turbines intended to generate electricity for homes or commercial establishments, as well as for vehicles such as hybrid buses; they are still in the research and design stage. CHP, also known as cogeneration, produces electricity as well as heat for homes and businesses from a single fuel source.

While only 0.1 percent of LPG in 2005 was used for transportation, propane was nevertheless the most common alternative transportation fuel in the U.S., used by public transportation fleets as well as many state and federal agency vehicles.[2] Propane has a lower energy output than gasoline, producing 84,000 British thermal units (Btu) per gallon, or about 74 percent of gasoline's energy potential.[3] The Texas Department of Transportation (TxDOT), which has the largest vehicle fleet in Texas state government, had 2,938 LPG-fueled vehicles in 2006, representing 28.5 percent of its fleet.[4]

LPG also ranks third in the U.S., behind gasoline and petroleum products, as a chemical feedstock.[5]

Texas is the nation's largest producer and consumer of LPG.

LPG IN TEXAS

Texas is the nation's largest producer and consumer of LPG. Chemical feedstock uses account for 90 percent of the state's LPG use, with nearly all of the remaining 10 percent used to produce energy.[6] LPG used for transportation accounted for just 0.1 percent of all LPG consumed in Texas in 2005, and 1 percent in the U.S.[7]

Economic Impact

LPG production is intertwined with the oil and gas industries, and it is therefore difficult to separate them for the purposes of estimating

Exhibit 6-1

Texas Average Employment and Wages for Industries Related to Liquefied Petroleum Gas, Third Quarter 2007

Industry	Average Number of Employees	Total Wages
Crude Petroleum & Natural Gas Extraction	73,436	$2,509,882,504
Natural Gas Liquid Extraction	3,728	116,232,357
Drilling Oil and Gas Wells	39,164	859,244,990
Support Activities, Oil/Gas Operations	81,741	1,510,925,468
Petroleum Refineries	21,308	591,346,879
Oil and Gas Field Machinery & Equipment	38,762	769,038,113
Petroleum Bulk Stations and Terminals	3,962	70,709,696
Other Petroleum Merchant Wholesalers	10,112	181,739,479
Pipeline Transportation of Crude Oil	3,833	89,218,207
Pipeline Transportation of Natural Gas	9,884	276,698,172
Refined Petroleum Product Pipeline Operations	255	4,900,710
All Other Pipeline Transportation	61	957,697

Sources: Texas Comptroller of Public Accounts and Texas Workforce Commission.

LPG's economic impact. **Exhibit 6-1** lists average employment and wages in the third quarter of 2007 for a series of industries linked to LPG. In the third quarter of 2007, there were about 3,021 Texas LPG dealers who earned a total of $31.9 million.[8]

A 2004 report commissioned by the National Propane Gas Association examined the impact of propane on the U.S. and state economies. **Exhibit 6-2** shows the estimated direct economic impact of the propane industry on the U.S. and Texas economies in 2002.[9]

Exhibit 6-2

Direct Value Added by the Propane Industry, 2002 (in Millions)

Sector	U.S.	Texas
Production	$2,977.1	$959.7
Transportation, Storage and Wholesaling	465.5	86.5
Retailing	6,121.5	444.3
Total	$9,564.0	$1,490.6

Note: Totals may not add due to rounding.
Source: National Propane Gas Association.

Consumption

Texas consumed 413.5 million barrels of LPG for fuel in 2005, 55.8 percent of all LPG consumed in the U.S. The state's industrial sector was the largest consumer, accounting for 97.3 percent of all Texas consumption and 71.2 percent of national consumption.[10]

Exhibit 6-3 details Texas LPG energy consumption by sector.

In 2002, Texas consumption of propane was spread among the following uses, ranked by volume: industrial (30 percent), residential (29 percent), commercial (22 percent), internal combustion (7 percent), farm (6 percent) and cylinders used for grills and camping (5 percent).[11]

Again, propane is the most commonly used alternative fuel for transportation. In 2006, Texas had 525 LPG fueling stations, or 22.9 percent of the national total. By contrast, Texas has about 16,500 gasoline fueling stations.[12]

LPG vehicles registered in Texas must display a prepaid "Liquefied Gas Tax" decal based on vehicle gross weight and the amount of miles driven during the previous year. **Exhibit 6-4** shows the number of

Exhibit 6-3

Texas LPG Consumption, Price and Expenditures by Sector, 2005

	Residential	Commercial	Industrial	Transportation	Total
Consumption (in thousands of barrels)	8,996	1,587	402,436	468	413,487
Consumption (in trillions of Btus)	32.6	5.7	1,456.8	1.7	1,496.8
Prices (in dollars per Million Btu)	$22.5	$18.1	$12.0	$21.7	$12.2
Expenditures (in $millions)	$733.0	$103.8	$17,416.7	$36.8	$18,290.0

Source: U.S. Energy Information Administration.

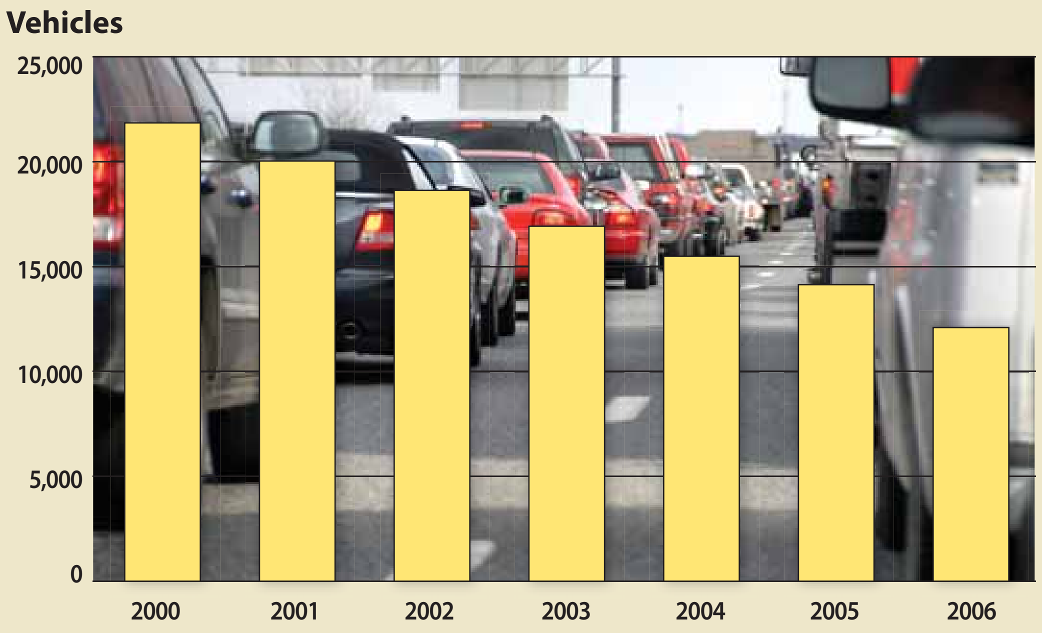
registered LPG vehicles in Texas from 2000 through 2006. Texas school districts and counties, the federal government and nonprofit telephone and electrical cooperatives are exempt from this tax and therefore are not included in the count of registered vehicles.

The number of registered Texas vehicles using LPG as a fuel source has been decreasing in recent years, dropping by 9,753 vehicles or 44.6 percent from 2000 to 2006.[13]

The federal Energy Policy Act of 1992, which required state governments to acquire light-duty vehicles powered by alternative fuels, spurred the popularity of LPG-fueled vehicles in state fleets. At that time, 221,000 of 250,000 alternative

Exhibit 6-4

Non-Exempt LPG Vehicles in Texas, 2000-2006



Source: Texas Comptroller of Public Accounts.

vehicles in the U.S., or 88.4 percent, were fueled by propane. Beginning in 1997, the act required 10 percent of new light-duty vehicles purchased by state governments to be fueled by alternative fuels and increased each year, from 15 percent in 1998 to 25 percent in 1999, 50 percent in 2000 and 75 percent from 2001 onward.[14]

Many state fleets, however, are shifting away from propane as other alternative fuels become available; and because of slow sales, some equipment manufacturers have stopped producing and selling LPG vehicles, which has contributed to the decreased size of LPG fleets. TxDOT has stated, moreover, that it is not comfortable with after-market conversions of gasoline-powered vehicles to LPG, and that this industry too, has declined.[15] The limited number of LPG fueling stations in Texas, moreover, requires TxDOT to maintain its own fueling stations.

The Texas state government fleet had 7,398 vehicles using alternative fuels in fiscal 2006, with LPG vehicles accounting for 73 percent of the total.

But the Office of Vehicle Fleet Management at the Comptroller's office has reported that the number of LPG vehicles in use is decreasing while the number of vehicles using other alternative fuels, such as ethanol, electric and hybrid options, is rising.[16]

In TxDOT's fleet, the state's largest, the number of LPG vehicles employing either an LPG and gasoline mix or 100 percent LPG has fallen precipitously (**Exhibit 6-5**). In fiscal 2001, TxDOT's fleet included 4,677 LPG vehicles, which remained relatively stable until 2004. By fiscal 2006, this portion of the fleet had dropped by 1,739 or 37.2 percent, to 2,938.[17]

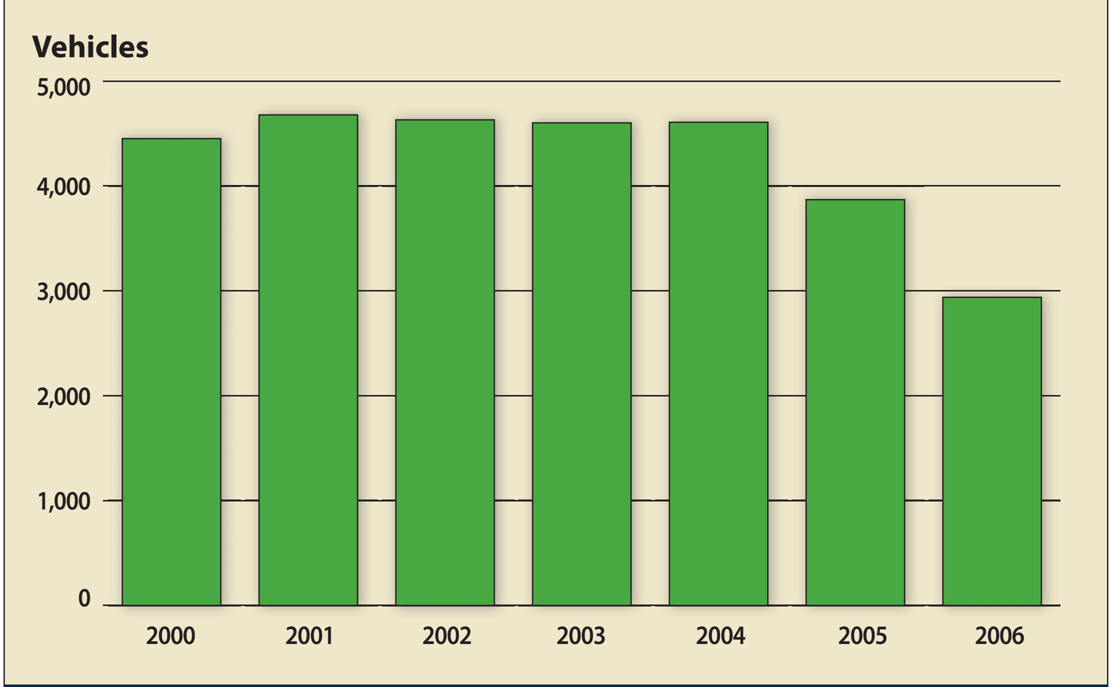
Production

In 2002, Texas produced 3.5 billion gallons of propane, or 36 percent of the national total.[18]

LPG is separated from crude oil at petroleum refineries and from natural gas at processing plants. Oil refineries create LPGs as a byproduct of gasoline and heating oil production. At natural gas process-

EXHIBIT 6-5

TxDOT Active Fleet of LPG Vehicles, 2000-2006



Source: Texas Department of Transportation.

ing plants, LPGs are extracted from the gas to prevent them from condensing and causing problems with natural gas transportation in pipelines.

Propane is transported by underground pipelines or by railroad to storage terminals and by trucks to storage facilities, residential homes and businesses (**Exhibit 6-6**).

Propane is stored in large tanks at various distribution points, and in smaller tanks at residential homes. Residential demand for propane tends to be seasonal, and propane and other LPGs can be stored whenever supply exceeds demand. Propane inventories often are built up during the summer months for use in the winter.

Availability

Because LPG is a byproduct of oil and gas, the amount available is directly tied to the amount of oil and gas available. Texas' crude oil reserves in 2006 represented almost one-fourth or 23.3 percent of total proven U.S. reserves.[19] Natural Gas reserves in Texas represented an even higher proportion of total reserve than did oil. Texas' proven reserves in 2006 accounted for 29.2 percent of all proven natural gas reserves in the U.S.[20]

COSTS AND BENEFITS

While propane is produced from both crude oil refining and natural gas processing, its price is more influenced by the cost of crude oil because propane competes mostly with oil-based fuels.[21]

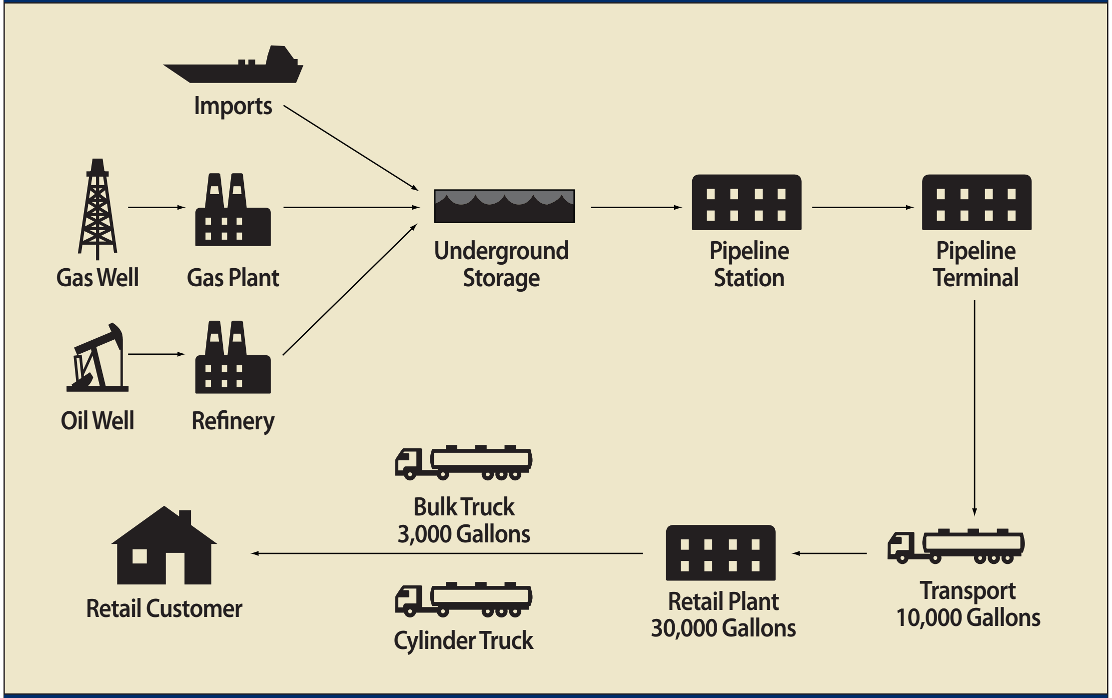
Weather, inventory levels and production all help determine LPG prices. As of January 8, 2007, residential propane cost $1.99 per gallon, while wholesale propane cost 96 cents per gallon. By March 17, 2008, the cost of residential propane had risen to $2.60 per gallon, while the wholesale price climbed to $1.63.[22]

Environmental Impact

LPG is a non-renewable fuel source, as is the natural gas and crude oil from which it is produced.

EXHIBIT 6-6

Propane Distribution Process



Source: U.S. Energy Information Administration.

Propane's price is influenced by the cost of crude oil because propane competes mostly with oil-based fuels.

LPG is a cleaner alternative to many fuels, but its combustion does produce pollutants. These include particulate matter, sulfur dioxide, nitrogen oxides, nitrous oxide, carbon monoxide, carbon dioxide, methane and non-methane total organic carbon.[23]

LPG vehicles emit around a third less reactive organic gas, which reacts with other pollutants in sunlight to create ozone, and about 50 percent less of the vapors that create smog, than do gasoline vehicles. LPG vehicles also release 20 percent less nitrogen oxide and 60 percent less carbon monoxide than gasoline vehicles. Finally, LPG contributes very little to acid rain because of its low sulfur content.[24]

Again, since LPG is a byproduct of oil and natural gas production, its water consumption and quality implications are similar to those of oil and gas. More information on oil and gas can be found in Chapters 4 and 5.

LPG is a cleaner alternative to many fuels.

Other Risks

There are federal and state regulations on the production, transportation and storage of LPGs and other pressurized gases to minimize risks. Though rare, LPG, particularly propane and butane, poses a risk of sudden depressurization and explosions during storage and transport.[25]

State and Federal Oversight

The Texas Railroad Commission (RRC) administers and enforces state laws and rules related to LPG. RRC also licenses LPG activities in the state including its sale, transportation and storage; the manufacture, repair, sale and installation of LPG containers; and the installation, servicing and repair of LPG-fueled appliances.

Drivers and dealers of LPG vehicles also must obtain a fuels tax permit from the Texas Comptroller of Public Accounts.

While most regulation of LPG is conducted at the state and local levels, two federal agencies also have related oversight responsibilities. The U.S. Environmental Protection Agency is responsible for oversight and regulation of emissions and clean air standards, while the U.S. Department of Transportation regulates the transportation of LPG.

Subsidies and Taxes

LPG and other alternative fuels receive a number of subsidies and incentives from the federal and state governments The most important of these is the federal motor fuel excise tax credit, which provides a 50 cent per gallon tax credit for alternative fuels, including LPG.

Because LPG is derived from oil and natural gas, its production also is affected by taxes and fees assessed on those resources. More information on subsidies for oil and gas, which affect LPG, can be found in Chapter 28. In addition, some taxes and fees apply directly to LPG.

Liquefied Gas Tax

Texas taxes LPG used in motor vehicles on public highways at a rate of 15 cents per gallon.[26] The state's gasoline tax, by contrast, is 20 cents per gallon. In fiscal 2007, the state collected more than $1.2 million through the LPG tax.[27] This was 17.1 percent less than in the year before and 41.9 percent less than in fiscal 2000 (**Exhibit 6-7**).

LPG Delivery Fees

Texas also imposes an LPG delivery fee on the first sale of LPG. The purpose of this fee is to provide funding to the Texas Railroad Commission's Alternative Fuels Research and Education division. Each person responsible for collecting and remitting a fee on the delivery of LPG into any cargo container

EXHIBIT 6-7

State Revenue Generated from the Liquefied Gas Tax, Fiscal 2000-2007

Fiscal Year	Liquefied Gas Tax	Percent Change
2000	$2,136,722	-
2001	$1,853,029	-13.3%
2002	$1,858,316	0.3%
2003	$1,572,057	-15.4%
2004	$1,586,076	0.9%
2005	$1,523,432	-3.9%
2006	$1,498,838	-1.6%
2007	$1,242,464	-17.1%

Note: State fleets are NOT exempt.
Source: Texas Comptroller of Public Accounts.

must collect fees from the purchaser ranging from $7.50 for small containers up to $25 per increment of 5,000 gallons for containers capable of holding 12,000 gallons or more.[28]

In fiscal 2007, these fees yielded nearly $2.5 million for the state.[29] This was 29.7 percent more than in fiscal 2006 and 25.3 percent more than in fiscal 2000 (**Exhibit 6-8**).

OTHER STATES AND COUNTRIES

As noted earlier, Texas is the nation's largest consumer of LPG for all sectors combined. Other states, however, exceed Texas in some sectors. Texas was the second-largest consumer of residential LPG in 2005, accounting for 6.3 percent of the nation's total; Michigan led the states with 9.7 percent.

Similarly, Texas was the second-largest consumer of commercial LPG in 2005, again accounting for 6.3 percent of the nation's total commercial use. Michigan was again first, with 9.7 percent of the national total.

Texas was the largest consumer of industrial LPG in the nation in 2005, accounting for nearly three-quarters (71.2 percent) of all industrial LPG used in the nation. Louisiana (8.5 percent) was a distant second.

EXHIBIT 6-8

State Revenue Generated from LPG Delivery Fees, Fiscal 2000-2007

Fiscal Year	Liquefied Gas Delivery Fees	Percent Change
2000	$1,956,752	-
2001	$2,167,909	10.8%
2002	$2,099,462	-3.2%
2003	$2,359,833	12.4%
2004	$2,112,984	-10.5%
2005	$1,965,716	-7.0%
2006	$1,890,508	-3.8%
2007	$2,451,651	29.7%

Source: Texas Comptroller of Public Accounts.

Finally, Texas was the fourth-largest consumer of LPG used for transportation in 2005, accounting for 6.4 percent of the nation's LPG used for this purpose. North Carolina was the largest with 17 percent, followed by California and Michigan with 11.5 percent and 6.9 percent respectively.[30]

While few automakers offer LPG vehicles in the U.S., they are much more common in Europe and Australia. Ford and GM both offer LPG-fueled models to those markets. The popularity of these vehicles is due to tax incentives for purchasing LPG and/or tax disincentives for gasoline.[31]

While few automakers offer LPG vehicles in the U.S., they are much more common in Europe and Australia.

OUTLOOK FOR TEXAS

As noted above, LPG for transportation has seen its market share fall in recent years. While a number of state and federal incentives encourage the use of LPG, Texas and the U.S. as a whole seem to be moving toward other alternative fuels such as ethanol. Falling sales of LPG vehicles have prompted manufacturers to curtail their production.

LPG as a source of heating and cooking fuel will continue to be common in Texas. Whether its use is for outdoor grilling or as a substitute for natural gas in rural areas, LPG is accessible and affordable.

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CHAPTER 7
Coal

INTRODUCTION

Coal is a combustible rock formed from prehistoric biomass. Like oil and natural gas, coal is considered a "fossil fuel" because it was formed from decaying plant material over hundreds of millions of years.

Coal is a combination of pure carbon and hydrocarbons with varying amounts of moisture, minerals and heavy metals. It was the first fossil fuel used extensively by humans, and is still vitally important today, generating 39 percent of the world's electricity, 49 percent of U.S. electricity and 36.5 percent of Texas' electricity in 2006.[1]

Coal is found on every continent and in some 70 countries. The U.S., Russia, China and India have the world's largest reserves. The World Coal Institute in London estimates proven world coal reserves at 984 billion metric tons (more than 1 trillion U.S. tons), enough to last for more than 190 years at current rates of consumption.[2]

In Texas in 2006, coal mining provided 2,241 jobs, earning an estimated $167.6 million in wages.[3] Other contributions of coal to the economy are indirect. Texas coal is mined at the surface, and the surface owner, usually large utilities, does not report the value of the coal nor does the owner owe state taxes on coal production, although federal taxes are owed.

History

Throughout recorded history, some degree of industrialization has accompanied the widespread use of coal. Some of the earliest archeological evidence of the human use of coal dates back to about 6,000 years ago in northeastern China. The Romans used coal they found in Britain both as jewelry and as fuel for their forts and blacksmiths' foundries until their exit from the islands in the fifth century A.D. Their knowledge of coal's fuel value was lost to their British subjects for almost seven centuries.[4]

By the 11th century, the Chinese were using charcoal and coke, a material derived from coal, to make iron.[5] Britain's use of coal in the eighteenth century led to the widespread availability of cheap iron and helped spur the Industrial Revolution.

In early America, English settlers reported an abundance of coal in the new country. Coal outcrops were found throughout the Appalachian Mountains and, in 1758, a new settlement named Pittsburgh was founded in an area of particularly abundant coal supplies. Within a few short years, Pittsburgh coal helped America begin its own industrialization.[6]

Today, the world consumes about 4.4 billion short tons annually, a 38 percent increase in 20 years. (A short ton is 2,000 pounds, the measure used in the U.S. and in this chapter. The metric "tonne" of 2,200 pounds is used by some sources cited in this chapter; these figures have been converted to short tons throughout.) The majority of this coal is used for electricity generation and steel production.[7]

Coal is one of the world's most widely used fuels.

Uses

Coal is one of the world's most widely used fuels. In the U.S., coal produces 22.5 percent of the British thermal units (Btu) consumed for all purposes from all sources — about the same as natural gas (22.4 percent), but less than petroleum (39.8 percent).[8]

Coal began as peat, a soft deposit formed by plant and animal matter collecting in boggy areas some 360 to 290 million years ago.[9] As the material aged, sank and became buried by sediments over eons — a process called coalification — ever-increasing overburden pressure and heat squeezed out moisture and impurities to create four "ranks," or grades, of coal. These are, in descending order of hardness and heat content, anthracite, bituminous coal, subbituminous coal and lignite. Each type of coal has specialized uses.

Of the four grades of coal, the hardest and rarest is anthracite, which is also geologically the oldest and purest, with the lowest moisture and mineral content. As such, it burns hottest, producing about 25 million Btu per ton, and produces the lowest emissions of all coals. In the U.S., anthracite is found only in northeastern Pennsylvania, and is used almost exclusively for home heating.

Bituminous and subbituminous coals, the most abundant types in the U.S., are found in Appalachia, the Midwest, Wyoming and Montana. The Powder River Basin (PRB) in Wyoming and Montana is a major source of this coal in the U.S. In addition to having a higher moisture and mineral content than anthracite, these coals contain bitumen, a thick tar-like material used in steelmaking and road building.

In the U.S., bituminous coal is often used to generate electricity. Its heat content averages 24 million Btu per ton, only slightly lower than that of anthracite. Subbituminous coal ranks between bituminous and lignite in its hardness and moisture content, and has a higher mineral content than bituminous coal.[10] Its heat value averages 17 to 18 million Btu per ton. Bituminous coal is found in the eastern and midwestern U.S., while subbituminous is mined only in the western U.S., most prominently in the Powder River Basin.[11]

As of 2006, Texas had 11 coal-fired utility plants using coal as a main or backup fuel.

Lignite, the lowest-quality coal, is geologically the youngest and has the highest moisture and mineral content. It is used almost entirely for electricity generation. Lignite produces an average 13 million Btu per ton, with higher emissions of nitrous and sulphurous oxides (NO_X and SO_X) and carbon dioxide (CO_2) than the higher ranks of coals.[12] Texas lignite is mined in an area east of Interstate Highway 35 running from San Antonio to the Oklahoma border. Lignite is also found in North Dakota.

This lower-grade coal is most often used to fire boilers, either to generate electricity or to create heat for industrial processes such as smelting. It also can be transformed into coke, which has its own applications in industrial processes.

COAL IN TEXAS

As of 2006, Texas had 11 coal-fired utility plants using coal as a main or backup fuel, seven in the Electric Reliability of Council of Texas (ERCOT) power grid and four in the Southern Power Pool. Combined, these plants had 19 generation units with a total nameplate (maximum) capacity of more than 11,000 megawatts (MW) of electricity.[13] In 2006, these plants generated 146.4 million megawatt-hours (MWh) of electricity, 36.5 percent of the state total. Nine of the plants burn subbituminous coal only, five burn both subbituminous and lignite coal and the remaining four burn only lignite. All but one used either diesel fuel oil or natural gas as a backup fuel.[14] (For more detail on electricity, see Chapter 27 of this report.)

Economic Impact

Coal production contributed 2,241 mining jobs to the Texas economy in 2006. Wages were estimated to be $167.6 million.[15] Texas has 13 active lignite mines, most supporting a nearby coal-fired electricity generation plant or industrial facility (known generally as “mine mouth” operations). Five other Texas mines are in reclamation, meaning that they are no longer in operation and the mine sites are being reclaimed for other uses. One is not operating but is not yet in reclamation (**Exhibit 7-1**).

Coal receives substantial financial subsidies from the federal government, but none from Texas state government. Coal extraction in Texas is taxed by the federal government, but not state government. For more information on subsidies and taxes, see Chapter 28 of this report.

Consumption

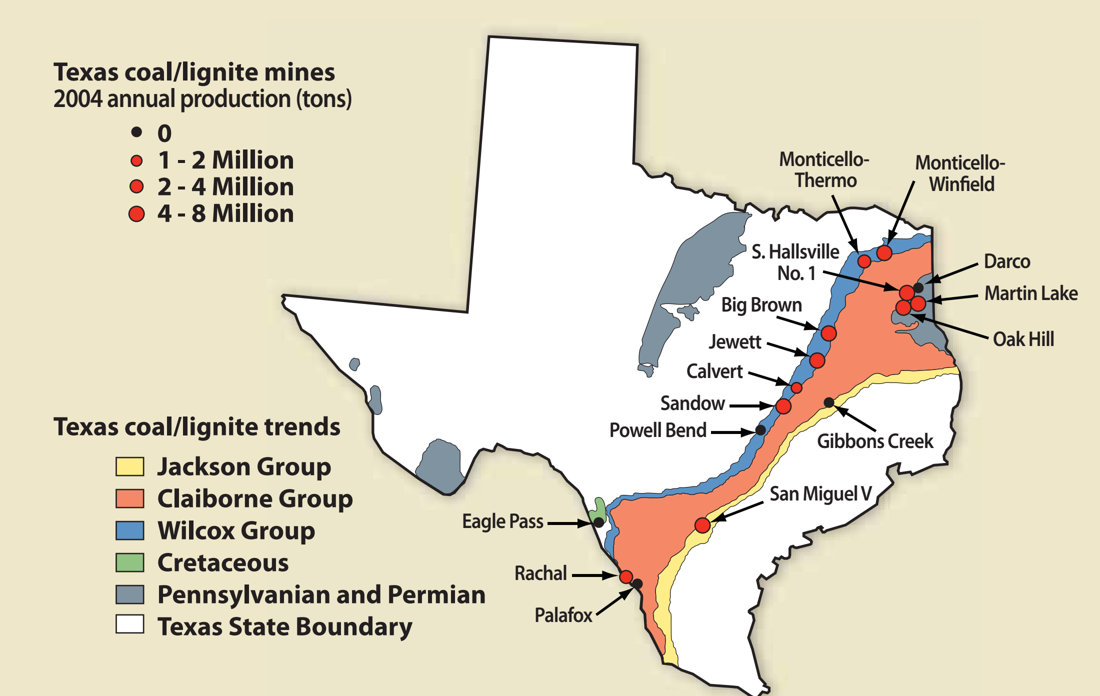
According to the federal Energy Information Administration (EIA), more than 96 percent of the coal consumed in Texas in 2006, or 99.6 million tons, was used to generate electricity. The remainder, about 4.1 million tons, was used for “other industrial” purposes.[16]

In 2006, U.S. imports of coal amounted to three-quarters of its exports of coal — 36.2 million tons versus 49.6 million tons. In that year, about 1 billion tons, or 92.1 percent of all U.S. coal consumption, was used for electricity generation. Industrial uses accounted for a relatively minor 83.5 million tons, or 7.5 percent of consumption. Residential use of coal was less than a tenth of 1 percent (**Exhibit 7-2**).[17]

In the U.S., coal’s share of all fuels used to produce electricity has declined slowly but steadily

EXHIBIT 7-1

Texas Coal Mine Locations



Note: Some locations have more than one mine.

Source: Railroad Commission of Texas.

Coal production contributed 2,241 mining jobs to the Texas economy in 2006. Wages were estimated to be $167.6 million.

over the past 10 years. As noted in **Exhibit 7-3**, Texas coal use follows a similar pattern after 1997.

Production

Coal is mined from surface or underground mines. Older coals, such as those in the Appalachian Mountains, usually are found in deeper formations, at depths between 600 and 2,000 feet.[18]

Lignite, the most common coal found in Texas, is found predominantly at shallower depths ranging from 40 to 120 feet beneath the surface, allowing for surface or "strip" mining.[19] Strip mining requires removal of topsoil and the "overburden," or underlying soil and rock, and storing the topsoil for later reclamation work. Coal is then mined with heavy surface mining equipment. After the coal is removed, the coal company is required by federal and state law to replace the overburden and plant vegetation to reclaim the land for other uses.[20]

In 2006, almost 70 percent of the U.S. coal produced in that year — 803.4 million tons out of 1.16 billion tons — came from surface mining.[21] Bituminous and subbituminous coal production accounted for more than 1.08 billion tons, or 92.6 percent, of all coal produced. Lignite mining, while prevalent in Texas, represented only 84.2 million tons or 7.2 percent of total U.S. production. The remainder, anthracite, was only 0.1 percent (**Exhibit 7-4**).

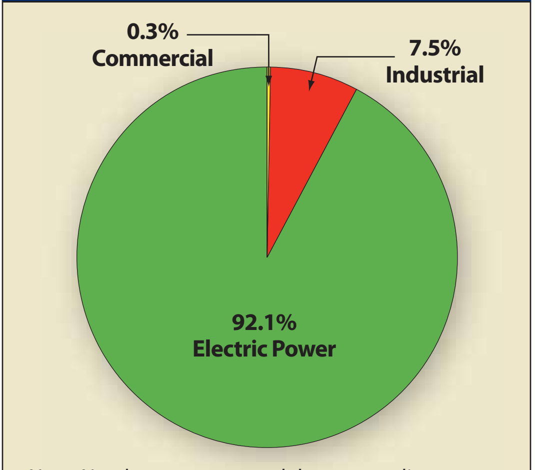
Because the combustion of lignite coal releases high levels of federal Clean Air Act "criteria pollutants" such as carbon dioxide (CO_2), nitrous oxides (NO_X), sulfuric oxides (SO_X) and particulate matter, four Texas electric generation plants mix it with cleaner-burning PRB coal from Wyoming and Montana.

Transportation

Rail is the overwhelming choice for coal transportation in the U.S., shipping some 71 percent of the nation's coal by weight in 2006, according to EIA. Eleven percent was shipped by truck, 10 percent by river barges, 7 percent by short-distance means, such as tramways, conveyers and slurry pipelines (pipelines carrying a mixture of water and finely ground coal), and 1 percent was undocumented (**Exhibit 7-5**).[22]

Exhibit 7-2

U.S. Coal Consumption by Sector, 2006



Note: Numbers may not total due to rounding.

Sources: U.S. Energy Information Administration and Texas Comptroller of Public Accounts.

Of the 680 million tons of coal shipped by railroad in the U.S., electricity generation plants received 93.7 percent; industrial plants received 4.5 percent; 1.5 percent went to coking plants; and the remainder went to other residential and commercial uses. More than 95 percent of the 85 million tons of coal shipped by conveyors or slurry pipelines went to electricity generation plants; 4.7 percent went to industrial plants; and the remainder went to other residential and commercial uses.[23]

Because tramways, conveyors and slurry pipelines are generally short-distance hauls, one can infer that the power plants they serve are mine mouth operations. Slurry pipelines carry either a paste made of equal parts pulverized coal and water, or a compressed "log" of coal using water for flotation. The slurry contains the same trace minerals of copper, lead and other metals as dry coal, so it must be dewatered and demineralized before it is suitable for burning.[24]

Until recently, the nation's longest slurry pipeline in operation was the Black Mesa pipeline, which

Exhibit 7-3

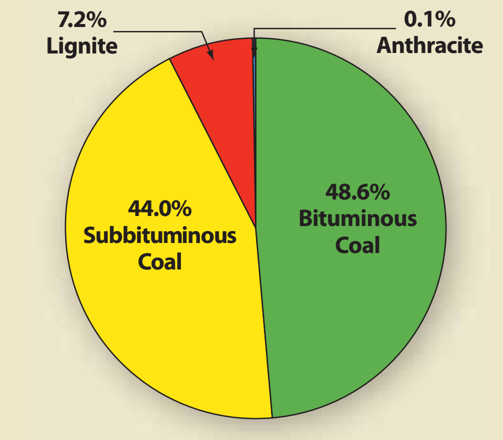
U.S. and Texas Net Electricity Production from Coal, 1995-2006

Year	U.S. Total Electricity Generation Percentage from Coal	U.S. Total Electricity Generation (Megawatt Hours)	Texas Total Electricity Generation Percentage from Coal	Texas Total Electricity Generation (Megawatt Hours)
1995	51.0%	3,353,487,000	39.3%	317,636,000
1996	52.1	3,444,188,000	41.3	328,949,000
1997	52.8	3,492,172,000	41.2	336,320,000
1998	51.8	3,620,295,000	38.1	355,320,000
1999	50.9	3,694,810,000	39.2	358,945,000
2000	51.7	3,802,105,000	37.2	377,742,000
2001	51.0	3,736,644,000	36.3	372,580,000
2002	50.1	3,858,452,000	36.8	385,629.000
2003	50.8	3,883,185,000	38.8	379,200.000
2004	49.8	3,970,555,000	38.1	390,299,000
2005	49.6	4,055,423,000	37.4	396,669,000
2006	49.0	4,064,702,000	36.5	400,583,000

Sources: U.S. Energy Information Administration and Texas Comptroller of Public Accounts.

Exhibit 7-4

U.S. Coal Production, 2006



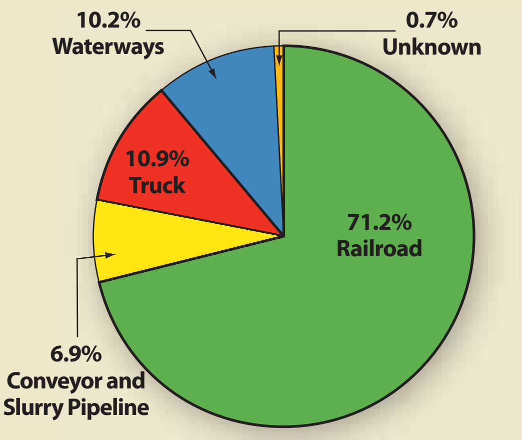
Total: 1,161.4 Million Tons

Note: Numbers may not total due to rounding.

Sources: U.S. Energy Information Administration and Texas Comptroller of Public Accounts.

Exhibit 7-5

Means of U.S. Coal Transportation, 2006



Note: Numbers may not total due to rounding.

Sources: U.S. Energy Information Administration and Texas Comptroller of Public Accounts.

While strip mining is the most economical method of retrieving shallow deposits of Texas lignite coal, it is hardly inexpensive. On the spot market, the commodity cost of lignite (excluding transportation costs) can be two to three times the cost of higher-quality PRB. The reason is the expense of surface mining in Texas.

For example, at the Big Brown coal and electric generating plant owned by Luminant, operators must move 130 feet of overburden to mine a five to 10-foot coal seam, remove more overburden to mine another shallow seam below the first, and so on. At present, the Big Brown plant's mine is about 200 feet deep.

In addition, operators must be sure to separate the lignite from the surrounding soil (visually, the two are quite similar) because too much dirt in the lignite lowers boiler temperatures and increases slag, a waste product.

Also, lignite's lower Btu value (about 6,500 to 7,000 Btus per pound, compared to PRB's 8,500 to 9,500 Btus per pound) means that more lignite is required to get boilers to the required temperature than the same volume of PRB. PRB, on the other hand, is within 30 to 50 feet of the surface in seams 40 feet thick and can be mined much less expensively.[25]

ran for 273 miles from a mine in northeastern Arizona to an electric plant in southern Nevada. In early 2007, however, the pipeline and the power plant it served shut down.[26]

Texas lignite generally is not transported for significant distances because most of its major consumers — electric utilities, aluminum smelters and other industrial users — are located within a short distance of active mines. Because it is not shipped, the fuel's total cost usually is lower than that of other coals that must be transported.[27]

Generation

To generate electricity, coal can be burned directly or gasified and then burned more cleanly. If burned directly, the coal is ground into a very fine powder and then blown into large combustion chambers. The resulting heat either drives turbines directly or boils water to drive steam turbines, which then drive generators to create electricity (**Exhibit 7-6**). If the turbines can do both, the process is called "combined cycle."

Gasification is a different process that can use coal, biomass, petroleum coke, petroleum residues or other organic waste (**Exhibit 7-7**). Under high heat, high pressure and controlled amounts of pure oxygen, most of the feedstock does not burn but instead breaks into its component parts.

The resulting synthetic natural gas, called "syngas," is primarily hydrogen and carbon monoxide. It can be burned to drive turbines, either directly or by boiling water or both. Mineral impurities can be removed before they combine with other elements to become regulated emissions such as NO_X, SO_X and H_2S. The burned coal is reduced to ash and removed.[28] The ash is either sold for use as an ingredient in concrete or as a roadbed material, or made into synthetic gypsum used in wallboard manufacturing. Occasionally, the ash is deposited in landfills.[29]

As of November 2007, Texas had only one coal gasification plant in the planning stages. Eastman Chemical is proposing to build a gasification plant near Beaumont.[30]

Availability

The U.S. has the world's largest known coal reserves, about 268 billion recoverable tons — enough to last the nation at least 236 years at current usage rates, according to EIA (**Exhibit 7-8**).[31] U.S. coal production in 2006 exceeded that of 2005, which in turn surpassed the prior record set in 2004. According to EIA, however, while coal production increased in 2006, it actually produced less overall energy due to the increased use of lower heat-value coals such as lignite.[32]

Texas has large, shallow lignite deposits in a band lying generally east of Interstate Highway 35. In 2006, Texas had 13 operating surface mines, fewer than 1 percent of the U.S. total, producing 45.5 million tons of coal, about 4 percent of the U.S. total.[33]

COSTS AND BENEFITS

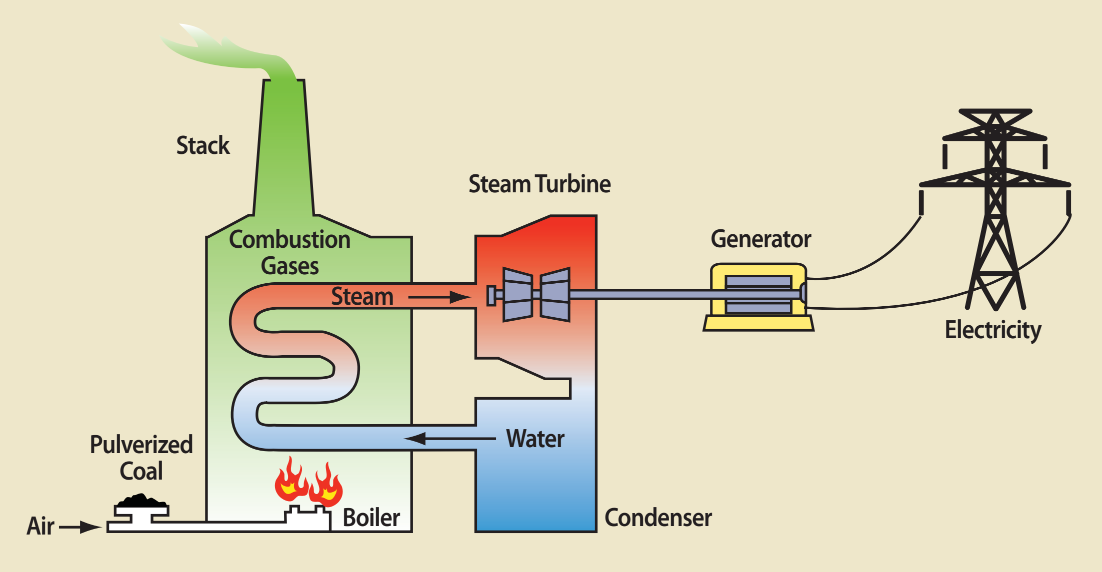
PRB coal must be transported to Texas by rail. Increased coal demand and rail shipment costs, combined with a rail system that in recent years has been prone to service disruptions, have raised questions as to the long-term reliability of PRB supplies.

An informal Comptroller survey of PRB coal-importing utilities in Texas indicated that rail costs constitute two-thirds to three-quarters of the final cost of the coal. The federal government has not collected data on coal rail transportation prices since 1999.

The U.S. has the world's largest known coal reserves.

EXHIBIT 7-6

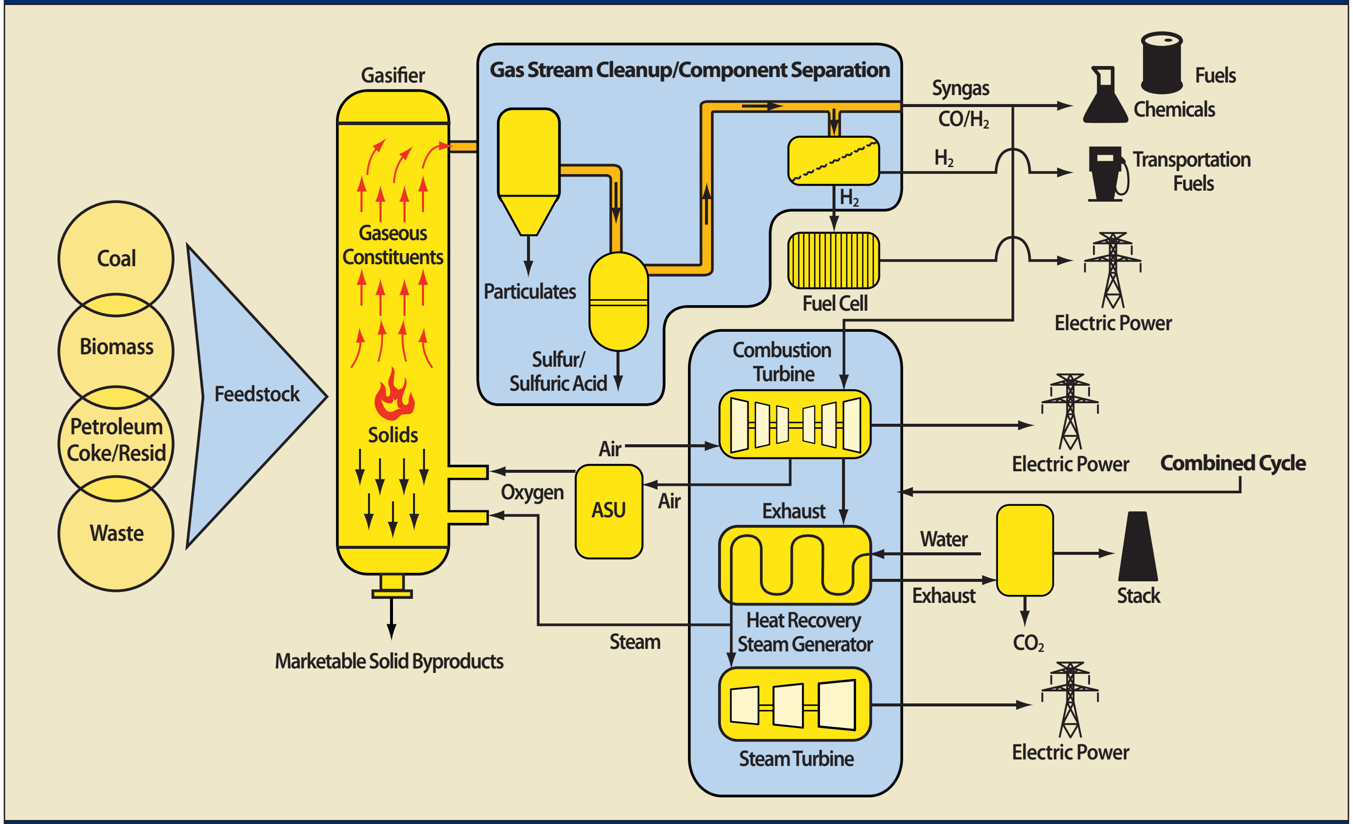
Schematic of a Coal-Fired Steam Turbine



Source: TXU Corporation.

Exhibit 7-7

Gasification-Based System Concepts



Source: U.S. Department of Energy.

The deputy general manager of Austin Energy, a municipally owned utility, said his utility buys 2 million tons of PRB per year, or about one trainload per day. Austin Energy pays about $20 million per year under its current contract with Union Pacific railroad. Soon, however, Union Pacific will move to a tariff system that will rely on posted, periodically updated prices rather than long-term contracts; this could double or triple Austin Energy's rail costs next year.

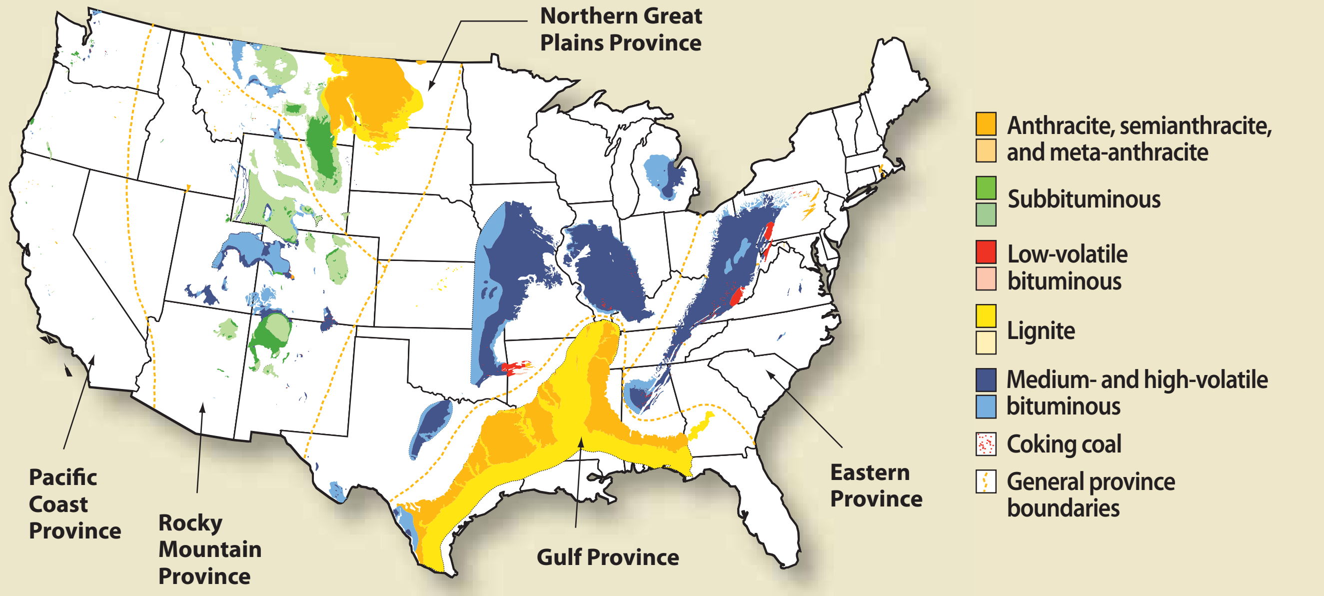
TXU Power imports PRB to co-fire with lignite from its own mine mouth operations; 75 percent of its PRB cost represents rail costs. In addition to these rates, railroads are adding on a surcharge to cover diesel's rising cost.[34]

According to 2005 EIA data, Texas imported 56.6 percent of its coal from out of state; 99.6 percent was shipped by rail, the remainder by rivers or trucks. In-state coal sources provided 42.7 percent; all of it was shipped via tramways, conveyors and slurry pipelines. The remainder was not documented.[35] Constraints on rail systems have required some power plants to make multiple arrangements with rail lines or to burn other fuels such as natural gas or fuel oils. The major railroad operators in Texas — Union Pacific/Southern Pacific and Burlington Northern-Santa Fe — are addressing these constraints by building more rail lines and increasing the use of existing lines.[36]

But railroad company construction efforts may not be adequate to meet demand. Rising rail prices for coal shipments, and shortfalls in those shipments, have prompted growing controversy in recent years.

EXHIBIT 7-8

U.S. Coal Mining Areas



Darker colors represent areas known to contain coal beds that are of commercial value at the present time or that may be of value to the future. In general the minimum thicknesses included are 14 inches for anthracite and bituminous coal, and 30 inches for subbituminous coal and lignite.

Lighter colors represent areas of doubtful value for coal. These may be divided into three classes- (1) areas containing thin or irregular beds, which generally have little or no value, but which locally may be thick enough to mine; (2) areas in which the coal is poor in quality; and (3) areas where information on the thickness and quality of coal beds is meager or lacking.

Source: U.S. Energy Information Administration.

The Federal Energy Regulatory Commission (FERC), which oversees the interstate electric and natural gas transportation systems, hosted a 2006 conference with utility and railroad representatives to address some utilities' concerns that unreliable and expensive coal shipments could impair their ability to generate electricity. As FERC stated in its 2006 *State of the Markets Report*:

> In 2005, major rail outages reduced deliveries of Wyoming's Powder River Basin (PRB) coal to electric generators. The resulting reductions in coal deliveries forced short-term changes in electricity markets and generation patterns. Over the longer term, markets responded as the railroads repaired damage and added new infrastructure, and customers devised ways to reduce their dependence on PRB coal.[37]

Coal shipped by conveyors and trucks is economical only for short-distance hauls, meaning that the almost 44 percent of coal consumed in Texas in 2005 came from nearby sources, as with mine mouth operations.[38]

Commodity Costs

The costs of producing Texas lignite coal are unknown, largely because nearly all of the coal is consumed at the point of production and its costs are embedded within the price of the resulting product, whether electricity, aluminum or chemicals. As noted earlier, rail costs for PRB coal make up two-thirds to three-quarters of its cost, although prices paid to ship coal by rail are not publicly available.

Due to increasing national demand, coal prices rose in 2006, according to EIA's 2006 *Annual*

Coal Report.[39] The average open-market commodity price of Texas coal in 2006 was $18.61 per ton, up from 2005's $17.39 per ton. At the same time, PRB coal cost an average of $9.03 per ton, up from 2005's $7.71 per ton. Spot prices at the end of 2007 for PRB coal was at $11.50, up from $9.95 per ton at the end of 2006. It should be noted, however, that very little Texas coal is sold in an open market, which may skew these prices. Furthermore, neither price includes transportation costs, which, again, can be substantial.

Environmental Impact

When burned, coal releases carbon dioxide, SO_X, NO_X and mercury compounds into the air. For this reason, the federal Environmental Protection Agency (EPA) requires coal-fired boilers to be equipped with emission control devices.[40] The residual ash also contains trace amounts of toxic heavy metals such as arsenic and mercury.

As of 2004, Texas' then-19 coal-fired plants accounted for 67 percent of the state's annual NO_X emissions from utility plants, and 66 percent of total NO_X emissions during the state's ozone season, which generally runs from April to November in the most populous areas.[41] The coal plants also emitted 99 percent of the utilities' annual SO_X emissions, 60 percent of their carbon dioxide emissions and 100 percent of their mercury emissions.[42]

According to EPA, NO_X emissions combine with volatile organic compounds in the presence of sunlight to create ozone, a ground-level pollutant regulated by the federal Clean Air Act.[43] SO_X emissions dissolve in water, creating a weak sulfuric acid that can become acid rain.[44]

Texas represents a meaningful portion of the nation's carbon dioxide (CO_X), sulphur dioxide (SO_2) and nitrous oxide (NO_X) emissions (**Exhibit 7-9**). EPA regulates the emissions of SO_2 and NO_X, so-called "criteria pollutants" under the Clean Air Act. Carbon dioxide is not yet regulated, but Congress is considering legislation to do so.

A coal plant's emissions are correlated with its age. Thirty- to 35-year-old coal-fired plants were built just as the Clean Air Act was becoming law. At that time, existing plants were "grandfathered" under the law and plant owners were not required to seek permits under the new law nor future permits for minor modifications. Over time, this situation spurred controversy in several areas of the country — including Central Texas — as some grandfathered plants received what many believed were more than minor modifications that led to an increase in emissions. Many of these grandfathered coal plants now are reaching the end of their useful lives, and also have more emissions than newer plants.[45]

Exhibit 7-9

Texas Electric Utility, Commercial and Industrial Air Emissions, 2006

2006	CO_2 (Metric Tons)	SO_2 (Metric Tons)	NO_X (Metric Tons)
Total U.S. Emissions	2,459,800,018	9,523,561	3,799,447
Total Texas Emissions	257,552,164	558,350	260,057
Percent of U.S.	*10.5%*	*5.9%*	*6.8%*
Coal in Texas	150,589,481	523,073	119,910
Percent of state	*58.5%*	*93.7%*	*46.1%*
Percent of U.S.	*6.1%*	*5.5%*	*3.2%*

Sources: U.S. Energy Information Administration and Comptroller of Public Accounts.

China is now building the equivalent of two 500-megawatt coal-fired electricity plants every week.

Coal plant emissions have been the source of considerable argument and debate for decades. In Texas, the debate reached new heights after the 2006 announcement by TXU (now Energy Future Holdings Corporation), the state's largest electricity generator and retailer, that it would build 11 lignite coal-fired electricity generation plants, some new and some representing retrofits of older plants that formerly burned natural gas.[46] A gubernatorial executive order issued prior to TXU's announcement required the Texas Commission on Environmental Quality, which reviews applications to build or make major modifications to utility plants, to hasten its review of any permit applications involving Texas energy resources.[47]

In early 2007, however, TXU announced that private investors would be purchasing the corporation for $45 billion and that the new owners would drop plans to build eight of the 11 coal-fired facilities.[48] As part of the deal, TXU announced it would bring 1,400 MW of "mothballed" (closed but not abandoned) natural gas-fired plants back into service.[49] TXU shareholders approved the buyout on September 7, 2007.[50]

In addition, coal power plants use some water. Depending on the plant type, electricity generation from coal requires withdrawals of between zero and 14,658 gallons per million Btu of heat energy produced. This is the amount of water extracted from a water source; most of the water withdrawn is returned to that source.

Water consumption refers to the portion of those withdrawals that is actually used and no longer available. Electric generation using coal consumes between zero and 150 gallons of water for each million Btu of heat energy produced.

Surface Reclamation

The Railroad Commission of Texas (RRC) is responsible for reclaiming abandoned mine lands under Title IV of the federal Surface Mining Control and Reclamation Act of 1977. Reclamation often includes soil recontouring; the burial or treatment of mine residues called spoil; the installation of erosion and water control structures; and revegetation of the landscape. Underground mine openings also must be sealed. [51] The act requires all current and future mine operators to post bond or to provide regulators with proof that they have the financial means to reclaim mines they abandon.[52]

RRC's Abandoned Mine Land (AML) program restores land and water resources damaged by mining before the law was passed. The program receives funding from the federal Office of Surface Mining Reclamation and Enforcement through a federal production tax levied on active coal mining operations. As of May 2005, Texas' AML program had reclaimed 2,411 acres of abandoned surface mines and closed 525 underground mine openings at a cost of $25 million.[53]

Transportation Emissions

The extensive use of diesel-fueled trains to move coal presents another challenge, since they often travel through or by highly populated areas that are being monitored for federal Clean Air Act compliance.[54]

Other Risks

The entire coal fuel stream, including mining, transportation and power generation, presents physical, logistical and financial risks.

Rail transportation of coal, as noted above, can be limited by several factors, including rail congestion and outages, labor disputes, diesel emissions and noise.

Furthermore, increasing public resistance to the use of coal to generate electricity because of its environmental effects, particularly in Texas, places financiers' potential investment in coal plants at risk.[55]

State and Federal Oversight

Coal mining comes under the purview of a number of federal and state agencies concerned with occupational and environmental health and safety. When used as a fuel for electricity generation, coal oversight extends to federal and state agencies such as the Federal Energy Regulatory Commission and, in the still-regulated areas of Texas' electricity grids, the Public Utility Commission.

Subsidies and Taxes

As noted in Chapter 3 of this report, the coal industry contributes to federal and state tax revenues through income taxes, franchise taxes, property taxes and indirectly through taxes paid by coal power plant owners.

By far, the largest coal-related federal subsidy, worth more than $2 billion in 2006, is coal's share of the Alternative Fuel Production Credit. Companies that create synthetic fuel from coal are eligible for this subsidy. Chapter 28 contains information on subsidies related to coal.

OTHER STATES AND COUNTRIES

The World Coal Institute predicts that global coal consumption will reach 7.7 billion tons by 2030, with China accounting for half the increase.[56]

China is now building the equivalent of two 500-megawatt (MW) coal-fired electricity plants every week. This is comparable to adding the total power capacity of the United Kingdom to China's electrical grid each year.[57]

China's exploding economy — and fuel consumption — is perhaps the biggest factor in world coal use. Coal provides fully two-thirds of the country's energy supply, more than 80 percent of its electricity, 50 percent of its industrial fuel and 60 percent of its chemical feedstocks (ingredients used to create fertilizers, plastics and other materials). China's coal production is double that of the U.S., and it consumes one-third of all coal used worldwide.[58]

Coal is the most widely used fuel for electricity generation in the U.S., and its status is unlikely to change dramatically.[59] Even as concerns grow about coal's high carbon dioxide, NO_X, SO_X and heavy metal emissions, new technologies such as Integrated Gasification Combined Cycle (IGCC) offer the potential to burn coal with reduced air emissions.

Texas has no IGCC plants either planned or operating at this time, although Austin Energy reviewed the possibility, ultimately concluding that the technology needs further refinement before it can be used economically.[60]

The U.S. Department of Energy (DOE), Southern Company and other partners recently began building an IGCC coal plant in Orlando, Florida that is expected to begin operations in June 2010. IGCC plants heat—but do not burn—coal so that it releases syngas, which is then burned to produce electricity. The Florida plant will generate 285 megawatts of electricity from the syngas derived from high-moisture, high-ash coals such as lignite, while generating 20 to 25 percent less emissions than lignite.[61] Construction on the plant began in September 2007.[62]

Another new clean coal technology is coal-to-liquids (CTL), also known as coal liquefaction. CTL produces syngas like that produced at an IGCC plant and then liquefies it via one of several methods. According to EIA, CTL can convert one ton of coal into two barrels of high-quality liquid fuel, such as a "CTL diesel" that can be used in place of regular diesel.

In the U.S., 14 CTL plant proposals are being evaluated for feasibility; none exist now. The world currently has only one operating CTL plant, the Sasol plant in South Africa, which produces 150,000 barrels per day of liquid fuel. China has six CTL plants in various phases of planning or construction; five others have been proposed in other parts of the world.[63]

China's coal production is double that of the U.S., and it consumes one-third of all coal used worldwide.

CTL products are considerably cleaner than the fuels they replace. CTL diesel, for example, produces few of regular diesel's hazardous air pollutants and mercury when burned, although it releases similar quantities of CO_2.[64]

While CTL technology has been developing for decades, cost remains a nearly prohibitive factor. Estimates of Sasol plant capital costs are $70,000 to $90,000 per barrel per day. EIA suggests that conceptual plant designs now under review in the U.S. would cost at least that much per barrel per day, or $3.5 to $4.5 billion total.[65]

OUTLOOK FOR TEXAS

Two coal-related issues prominent in Texas today are a microcosm of the worldwide debate over coal.

The first and probably the best known is then-TXU's effort to replace natural gas-burning electricity generation plants with plants that would burn lignite. Public opposition quickly emerged. Opposition came mainly from the Dallas, Waco and Houston metropolitan areas, whose leaders feared that prevailing winds would blow increased CO_2, NO_X and SO_X air emissions from the TXU plants into their area.

In addition to the concerns for the general health of their citizens, the mayors of these cities recognized that increased coal plant emissions could jeopardize their struggles to meet federal air quality standards. At risk is the potential loss of future federal transportation funding for noncompliance. Some local businesses also were opposed because, if utility plants were allowed to increase emissions — even though there was considerable debate on whether the plants would in fact do so — other businesses and residents would be required to reduce their own pollution, if their areas are to meet federal standards.[66]

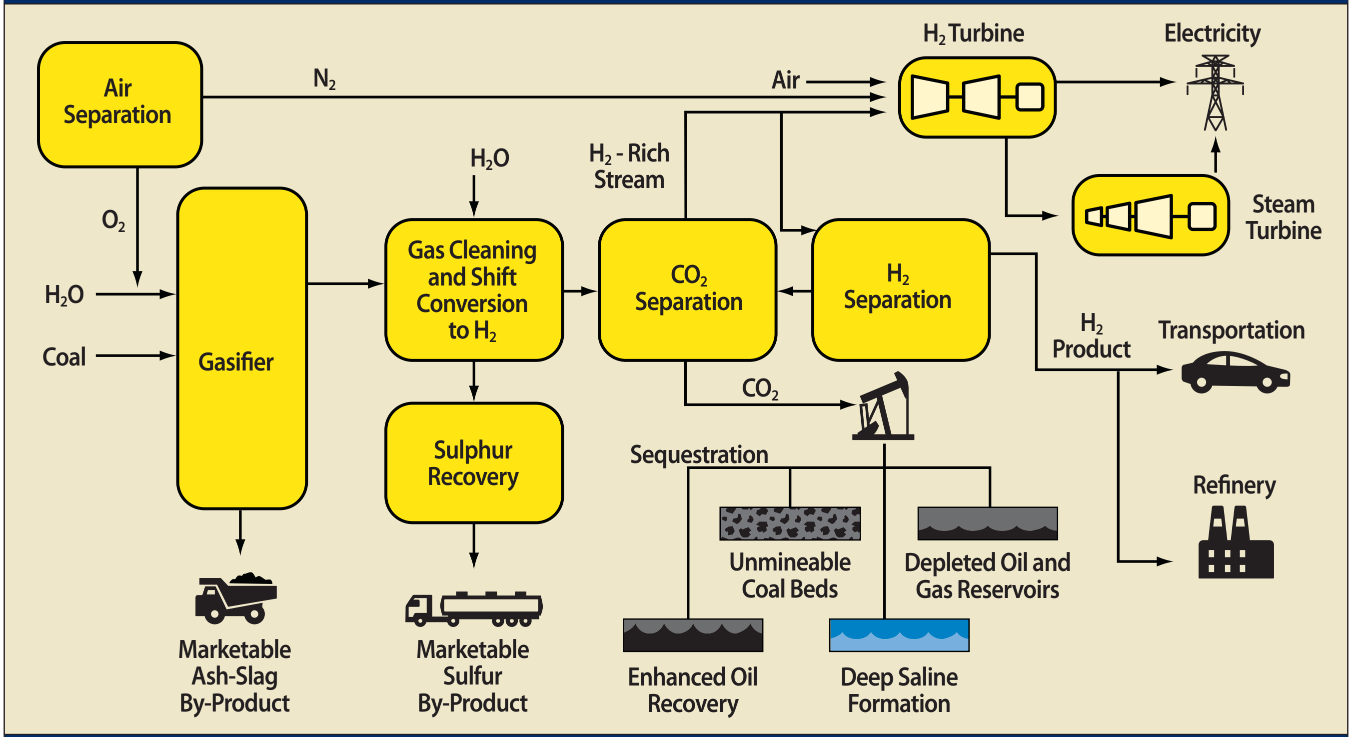
This issue is not just local; nations have been trying for years to agree on how to constrain these emissions, particularly CO_2, as concerns about climate change mount. The balance between environmental quality, economic viability, energy needs and quality of life is a challenge, and solutions have yet to be found.

The second prominent coal-related issue for Texas is FutureGen, a project by DOE and an alliance of private partners to create a "clean coal" demonstration and research plant. In December 2007, the alliance announced that a site in Mattoon, Illinois, was selected for the FutureGen project instead of two potential sites in Texas, one near Jewett and the other near Odessa. However, almost immediately after the alliance's announcement, DOE officials were saying publicly that FutureGen's escalating projected costs would demand DOE's reconsideration of the project.[67] In January 2008, DOE rescinded its support of the project, citing costs.[68]

DOE had touted FutureGen as "a first-of-its-kind coal-fueled, near-zero emissions power plant" (**Exhibit 7-10**). FutureGen costs exceeded $1.8 billion to develop. FutureGen would have gasified coal, captured and stored, or "sequestered," CO_2 and other potentially harmful emissions in underground salt domes or delivered them for use in

Exhibit 7-10

FutureGen Operations



Source: FutureGen Alliance.

depleted oil and gas fields to increase production through enhanced recovery methods.[69]

While neither Texas site was selected for the project, the Texas alliance that worked with DOE is still working on bringing this clean-coal technology to the state. In addition, news reports have indicated that the FutureGen project may be broken into several pieces, one of which could be sited in Texas.[70]

The siting of even a portion of FutureGen in Texas might be an economic and research boon, but the development of such a plant also has significant consequences for the use of coal in the future. Carbon capture, if proven to be economical on a large scale, may allow coal emissions to be cleaned enough to encourage its use as a fuel and simultaneously to help develop depleted oil and gas fields. (See Chapter 4.)

Tenaska Inc. of Omaha, Nebraska announced in February 2008 that it had applied for an air permit to build a 600 megawatt, conventional coal-fired electricity generation plant near Sweetwater, Texas. (Six hundred megawatts would provide power to more than 350,000 Texas homes, based on 2006 average residential electricity use.) The $3 billion "Trailblazer Energy Center," as Tenaska describes it, would burn PRB shipped in by rail and capture 85 to 90 percent of the CO_2 emissions for re-use in nearby oilfields. Depending on the coolant technology employed, the Center could also consume up to 10 million gallons of water daily. Tenaska estimates the plant could also provide up to 2,000 construction and 100 long-term jobs. Construction could begin as early as 2009.[71]

While coal will be an important fuel for the foreseeable future, it faces daunting challenges such as air emission controls, escalating transportation costs and, because of these challenges, the growing reluctance of corporate executives to plan major, capital-intensive industrial plants that rely on coal, particularly lignite. Another limitation on coal is that it has not adapted readily to seaborne transportation, meaning that it remains primarily a domestically produced fuel and that intercontinental imports or exports are, at best, stopgap measures until domestic supplies are restored. This may change if coal can be gasified and transported as liquified natural gas (LNG) economically. (See Chapter 5.)

Coal is readily available and can be shipped domestically. The environmental consequences of mining and burning coal, however, are challenges that must be addressed.

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CHAPTER 8

Nuclear Energy

INTRODUCTION

An enormous amount of energy exists in the bonds that hold atoms together. This energy can be released through nuclear fission, the splitting of one atom into two or more lighter atoms; or nuclear fusion, the joining of two atoms. At present, only fission can be used to generate electricity.

Energy is released when the nuclei of certain atoms absorb a free neutron, become unstable and split apart, releasing one or more free neutrons. The process is repeated, creating a self-sustained chain reaction. In commercial nuclear power plants, the resulting heat is used to create steam that turns a turbine and generates electricity, without producing greenhouse gas emissions.

Texas has two operating nuclear power facilities, Comanche Peak in Glen Rose and the South Texas Project located near Bay City. Together, the two facilities employ more than 2,000 people with a combined payroll of nearly $200 million annually.[1]

And more facilities are on the horizon. Owners of the South Texas Project have submitted an application to the U.S. Nuclear Regulatory Commission (NRC) to expand their facility. And over the next two years, the NRC expects to receive applications for six more new nuclear reactors in Texas, two more at Comanche Peak and four at two new sites. Once complete, these new reactors will require several thousand employees.

History

Ancient Greek philosophers first developed the idea that all matter is made of atoms. During the 18th and 19th centuries, scientists conducted experiments to unlock the secrets of the atom. In 1904, British physicist Ernest Rutherford wrote, "If it were ever possible to control at will the rate of disintegration of the radio elements, an enormous amount of energy could be obtained from a small amount of matter."[2] One year later, Albert Einstein developed his theory of the relationship between mass and energy. Einstein's mathematical representation of his theory, $E=mc^2$, related the amount of energy that could be derived from a mass if it were transformed to energy. In 1938, Lise Meitner and Otto Hahn first provided the first experimental evidence of the release of energy from fission.

The world's first self-sustained nuclear fission chain reaction occurred on December 2, 1942, in a squash court under the University of Chicago's Stagg Field.[3] Enrico Fermi's reactor, Chicago Pile 1, was built of six tons of uranium metal, 34 tons of uranium oxide, nearly 400 tons of graphite bricks (to moderate the reaction) and cadmium rods to absorb free neutrons.[4] After World War II, following the success of the Manhattan Project that developed the atomic bomb, the U.S. began to use nuclear energy for non-military purposes.

The first reactor to generate electricity was an experimental breeder reactor run by the U.S. government in Arco, Idaho, beginning on December 20, 1951.[5] Breeder reactors differ from commercial light-water reactors by using a fast neutron process that produces, or breeds, more fuel than it consumes. Civilian commercial nuclear reactors in the U.S. are all light-water reactors, which use ordinary water to cool the reactor cores.

The first civilian nuclear power plant began generating electricity at Santa Susana, California on July 12, 1957. The first large-scale commercial nuclear power plant in the U.S. began operating on December 2, 1957, in Shippingport, Pennsylvania and continued to operate until it was shut down in 1982.[6]

Uses

The military uses nuclear energy for explosive warheads and naval propulsion, which was pioneered by the U.S. Navy. The first nuclear-powered submarine, the USS Nautilus, was launched in 1954.

Texas has two operating nuclear power facilities, Comanche Peak in Glen Rose and the South Texas Project located near Bay City.

The eight new reactors anticipated in Texas will need several thousand workers.

Commercial nuclear energy is used primarily to generate electricity. Today, the U.S. has 104 licensed commercial nuclear reactors that provide approximately 20 percent of the nation's electricity.[7] In 2006, total generating nameplate capacity for the nation's nuclear power plants was about 106,000 megawatts (MW), or 9.8 percent of the total nameplate capacity of all electricity generation in the U.S.[8] Nameplate capacity is the maximum rated output of a generator as designated by the manufacturer. It is called such because this capacity is typically written on a nameplate that is physically attached to the generator.

NUCLEAR POWER IN TEXAS

In 2006, Luminant's Comanche Peak near Glen Rose and the South Texas Project (STP) in Matagorda County together produced 10.3 percent of the state's electricity.[9] Electricity generated at these sites goes to the state's electric grid for purchase by commercial, industrial and retail consumers.

Economic Impact

Comanche Peak has two reactors with a net generating capacity of 2,300 megawatts, enough to power almost 1.3 million homes, based on average electric use in 2006. Luminant has about 1,050 employees at Comanche Peak, 800 company employees and 250 contractors who work on outsourced projects.The Comanche Peak operation paid $24.4 million in property taxes and $100 million in payroll in 2006.[10]

The South Texas Project has two reactors with a net generating capacity of 2,700 megawatts, enough to power more than 1.5 million homes, based on average electric use in 2006. STP is operated by the South Texas Project Nuclear Operating Company (STPNOC), which is owned by NRG Texas LLC (44 percent), CPS Energy (40 percent) and Austin Energy (16 percent). STPNOC has an annual payroll of $96 million for 1,150 employees. Hourly wages at South Texas average $31; hourly employees earn an average of $64,000 annually without overtime.[11] The average annual salary for other employees is $94,000.[12] By comparison, the average annual salary for Texans in 2006 was $36,373.[13]

However, there are concerns about meeting the demand for a growing nuclear workforce.

Workforce Issues

New nuclear power plants obviously will need trained employees — but finding them may be a challenge. The nuclear industry already foresees difficulties with an aging work force; a large percentage of the nation's nuclear employees will be eligible for retirement in five to ten years. In addition, new "Generation III" and "Generation III+" plant designs feature updated technologies, such as digital instrumentation and control systems, which are not present in the operating plants.

Problems involving the energy industry work force have caught the attention of the nation's leaders. At an August 2007 meeting of the Southern Governors Association, an "Energy Summit" was convened in conjunction with the U.S. Department of Labor Employment and Training Administration. Assistant Secretary of Labor Emily Stover DeRocco led the conference.[14] Each state was asked to develop a strategy to respond to the challenge of producing the work force needed by the energy industry. Nuclear energy was a major part of this discussion.

The eight new reactors anticipated in Texas will need several thousand workers. Many of these positions will involve technically sophisticated tasks requiring qualified and well-trained individuals.

For operational and technician positions, nuclear utilities provide training lasting up to three years. The curriculum for such training is established by the National Academy for Nuclear Training (NANT) and the Institute of Nuclear Power Operations (INPO).

The utilities with plans to build new plants in Texas have identified additional workers as part of the "critical path" to successful operations. The Texas Workforce Commission is working with these utilities to create the Texas Nuclear Workforce Development Initiative, a grant program to encourage universities, community colleges and the Texas State Technical College to recruit young people into two-year and four-year programs to prepare them for jobs in the new plants. These programs will give students the background in nuclear systems and operations they will need to enter into accelerated training programs upon hiring.[15]

The initiative will offer attractive opportunities for young Texans to find high-paying jobs that allow them to remain in the state and contribute to the growth of the Texas economy.

Production

All U.S. commercial nuclear power plants use enriched uranium fuel pellets in their reactor cores. The three naturally occurring varieties, or isotopes, of uranium are U-234, U-235 and U-238. Uranium-235, which makes up only 0.72 percent of all available uranium, is the only naturally occurring uranium isotope capable of undergoing fission and sustaining a chain reaction under typical civilian power generation conditions.

Uranium Mining and Enrichment

Uranium is found in the earth's crust and in seawater. All uranium used in the nuclear fuel cycle comes from deposits found on land.

In its natural state, uranium is an ore that must be mined. Once mined, uranium is processed into uranium oxide, sometimes called "yellowcake." To be enriched for use in a nuclear power plant — that is, to increase its amount of U-235 — uranium oxide must be converted to uranium hexafluoride and then transformed to a gas.

After being enriched to a level of between 3 percent and 5 percent U-235, uranium hexafluoride is converted to uranium dioxide and fabricated into cylindrical fuel pellets. These pellets are loaded into fuel rods that are in turn grouped in fuel assemblies, built to the specifications of each individual reactor. In theory, one pellet weighing only 0.24 ounces can generate as much energy as 1,780 pounds of coal or 19,200 cubic feet of natural gas.[16]

Commercial nuclear reactors have a core composed of fuel assemblies and control rods made of neutron-absorbing materials such as boron or hafnium that can be used to dampen and thus control the nuclear reaction.

Transportation

Fuel assemblies are transported by truck, rail, air or water to their specific nuclear reactor. Both the U.S. Department of Transportation and the U.S. Nuclear Regulatory Commission (NRC) oversee the security of the transport of nuclear materials.[17]

Power Generation

The number of fuel assemblies in the reactor core depends on the reactor's size and design. Reactor power output can vary significantly depending on the number of assemblies as well as other factors.

Inside the reactor core, U-235 atoms absorb a neutron and become U-236, which has an unstable nucleus. About 84 percent of the time, the U-236 atoms spontaneously split apart. This fission releases a number of products including gamma rays, beta particles, neutrons, neutrinos and, usually, two fission fragments of the original atom.

These fission fragments carry a large amount of kinetic energy. They collide with the fuel, converting their kinetic energy into increased vibrational energy, or heat. Neutrons released by the fission process are absorbed by other U-235 atoms, turning them into U-236. The process repeats, creating a self-sustaining chain reaction. Control rods are inserted into or withdrawn from the reactor core to regulate the chain reaction by absorbing neutrons and thus preventing them from striking more U-235 atoms.

The heat produced by this self-sustaining chain reaction is used to turn water to steam. The steam then is used to spin a turbine attached to a generator, producing electricity.

In addition to the fission fragments, neutrons that are absorbed by U-235 that do not result in fission or are absorbed in U-238 will produce other radioactive isotopes called actinides or transuranic elements, including plutonium, neptunium, americium and curium.

Reactor Types

The two most common types of commercial nuclear reactors used to generate electricity are pressurized water reactors (PWRs) and boiling water reactors (BWRs). Of the 104 commercial reactors in the United States, 69 are PWRs and 35 are BWRs.[18] Both Comanche Peak and STP use PWRs.

The two most common types of commercial nuclear reactors used to generate electricity are pressurized water reactors and boiling water reactors.

Pressurized water reactors (PWRs) involve three "loops." The primary loop passes through the reactor core and carries away the heat energy generated in the fuel. The secondary loop absorbs the heat from the first loop in a component called a steam generator, and carries it to the turbine. A third loop rejects the unused heat energy to the atmosphere, either through a cooling tower or into a cooling pond or river. The primary water loop is heated to about 600°F; because the water is under high pressure, it does not boil. Water in the secondary water loop is under lower pressure and heated to 450 to 500°F, which creates steam. The steam hits turbine blades with a pressure of about 1,000 pounds per square inch. The turbine turns a generator that produces electricity (**Exhibit 8-1**).

BWRs have only two loops. Water passes through the reactor core where it boils, creating steam. From the steam generator, a steam line is directed to a turbine that turns a generator used to produce electricity. The steam passes through a condenser where it is turned into water and returned to the reactor core, repeating the process. A secondary coolant loop rejects excess heat energy to the atmosphere. The steam used to turn the turbine comes in contact with the reactor core, making it radioactive (**Exhibit 8-2**).

Depending on variables unique to each reactor, fuel assemblies within the reactor core are replaced about every 18 months to ensure optimum performance.

Next-Generation Reactors

The U.S. Nuclear Regulatory Commission (NRC) has certified or is reviewing design certification applications for a new generation — “Generation III” — of nuclear reactors in the U.S. Generation III reactors feature design improvements over Generation II reactors, which are currently operating in the U.S.

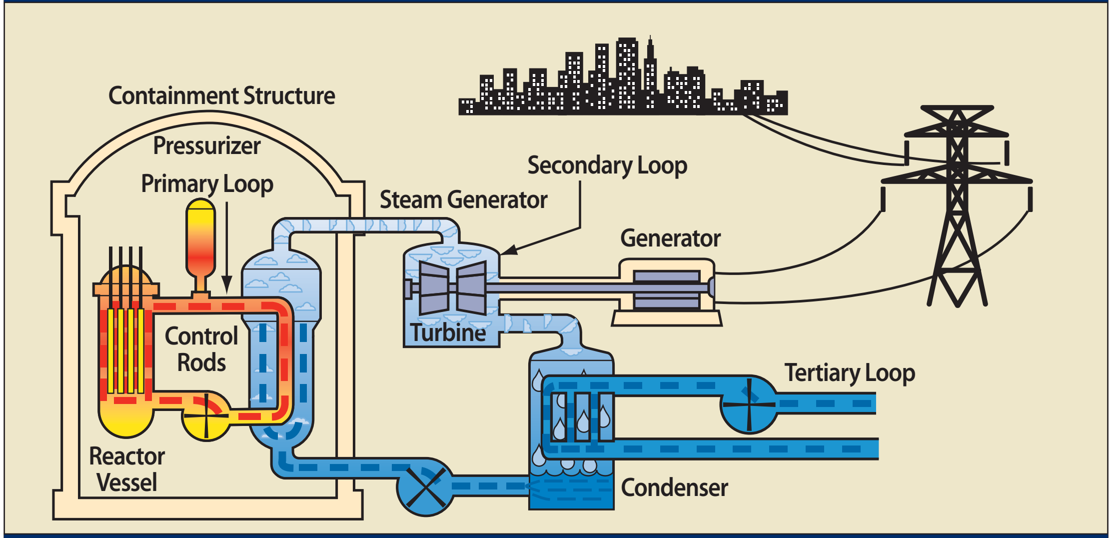
NRC has certified the design of the Westinghouse AP1000, a 1,000 to 1,200 MW (electric) pressurized water reactor. Six utility companies have selected the AP1000 for 14 reactors to be constructed at seven sites across the U.S.[19]

General Electric has received design certification for its advanced boiling water reactor (ABWR) design, capable of producing 1,350 to 1,600 MW.[20] NRG Energy has chosen the ABWR design for two new reactors it plans to build at the South Texas Project in Matagorda County.[21] On September 24, 2007, NRG submitted the first combined Construction and Operating License Application to NRC for the new reactors. NRG expects both units to be operational by 2015.[22]

NRC also has received an application for design certification for General Electric’s Economic

EXHIBIT 8-1

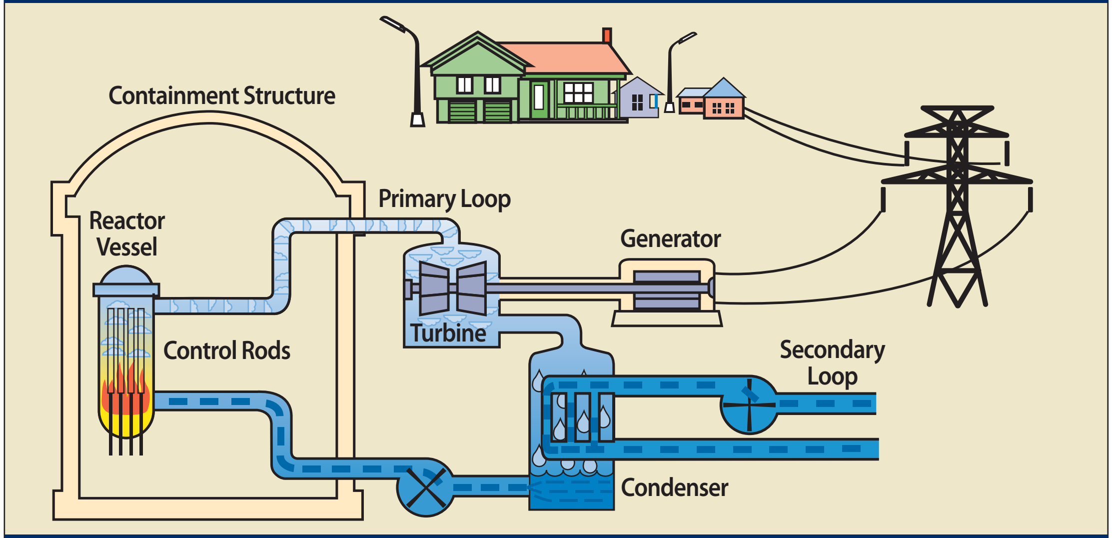
Pressurized Water Reactor



Source: U.S. Nuclear Regulatory Commission.

Exhibit 8-2

Boiling Water Reactor



Source: U.S. Nuclear Regulatory Commission.

Simplified Boiling Water Reactor (ESBWR). The review process for the ESBWR should be completed by fiscal 2012. [23] NRC received design certification applications for the Mitsubishi U.S. Advanced Pressurized Water Reactor (US-APWR) and the Areva Evolutionary Pressurized Water Reactor (EPR) in December 2007.[24]

Other types of reactors include pressurized heavy water reactors, high-temperature, gas-cooled reactors, pebble-bed reactors, sodium-cooled reactors, heavy metal-cooled reactors, supercritical water reactors and molten salt reactors. With the exception of the heavy water reactor, all are considered to be "Generation IV" designs that could be ready for commercial deployment by 2030. So far, none of these types have been submitted to the NRC for use in civilian power plants in the U.S.

Storage

Once removed, the highly radioactive spent fuel is stored in containment pools or dry casks.[25] At present, in the U.S., all commercial spent nuclear fuel is stored on site at the reactor where it was produced. Environmental issues related to storage are discussed below.

Availability

In its natural state, uranium must be mined or extracted using one of three methods: underground mining; open-pit mining; or in-situ leach (ISL) mining. Underground and open-pit mining involves removing rock from the ground, breaking it up and sending it to a mill to remove the uranium. ISL mining, also called solution mining, pumps a leach solution through the ground to separate uranium ore from its source rock. It causes little surface disturbance or rock waste. The source rock, however, must be permeable to the leach solution and located in a geologic formation that prevents groundwater contamination.[26]

Canada, Australia and Kazakhstan were the three leading producers of uranium in 2006. Canadian mines produced 9,862 tons of uranium, accounting for 25 percent of world supply; Australian mines produced 7,593 tons, 19 percent of world supply; and Kazakh mines produced 5,279 tons, 13 percent of world supply in 2006. [27]

U.S. uranium mines are found in western states and produced 1,672 tons, or just over 4 percent of the world supply, in 2006. [28]

Uranium is originally deposited on the earth's surface in igneous rock. Uranium is easily oxidized and very soluble in water. As water percolates through a source rock or sediments, uranium is dissolved into the water and flows downhill. When the water comes into contact with a "reducing environment" containing chemical compounds such as coal, oil and gas or sulfides, uranium precipitates from the solution and is deposited in an ore body called a "roll front" (**Exhibit 8-3**). Uranium deposits capable of sustaining commercial mining accumulate over millions of years.[29]

Uranium deposits in Texas are found in relatively narrow bands that parallel the coastline, deposited by uranium-laden water flowing toward the Gulf of Mexico (**Exhibit 8-4**). In Texas, all uranium is mined using in-situ recovery, since it is deposited in permeable sands.

There are three companies with permits to mine uranium in Texas. Two, Mesteña Uranium, L.L.C. and Uranium Resources, Inc. (URI), are producing uranium and one, COGEMA Mining, has a mine reclamation. A fourth company, South Texas Mining Venture, expects to be producing uranium by the end of 2008.

According to Paul Goranson, Mesteña's vice president and Alta Mesa operations manager, the Alta Mesa project produced more than 1 million pounds of yellowcake in 2006.

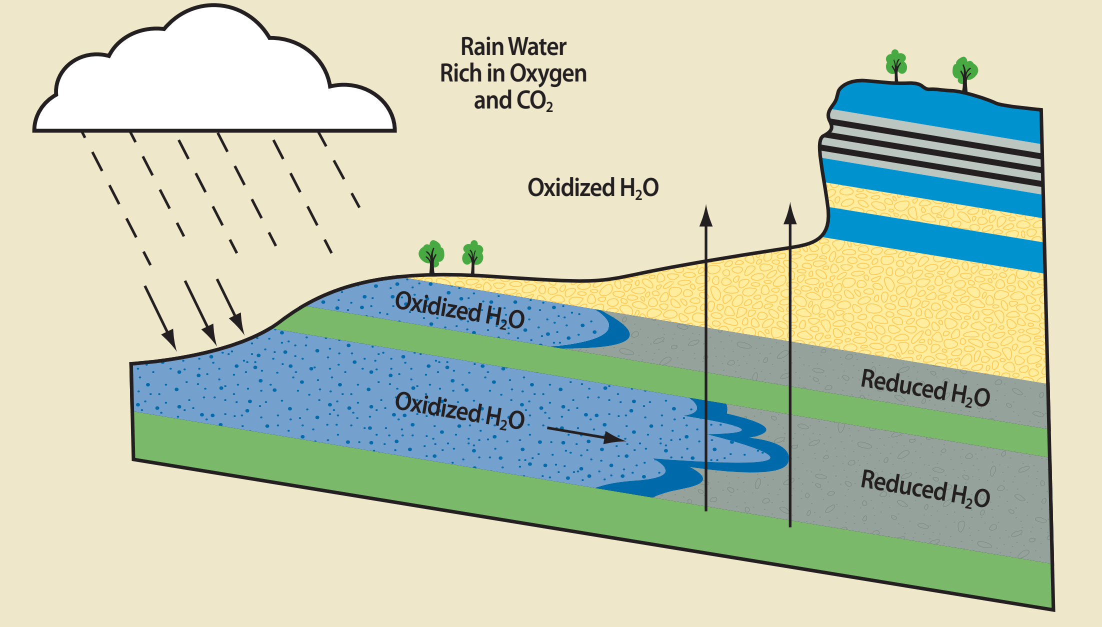
At the Mesteña mine, a leach solution is pumped into the ore body through injection wells. After flowing through the ore body, the "pregnant" solution is recovered through production wells and pumped to a processing mill, where the uranium is precipitated out of the solution, run through a filter press and placed in a vacuum dryer. The finished yellowcake is loaded in drums and shipped to Metropolis, Illinois, where it is enriched.[30]

Uranium Resources, Inc. (URI) mines and processes uranium at Kingsville Dome in Kleberg County and mines uranium at Vasquez in Duval County. According to Mark Pelizza, URI vice president for health safety and environmental affairs, the two

There are three companies with permits to mine uranium in Texas.

EXHIBIT 8-3

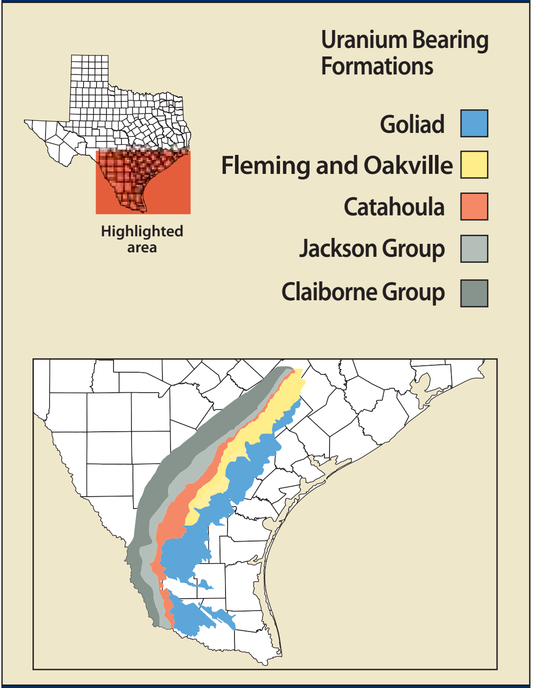
Uranium Roll Front



Source: Texas Mining and Reclamation Association.

Exhibit 8-4

Uranium Deposits in Texas



Source: Texas Mining and Reclamation Association and Bureau of Economic Geology.

mines combined produced 260,000 pounds of yellowcake in 2006. URI plans to recommence mining and processing at a Rosita facility in northern Duval County by the end of 2007 or early 2008.[31]

Between the Mesteña mine and the URI mines, Texas produced 1,260,000 pounds of yellowcake in 2006. One pound of yellowcake is equivalent to 10 tons of coal, meaning that Texas uranium mines produced an equivalent to 12.6 million tons of coal, with a total energy content of 262 trillion Btu.[32]

South Texas Mining Venture has submitted an area permit application with the Texas Commission on Environmental Quality (TCEQ) for ISL mining at its La Palangana site in Duval County. According to Larry McGonagle, general manager for South Texas Mining Venture, they expect to secure all necessary permits by the fourth quarter of 2008, with production beginning by the end of 2008.[33]

COGEMA Mining operated wells in Duval County, all of which are in reclamation. According to David Benavides, COGEMA's radiation safety officer, the reclamation process should be completed in 2009, and that the company has no plans for future uranium mining operations in Texas.[34]

ISL mining in Texas is advantageous because of the state's mild climate. ISL mining in Wyoming requires lines carrying mining solution to and from the well field to be buried and machinery to be contained in buildings to prevent freezing. Subsequently, capital costs for ISL in Texas are about two-thirds less than in Wyoming.[35] Another benefit to above-ground ISL mining is that leaks are visible and easily detected and fixed. Buried infrastructure can hide leaks until detected in monitor wells surrounding the ore body.

Another uranium mining company is currently in the exploration phase near Goliad, Texas. Citizens of the area claim that the company's explorations have caused contamination of drinking water and are a violation of the U.S. Safe Drinking Water Act. Goliad County commissioners have filed suit against the company for this alleged violation, and they claim that test holes were left unplugged allowing chemicals to leak into the aquifer. The Railroad Commission of Texas, however, determined that the company was not in violation of their exploration permit and that no groundwater contamination had occurred.[36]

Texas uranium mines produced an equivalent to 12.6 million tons of coal, with a total energy content of 262 trillion Btu.

COSTS AND BENEFITS

A 2004 University of Chicago study, *The Economic Future of Nuclear Power,* estimated the levelized cost of electricity (LCOE), which is the price necessary to recover operating and capital costs, for new nuclear power plants coming on line during the next decade. The study estimated the price for new nuclear energy to be from $47 to $71 per megawatt-hour. By contrast, the LCOE for coal-fired plants ranges from $33 to $41 per MWh and between $35 and $45 per MWh for natural gas-fired plants.[37] Prices for nuclear power generation are higher due to higher initial capital costs.

The University of Chicago study also stated that the first new nuclear power plants coming on line in the next decade will have higher LCOEs due to engineering costs that could raise capital costs by 35 percent.[38]

The study estimated that, with the assistance of loan guarantees, accelerated depreciation and investment and production tax credits, the LCOE for nuclear power could fall to $32 to $50 per MWh. With lessons learned from the first few new-generation nuclear plants, LCOEs could fall to $31 to $46 per MWh, which would alleviate the need for financial assistance and allow nuclear energy to compete in the marketplace with coal-fired and natural gas-fired plants.[39]

Fuel costs to the U.S. nuclear energy industry fall in two parts: the front-end cost of ore purchase, conversion, enrichment and fabrication, and the back-end costs of storage and disposal. In its study, the University of Chicago calculated the front-end cost of nuclear fuel at between $3.56 and $5.53 per MWh in 2003 dollars, including ore purchase, conversion, enrichment and fabrication costs.[40] World uranium prices have risen substantially since 2003.

According the World Nuclear Association, the nuclear energy industry is the only energy-producing technology that takes full responsibility for the cost of its waste and builds the full cost of storage and disposal of spent nuclear fuel into the price of generation.[41]

Under U.S. law, the U.S. Department of Energy (DOE) is responsible for the ultimate disposal of spent nuclear fuel. This disposal is funded by a surcharge on nuclear power plant operators of 0.1 cents per kilowatt hour of electricity.[42] DOE has not yet taken responsibility for spent fuel, however. Again, all commercial spent nuclear fuel currently is stored at the reactor; the cost of this storage is borne by the utility that owns or operates it. (The nation's search for a permanent storage facility is discussed below.)

The University of Chicago study estimated spent fuel storage and disposal costs, at 2003 prices, to be $1.09 per MWh — nine cents for temporary on-site storage and $1 to pay for eventual permanent disposal at a centralized geologic repository.[43] Converted from megawatt hours, the cost of spent fuel storage and disposal is 0.109 cents per kilowatt hour (kWh) of electricity produced.

According to the U.S. Energy Information Administration, *not including capital costs*, the total cost of producing electricity using nuclear power was 1.95 cents per kWh in 2006. This includes costs of 0.893 cents for operations, 0.568 cents for maintenance and 0.485 cents for fuel costs. By contrast, it costs 2.96 cents per kWh to produce electricity from fossil fuel steam and 5.78 cents per kWh to produce electricity from gas turbines. When capital costs are excluded, only electricity produced from hydroelectric generation is cheaper than nuclear, at 0.85 cents per kWh (**Exhibit 8-5**).[44]

Environmental Impact

The increased acceptance of nuclear power is not without criticism and challenges. Critics of nuclear power cite the potential environmental impact of accidents at nuclear reactors, ranging from a catastrophic meltdown of a reactor core to minor

Exhibit 8-5

Average Operating Expense of Electricity Generation for Major U.S. Investor-Owned Electric Utilities, 2002-2006
In Cents Per Kilowatt Hour

Year	Nuclear	Fossil Steam	Hydroelectric	Gas Turbine
2002	1.82	2.13	0.87	3.69
2003	1.87	2.26	0.75	4.89
2004	1.83	2.39	0.87	5.01
2005	1.82	2.77	0.89	5.89
2006	1.95	2.96	0.85	5.78

Note: Excludes capital costs, a major expense for nuclear electricity.
Source: U.S. Energy Information Administration.

accidents that release relatively small amounts of radioactivity into the environment.

On March 28, 1979, Pennsylvania's Three Mile Island's Unit 2 suffered a partial meltdown of its reactor core. According to a report by the Nuclear Regulatory Commission, equipment failures, design-related problems and human error led to this, the nation's most serious commercial nuclear accident.[45] No lives were lost as a result of the accident. Following the accident, NRC improved the level of safety at reactor sites by increased safety regulations inspection procedures.[46]

On April 26, 1986, the world's most significant nuclear accident occurred in the Ukraine, then part of the Soviet Union. A sudden surge of power in the Unit 4 reactor at the Chernobyl nuclear power plant caused an explosion and fire that destroyed the reactor and released massive amounts of radioactive material into the surrounding area. The accident was caused by breaches of technical operating procedures as well as inadequate safety systems. About 116,000 people were evacuated from the surrounding area. The death toll from the explosion and immediate aftermath is officially 30, with 28 deaths due to radiation exposure among power plant employees and firemen.[47]

In addition, nuclear power plants use large quantities of water for cooling purposes. Depending upon the plant type, electricity generation from nuclear power requires withdrawals of between zero and 17,590 gallons per million Btu of heat produced.[48] This is the amount of water extracted from a water source; most of the water withdrawn is returned to that source.

Water consumption refers to the portion of those withdrawals that is actually used and no longer available. Nuclear energy consumes between zero and 211 gallons of water for each million Btu of heat energy produced.[49]

Storage and Disposal

High-Level Waste

Disposal of high-level radioactive waste — spent reactor fuel — is the most hotly debated issue between critics and proponents of nuclear power. Almost all nuclear experts agree that a permanent geologic repository is the best means to store it.

Two options for handling and storing spent fuel are: reprocessing to extract the remaining energy and separate out fission products, actinide elements and fissionable material, called a *closed-fuel cycle*; or storage and final disposal without reprocessing, called a *once-through fuel cycle*.

The 104 U.S. commercial nuclear reactors produced about 2,400 tons of high-level radioactive waste in the form of spent fuel in 2002 (most recent data available).[50] In all, about 47,000 tons of spent nuclear fuel is being held in storage and awaiting final disposal around the nation, almost all of it on site at nuclear power plants. Ninety percent of the spent fuel is stored underwater in containment pools, while the remainder is contained in dry casks.[51]

The U.S. nuclear industry uses a once-through fuel cycle. Fuel assemblies are removed from reactor cores after about 18 months due to a loss of "reactivity," as a result of the decrease in the number of fissionable atoms in the fuel. The spent fuel assemblies are roughly 14 feet long and weigh several tons apiece.

In the late 1970s, the U.S. Department of Energy began considering Yucca Mountain, Nevada as a permanent geologic repository for high-level radioactive waste (**Exhibit 8-6**). Yucca Mountain is located in a remote, federally-owned section of Nye County, Nevada, about 100 miles northwest of Las Vegas.[52]

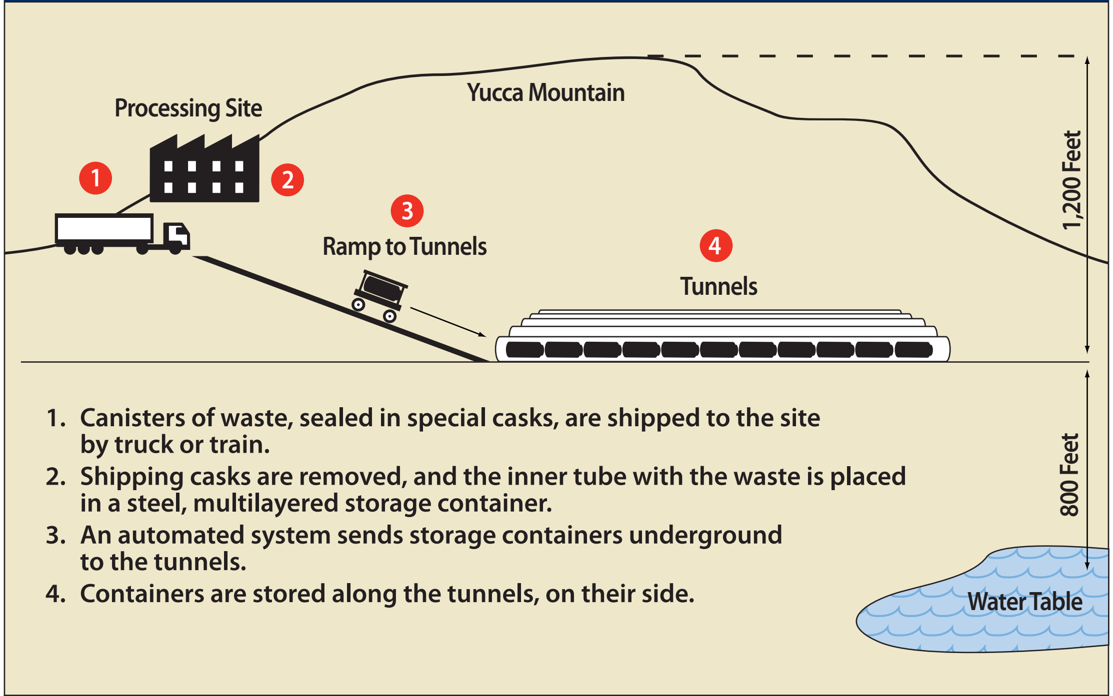
The federal Nuclear Waste Policy Act of 1982 and the Nuclear Waste Policy Amendments Act of 1987 directed the DOE and NRC to develop Yucca Mountain as a permanent repository for high-level radioactive waste. DOE estimates that Yucca Mountain can begin accepting spent nuclear fuel no earlier than 2017. Before this can happen, however, the U.S. Environmental Protection Agency, DOE and NRC must work together to set safety standards and obtain all required licenses for the facility. DOE plans to submit a license application to NRC by June 30, 2008. This license would allow DOE to begin building the storage facility beneath Yucca Mountain.[53]

Most countries with nuclear programs have begun programs to develop similar sites for geologic repositories. At present, however, no country has opened a permanent geologic repository.

Disposal of high-level radioactive waste is the most hotly debated issue between critics and proponents of nuclear power.

EXHIBIT 8-6

Yucca Mountain Storage Facility



1. Canisters of waste, sealed in special casks, are shipped to the site by truck or train.
2. Shipping casks are removed, and the inner tube with the waste is placed in a steel, multilayered storage container.
3. An automated system sends storage containers underground to the tunnels.
4. Containers are stored along the tunnels, on their side.

Source: U.S. Nuclear Regulatory Commission.

Low-Level Waste

Nuclear power plants also produce significant amounts of low-level radioactive waste. Low-level waste includes protective clothing used at nuclear reactors and parts from inside dismantled reactors, among others. The same waste policy act that directs DOE to take responsibility for the disposal of spent fuel dictates that the states are responsible for disposing of low-level radioactive waste. Medical facilities also produce low-level radioactive waste.

Many states, including Texas, have joined Congressionally approved compacts that allow them to deposit low-level waste in a single facility serving the compact member states, without having to accept waste from other states. The Texas Compact currently consists of Texas and Vermont.[54] Currently, no low-level waste is being stored in Texas as a result of the compact, because no storage facility exists at this time. In its compact, Texas is the host state — meaning that the low-level waste storage site will be located in Texas. In return, Vermont has agreed to pay Texas $25 million to help with construction costs.[55]

Waste Control Specialists, a company based in Andrews County, Texas, has applied to TCEQ for a license to construct a storage facility for commercial low-level radioactive waste from the compact state, Vermont, as well as DOE.[56]

Eight states (Maine, Massachusetts, Michigan, Nebraska, New Hampshire, New York, North Carolina and Rhode Island), the District of Columbia and Puerto Rico do not belong to any compact, and run the risk either of not being able to dispose of their own low-level waste or, should they build a facility, having to accept waste from the other states without a compact.[57]

Low-level waste is stored on site in special containers. Medical facilities — including hospitals, research institutions and industries store this waste until they have enough to ship to one of three low-level waste facilities in the U.S. These three facilities are located in Washington, Utah and South Carolina.[58]

Reprocessing

Reprocessing spent fuel separates its remaining uranium (U), plutonium (Pu) and higher actinides from fission products, or high-level waste (HLW) (**Exhibit 8-7**). The uranium must be "re-enriched" and can be formed into uranium oxide fuel pellets, or combined with plutonium to form a mixed-oxide fuel that can be used in reactors.[59]

Reprocessing nuclear fuel would extend the availability of nuclear fuel by hundreds of years. It would also greatly reduce the volume of high-level radioactive waste that must be stored. Spent fuel is regularly reprocessed at facilities in France, the United Kingdom, Russia and Japan.[60]

In the U.S., however, spent fuel reprocessing has been and continues to be controversial. Critics argue that spent fuel reprocessing increases the world's supply of plutonium, which could be obtained by countries and terrorist organizations and used to manufacture nuclear weapons.

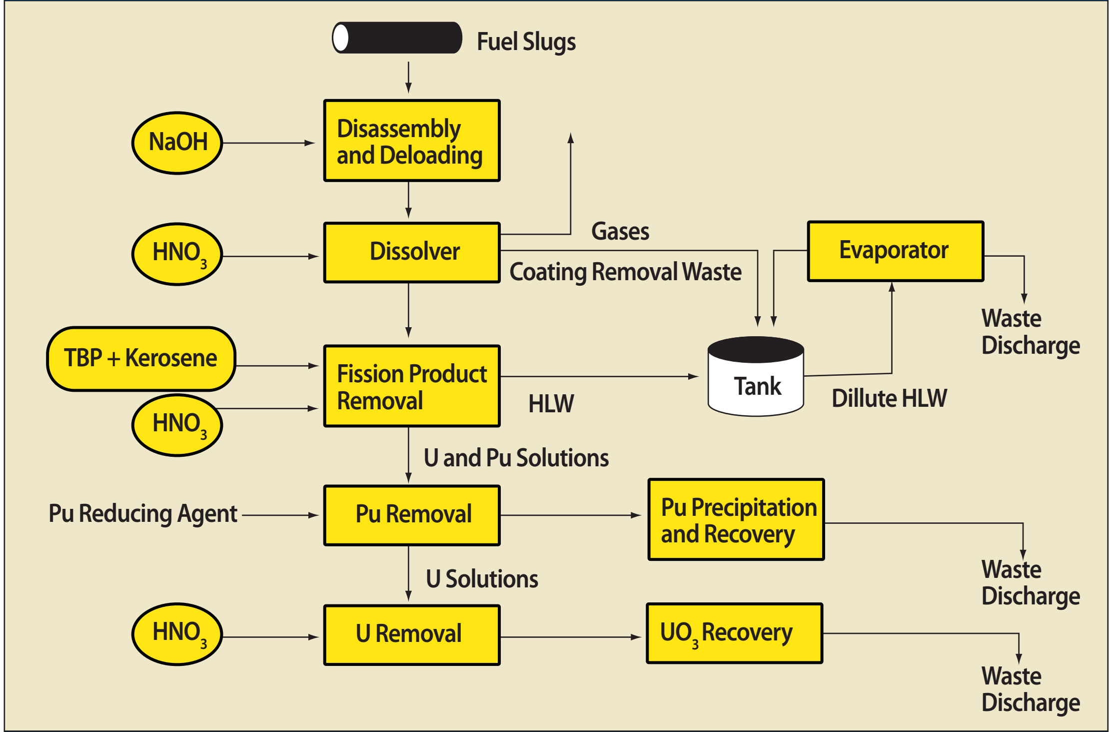
Due to concerns over nuclear weapons proliferation, in 1977 President Jimmy Carter decided to indefinitely defer the reprocessing of spent fuel from commercial nuclear power plants in the U.S.[61]

The Reagan administration opened the door for the reprocessing of spent fuel from commercial reactors, but economic factors, regulatory issues and potential litigation proved prohibitive to private investment in reprocessing facilities. In July 2007, the Global Nuclear Energy Partnership (GNEP) announced that the U.S. Department of Energy would award $16 million to support studies on spent fuel recycling. The goal of the GNEP funding is to spur the development of advanced

Reprocessing nuclear fuel would extend the availability of nuclear fuel by hundreds of years.

Exhibit 8-7

Uranium Reprocessing



Source: U.S. Department of Energy.

technologies to recycle spent nuclear fuel in ways that enhance proliferation resistance.[62]

Dr. Phillip Finck of the Argonne National Laboratory has stated that, at the currently projected growth rate for U.S. nuclear plants, the nation will need up to nine repositories the size of Yucca Mountain by 2100 if the fuel is not reprocessed.[63]

State and Federal Oversight and Regulation

The U.S. Nuclear Regulatory Commission (NRC) sets all standards and regulations for nuclear power plants and the power they generate. NRC provides the guidelines and standards that must be followed to receive a construction and operating license.

NRC sets out guidelines for prospective operators in Title 10 of the Code of Federal Regulations. These guidelines cover all relevant areas, including building, power generation, energy transportation, waste disposal, recycling, radiation monitoring and terrorism prevention.[64]

The Texas Commission on Environmental Quality (TCEQ) has some limited rules pertaining to nuclear plants regarding water quality, but these rules are based on the NRC standards.

The Railroad Commission of Texas regulates uranium exploration. Companies engaged in uranium exploration must obtain an exploratory permit that designates the area to be explored and the method of exploration. The most common method used is borehole drilling.

Once an ore body has been identified, the company must obtain an area mining permit, a production area authorization, a wastewater disposal permit and a radioactive material handling license from TCEQ, which regulates uranium mining. The company also must obtain an aquifer exemption from TCEQ and the U.S. Environmental Protection Agency if it wishes to use injection mining in or near a drinking water aquifer.

The Texas Department of State Health Services (DSHS) regulates the transportation and routing of all radioactive material, including radioactive waste.[65] In addition, DSHS prepares and maintains emergency response plans for all fixed nuclear facilities and coordinates full-scale safety exercises in support of local government at each nuclear plant.[66]

The federal Energy Policy Act of 2005 provided the nuclear industry with a variety of financial incentives for new nuclear power plants.

Subsidies and Taxes

The federal Energy Policy Act of 2005 provided the nuclear industry with a variety of financial incentives for new nuclear power plants. These included:

- An eight-year production tax credit of 1.8 cents per kilowatt-hour for up to 6,000 megawatts of capacity from new, qualified advanced nuclear power facilities;
- Loan guarantees for up to 80 percent of project costs for advanced nuclear energy facilities;
- Extended Price-Anderson Act protection until December 31, 2025, which establishes an insurance system for nuclear plants in the case of accidents;
- DOE authorization to enter into contracts to pay utilities that incur costs due to regulatory delays and litigation;
- A total of $1.25 billion for fiscal 2006 through 2015 for a prototype next-generation nuclear power plant at the Idaho National Laboratory that will produce both electricity and hydrogen; and
- An advanced fuel recycling technology, research, development and demonstration program for proliferation-resistant fuel recycling and transmutation technologies.[67]

Texas Tax Code Section 151.318 exempts manufacturing equipment used to generate electricity from sales tax. Nuclear plant equipment exempted from sales tax includes steam production equipment and fuel, cooling towers, generators, pollution control equipment and heat exchangers.[68] There is no limit to this exemption.

In states where the electricity market is not deregulated, nuclear power producers are permitted to include construction costs into the rate base. The rate base is the value upon which a utility is permitted to earn a specific rate of return — this rate base must be approved by the state's utility regulators. In some states, such as North Carolina and Virginia, special incentives allow nuclear power producers to include construction costs in the rate base during the construction phase of the project — well before any nuclear power is produced.[69] Other states, such as Florida and Georgia, allow utilities to recover pre-construction and construction costs even if a plant is started and then the project is canceled.[70]

This is not the case in Texas, which has deregulated its wholesale electricity market. During the last legislative session, however, the Legislature passed bills granting certain incentives to nuclear power producers in Texas.

In 2007, the Texas Legislature passed House Bill 1386, which provides guidelines for a nuclear plant to establish a decommissioning fund to cover the costs of decommissioning and decontaminating a reactor, making annual payments. Additionally, this legislation requires retail electric customers to cover any shortfalls in the cost of decommissioning a nuclear plant.[71]

The 2007 Legislature also passed legislation to allow local taxing authorities to grant property tax value limitations for nuclear power plants. In recognition of the lengthy licensing process for nuclear power plants, House Bill 2994 allows local taxing authorities to defer commencement of the property tax value limitation period for up to ten years.[72]

More information on subsidies for nuclear power can be found in Chapter 28.

OTHER STATES AND COUNTRIES

The accidents at Three Mile Island and Chernobyl, along with environmental difficulties of dealing with waste, slowed the commercial development of nuclear power in the U.S. The Nuclear Regulatory Commission issued the last separate construction permit for a new nuclear plant in January 1978. (As noted earlier, NRG Energy of Houston has submitted an application for two new reactors to be built at the South Texas Project.)

Recently, NRC developed a combined construction and operating license called a COL. None of these have been issued yet. At this writing, the last operating license issued by the NRC was for the Tennessee Valley Authority's Watts Bar nuclear power plant in 1996.[73]

Concerns about global climate change and energy independence have led to increased worldwide interest in nuclear energy. Proponents and critics agree that nuclear power plants generate electricity with little or no greenhouse gas production. Nuclear energy has received increasing support from the federal government, state governments and even some environmental organizations. NRC expects to receive 22 COL applications for new nuclear power plants with 33 reactors in the U.S. between 2007 and 2010.[74]

Thirty foreign nations operate commercial nuclear reactors, with the greatest concentration of them in North America, Europe and Asia. A total of 439 power reactors are operating around the world.[75]

France

After the 1973 oil shock, the French government realized it had "no oil, no gas and no coal," and no choice but to pursue nuclear energy aggressively to ensure its energy independence.[76] Nearly 35 years later, France operates 59 nuclear reactors that generate over 63,000 MW, or 78 percent its electricity.[77] By contrast, as previously noted, nuclear reactors produce just 20 percent of U.S. electricity.

France operates 59 nuclear reactors that generate over 63,000 MW, or 78 percent its electricity.

Today, France is the world's leading exporter of electricity and an active exporter of nuclear technology. NRC expects the French company Areva to submit its Evolutionary Pressurized Water Reactor technology for design certification in early 2008. Five U.S. utilities have chosen EPR technology for seven new reactors; four reactors will be built at existing plant locations, and three at new facilities.[78]

The French nuclear program reprocesses spent fuel at its La Hague facility in Normandy. This facility also combines plutonium with uranium to make a mixed-oxide (MOX) fuel that can be used in about 35 European nuclear reactors.[79]

Like most countries that produce high-level radioactive waste, France has declared deep geologic storage as its preferred method of disposal. The government has set a target date of 2015 for licensing a repository, and 2025 as its opening date.[80]

Japan

Japan has pursued nuclear energy for more than 50 years. Japan has few natural resources of its own and must import about 80 percent of its energy supply. Today, 55 nuclear reactors generate 47,500 MW or about 30 percent of Japan's electricity.[81]

Japan's first nuclear reactors were designs imported either from the U.S. or the United Kingdom. By the end of the 1970s, Japanese companies had developed the capability to design and build their own light water reactors. Today, Hitachi Co. Ltd., Toshiba Co. Ltd. and Mitsubishi Heavy Industry Co. Ltd. are among the world leaders in nuclear reactor design and construction.

Mitsubishi Heavy Industry has notified NRC that it plans to submit its USAPWR for design certification and will market the reactor to American utility companies. Luminant chose Mitsubishi's technology for the two new reactors it plans to build at Comanche Peak near Glen Rose, Texas.[82]

Japan reprocesses its spent fuel. In May 2000, Japan's parliament, the Diet, passed legislation mandating deep geologic disposal for high-level radioactive waste, which it defined as vitrified waste from reprocessed spent fuel. The nation's private sector has established a Nuclear Waste Management Organization to develop plans for final disposal. Japan's geologic repository is expected to be operating by 2035.[83]

A new generation of advanced reactors, rising global energy demands and the cost of natural gas coupled with the need to reduce greenhouse gas emissions all point to a renaissance for nuclear energy.

Canada

Canada leads the world in uranium production, supplying about a third of the world's supply. In 2004, Canada produced nearly 14,000 tons of uranium dioxide concentrate. Production will increase after 2011 when new mines come into production. Canada's reserves total 524,000 tons, second only to Australia's, which has two and a half times that amount.

Canada's 18 nuclear reactors produce 12,600 MW, or 16 percent of the nation's electricity, using domestically developed technology. Canada Deuterium Uranium (CANDU) reactors are pressurized heavy water reactors (PHWRs). Heavy water contains a higher-than-normal proportion of deuterium, an isotope of hydrogen. Its physical and chemical properties are similar to those of normal water, but it has significantly different neutronic properties.

In 2002, Canada established a Nuclear Waste Management Organization (NWMO) to explore options for nuclear waste storage and disposal. NWMO has proposed extended on-site storage, centralized dry cask storage and a deep geologic repository for high-level radioactive waste.[84]

Other Countries

Russia has 31 operating nuclear reactors, seven under construction, eight planned and 20 proposed. China has 11 operating nuclear reactors, five under construction, 29 planned and 86 proposed. India has 17 operating reactors, six under construction, 10 planned and nine proposed. Ukraine has 15 operating reactors, two planned and 20 proposed. South Africa has two operating reactors, one planned and 24 proposed.[85]

OUTLOOK FOR TEXAS

The aging of existing nuclear reactors, a new generation of advanced reactors, rising global energy demands and the cost of natural gas coupled with the need to reduce greenhouse gas emissions all point to a renaissance for nuclear energy. But several regulatory and economic hurdles must be addressed before the next generation of nuclear reactors comes on line.

As noted above, Luminant plans to add two Mitsubishi advanced pressurized water reactors at Comanche Peak; NRG Energy LLC, one of the partners in STP, has submitted an application to add two General Electric advanced boiling water reactors at the site in Matagorda County, each capable of generating more than 1,300 MW.[86]

In addition, Exelon has announced plans to submit a combined construction and operating license application for two reactors in September 2008. The site is 20 miles south of Victoria in Victoria County. Exelon has chosen the ESBWR as its reactor of choice.[87]

Amarillo Power, LLC has announced plans to build a nuclear power plant with two UniStar U.S. evolutionary power reactors in the Texas panhandle. Together, these two reactors would be capable of generating 2,700 MW. Amarillo Power has not submitted a COL application, but they have notified the NRC that it plans to do so in the last quarter of 2008.[88]

If all eight proposed reactors are built and operating in Texas, they and the four existing nuclear reactors would have the capacity to generate more than 17,000 MW of electricity, or about 16 percent of Texas' total 2006 capacity, compared to the 4.6 percent of capacity that the four existing reactors contributed in 2006.[89]

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CHAPTER 9

Overview: Renewable Energy

The oil price shocks of the 1970s and 1980s spurred a national movement to develop other kinds of energy and decrease our dependence on petroleum. In this period, Texas oil and gas production peaked and the industry began to play a diminishing yet still important role in the state's economy. As energy prices fell, however, interest in renewable energy sources waned. Recent events, including dramatically higher oil prices and environmental concerns, again have led to heightened interest in renewable sources of energy, such as solar and wind energy, biomass, hydropower and geothermal power, which are virtually inexhaustible and relatively clean.

In a sense, at the beginning of the 21st century, Texas has come full circle. Windmills that pumped water for farms and ranches in the late 1800s now stand in the shadow of giant wind turbines that generate electricity. Native Americans and settlers once gathered buffalo chips for fuel to build fires on the High Plains; soon cattle feedlots near Hereford will provide manure to fuel ethanol plants. Settlers once burned wood in East Texas to heat their cabins and cook their food — and a proposed plant near Nacogdoches may burn forest products to produce electricity.

By definition, renewable energy is abundant and constantly replenished. It includes energy from the sun, earth and wind. Most renewable energy comes either directly or indirectly from the sun, which itself is a fusion nuclear reactor 93 million miles from earth. The sun projects a reliable, continuous spectrum of radiation. Sunlight intercepted by the earth provides renewable solar energy that can be used to generate electricity, provide heat and light and drive photosynthesis — the essential life-giving process by which the energy of sunlight creates food for green plants.

The sun's heat also drives the earth's winds. The earth's rotation and topography combine to produce predictable wind patterns that can be used by large wind turbines to generate electricity. The motive power of wind (and moving water) has historically played a valuable role in turning milling wheels, driving pumps and sending ships across the sea. Today, wind power accounts for a growing part of Texas' energy portfolio.

Biomass is defined as any plant or animal matter used to produce electricity, heat or transportation fuels. Sources of biomass include wood products, food crops, grasses, agricultural residues, manure, municipal solid waste and landfill gas. The stored hydrocarbons in biomass provide the same chemical building blocks as coal, oil and natural gas, which are simply ancient forms of biomass gathered and transformed by nature. While most renewable sources of energy are used to produce electricity, some biomass sources are well-suited, through appropriate technology, for conversion into transportation fuels or boiler fuels.

Just 7 percent of the energy consumed in the U.S. in 2006 came from renewable energy sources.

Hydropower relies on capturing the energy in flowing water, which is linked to the sun through the hydrological cycle — water evaporation from the oceans turns into clouds and later condenses, falling as rain. The ocean itself can produce energy from the action of the waves (driven by the sun's heat and winds) and tides, based on the gravitational pull of the sun and moon.

Geothermal energy uses the internal heat of the earth to generate electricity, as well as more direct uses such as spas and greenhouses. The ground itself, due to its more constant temperatures, provides a form of geothermal energy that is used for climate control of buildings (as with ground-source heat pumps). The heat of geothermal resources generally increases in intensity with depth. In the richest geothermal zones, heat from deep underground penetrates the earth's surface as geysers and volcanically active areas.

RENEWABLE ENERGY CONSUMPTION IN THE U.S.

According to the federal Energy Information Administration (EIA), just 7 percent of the energy consumed in the U.S. in 2006 came from renewable energy sources, just behind nuclear power, which accounted for 8 percent (**Exhibit 9-1**). Fossil fuels — petroleum, coal and natural gas — supplied the remaining 85 percent of the nation's energy needs. Renewable energy production and consumption rose by more than 6 percent between 2005 and 2006, a faster pace than in the previous three years, but not enough to overtake nuclear power.[1]

Renewable energy provided 9.5 percent — 385 billion kilowatt-hours (kWh) — of U.S. electricity in 2006, slightly more than in the previous two years.[2] In 2006, the electric power sector accounted for 56 percent of the nation's renewable energy consumption. The remaining 44 percent was used for industrial, transportation, residential and commercial purposes.

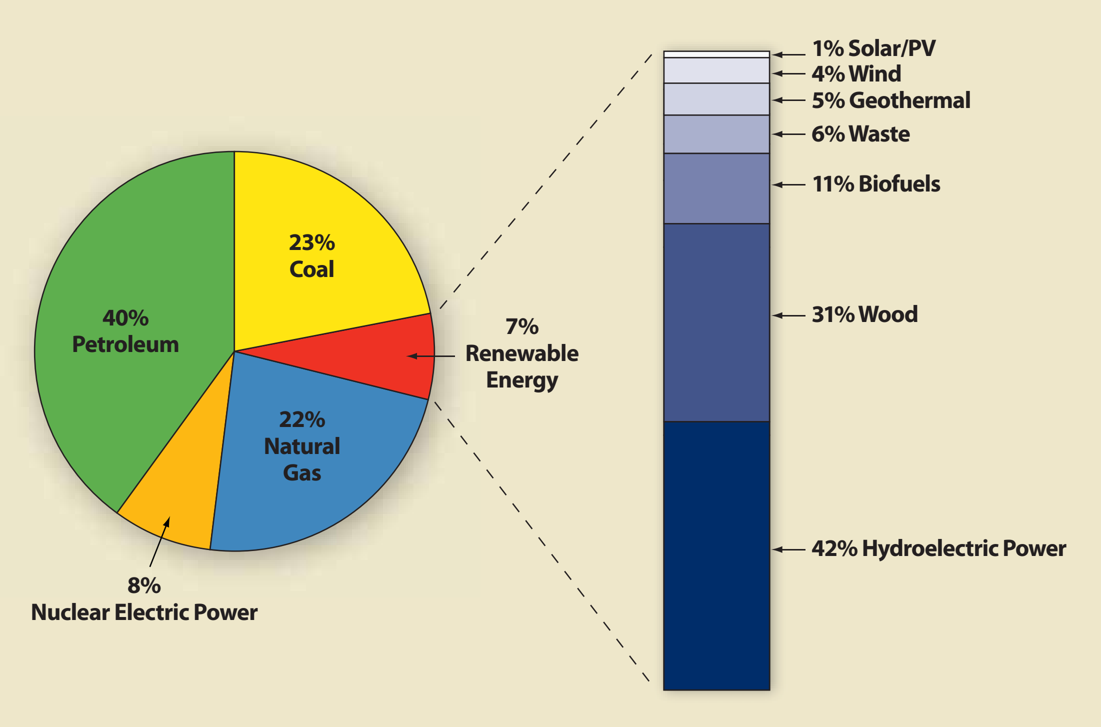
In the industrial sector, wood and wood waste are an important source of energy for the lumber and paper manufacturing industries, which use these products for boiler fuel to produce electricity, and in some cases steam. Wood also accounts for the majority of the renewable energy consumed in the residential sector, followed by solar/PV and geothermal energy. The transportation sector is using more biofuels; ethanol consumption rose by 34 percent between 2005 and 2006. The commercial sector primarily used wood and wood waste, landfill gas and other biomass and some geothermal energy.[3]

Eight states — Washington, California, Oregon, New York, Idaho, Alabama, Montana and Texas — provided 70 percent of all U.S. renewable energy generated in 2006. Texas ranked eighth, accounting for 2 percent of total renewable energy generated in 2006.[4] Washington and California continue to rank first and second, respectively, due to their abundant hydropower supplies. Texas leads the nation in electricity generated from wind; Washington leads

Eight states — Washington, California, Oregon, New York, Idaho, Alabama, Montana and Texas — provided 70 percent of all U.S. renewable energy generated in 2006.

Exhibit 9-1

U.S. Renewable Energy Consumption as Share of Total Energy in 2006



Source: U.S. Energy Information Administration.

in hydroelectric power; Florida leads in landfill gas; Alabama leads in the use of wood and derived fuels to generate power; and California leads in geothermal, other biomass and solar power.[5]

RENEWABLE ENERGY CONSUMPTION IN TEXAS

In Texas, wind energy accounts for the vast majority—about 79 percent—of all renewable energy generated in 2006 (**Exhibit 9-2**). Texas' total wind energy capacity rose from 180 megawatts (MW) in 1999 to 2,739 MW in 2006. By the end of 2007, wind energy capacity was 4,296 MW.[6]

Wood and hydropower each accounted for about 11 and 8 percent, respectively, of renewable energy generated in the state in 2006. The pulp and paper industry often uses the biomass energy from wood it produces to generate electricity, heat and steam it uses on site. This biomass energy is not placed on the electric grid, however.

Wind energy provided 2.1 percent of the Electric Reliability Council of Texas' (ERCOT's) electricity in 2006, up from 1.1 percent in 2004.[7] In 2007, wind energy accounted for 2.9 percent of electricity generated in the ERCOT region. Unlike biomass energy, the vast majority of Texas wind-generated energy is sent over transmission lines to electric utilities. In 2007, hydroelectric power accounted for 0.4 percent of ERCOT's electricity, and another 0.4 percent of its electricity was categorized as "other" and included some renewables — landfill gas, biomass solids, biomass gases — in addition to very small amounts of petroleum coke and other fuels.[8]

Renewable Energy Potential

Although Texas does not yet use much renewable energy, it has an abundance of renewable energy resources, especially wind and solar power.

A federal research center ranked Texas as second for wind potential, just behind North Dakota.[9] The state's strongest winds are in the Panhandle and along the West Texas mesas. Other promising areas for wind development are in South Texas along the coast and offshore.[10] In 2006, Texas surpassed California to become the state with the most wind generating capacity.[11]

EXHIBIT 9-2

Total Renewable Net Generation in Texas by Energy Source, 2006*

Fuel Type	Total MWh	Percent of Total Renewable Net Generation
Wind	6,670,515	78.5%
Wood & Derived Fuels	900,888	10.6
Hydropower	661,971	7.8
Landfill Gas	218,813	2.6
Biomass	43,516	0.5
Solar	not available	0.0
Geothermal	not available	0.0
Total**	**8,495,704**	

*Includes renewable energy sent over transmission lines to electric utilities, and renewable energy generated and used on site.
**Does not reflect solar or geothermal energy production. Numbers may not total due to rounding.
Source: U.S. Energy Information Administration.

Texas also is one of seven states identified as having the nation's most plentiful solar resources. West Texas has the state's highest solar radiation readings, making it a good candidate for utility-scale concentrating solar power.[12] Since Texas has abundant solar resources statewide, photovoltaic (PV) systems and solar water heating can be used in every Texas county, in rural and urban settings alike.[13]

Texas has many opportunities to generate energy from biomass. One example is the use of feedlot biomass as fuel; ethanol plants under construction or planned in the Panhandle will use manure for this purpose. And using manure along with coal for electric generation, in what is called a reburn process, can cut air pollution. Perhaps most importantly, using manure for fuel mitigates possible environmental problems associated with feedlot and dairy operations, helping maintain this vital segment of Texas' agricultural economy.

Another energy source with some potential in Texas is landfill gas, which is generated by the decomposition of organic waste deposited in landfills. The methane gas emitted by landfills can be used to generate electricity or to fire boilers. There are 23 landfill gas facilities already in operation and an estimated 58 to 89 sites that could develop

Although Texas does not yet use much renewable energy, it has an abundance of renewable energy resources.

landfill gas.[14] Texas has an opportunity to turn more of its waste into cash.

Wood biomass is used to produce electricity for the grid in various places around the U.S., although it is not being used in Texas at this writing. But Texas mills and pulp and paper plants routinely use wood waste to create electricity to power their own facilities. Wood biomass has strong potential to be a niche energy market, greatly benefiting rural communities in Texas.

Hydropower provides a fraction of 1 percent of Texas' electricity; only 23 of the many dams in the state have a generating plant.[15] While there is some undeveloped potential for additional hydroelectricity, the importance of managing Texas water as a scarce resource is likely to outweigh the relatively tiny amount of power it could add to the grid. The value of Texas' existing hydro plants lies in their ability to come online within seconds and boost supply during times of peak demand. This is dependent, however, on sufficient supplies of water in the reservoirs to allow its release through turbines. Unlike other renewable forms of energy, hydropower has probably developed about as far as it can in Texas.

Texas is the nation's leading producer of biodiesel.

Ocean power — generating electricity from waves or tidal currents — is making waves of its own in various places around the world. Texas, however, is not one of those places. Despite hundreds of miles of coastline, the characteristics of the Gulf of Mexico do not make it a good candidate for producing this form of power.

Geothermal power comes from the heat contained within the earth itself, usually accessed by means of heated water. This includes not only electricity generation, but also direct uses such as drying lumber and aquaculture. Geothermal energy is also applied to buildings' heating and cooling systems with geothermal heat pumps (GHPs), a very efficient form of air conditioning. Texas can make use of GHPs' energy-saving technology to offset some of the large amount of electricity it uses to cool and heat its homes and other buildings. Experts believe that 2,000 to 10,000 MW of geothermal electric capacity could be developed in Texas in the not-too-distant future, particularly if existing depleted oil and gas wells can be converted to access geothermal resources. The state's first geothermal land leases were purchased in January 2007.[16] Geothermal power may have a significant role to play in the state's renewable portfolio.

In the arena of renewable transportation fuels, Texas has taken the lead in producing biodiesel, but is not as strong in ethanol production and consumption. Texas is the nation's leading producer of biodiesel, with 22 plants capable of making 200 million gallons of the fuel each year.[17]

Ethanol in the U.S. currently is produced from corn. At present, there are two ethanol production facilities operating in Texas, and two more facilities are under construction. All are expected to begin operations in 2008. Ethanol can be blended with gasoline to fuel vehicles. E85 is 85 percent ethanol and 15 percent gasoline and can be used by special flexible fuel vehicles (FFVs), which are widely available in Texas. But E85 fueling stations are scarce; there are fewer than 30 public fueling stations in the state.[18]

Recent increases in the price of corn and other crops have resulted in growing criticism of government biofuels policy, including incentives to produce ethanol. Federal subsidies and mandates have resulted in the expansion of ethanol preoduction. As a result, an increasing percentage of the U.S. corn crop goes to ethanol, contributing to increased feed costs for poultry and livestock feeders.

GOVERNMENT POLICIES AND RENEWABLE ENERGY

Government policies are used to encourage the development and deployment of renewable energy sources.[19] Several countries and U.S. states have set ambitious targets for renewable energy use, and provide various investment and production incentives that have spurred growth in the renewables industry.[20]

According to the U.S. Government Accountability Office (GAO), government leadership is needed to overcome technological and economic barriers to advanced energy technologies, whether renewable energy, nuclear or clean coal.[21] GAO identified numerous barriers to the deployment of advanced renewable energy technologies, including the difficulty of making the technologies more efficient and the high up-front capital cost that make them less cost-competitive with existing energy sources.[22]

Federal Policies

The U.S. Congress has been debating the need for a federal Renewable Portfolio Standard (RPS) that would require utilities to generate or buy a percentage of their electricity from renewable sources. At present, the main federal policy promoting renewables is the Volumetric Ethanol Excise Tax Credit (VEETC), accounting for 41.6 percent of 2006 federal subsidies for all renewables (see Chapter 28 of this report for further discussion of the tax credit).

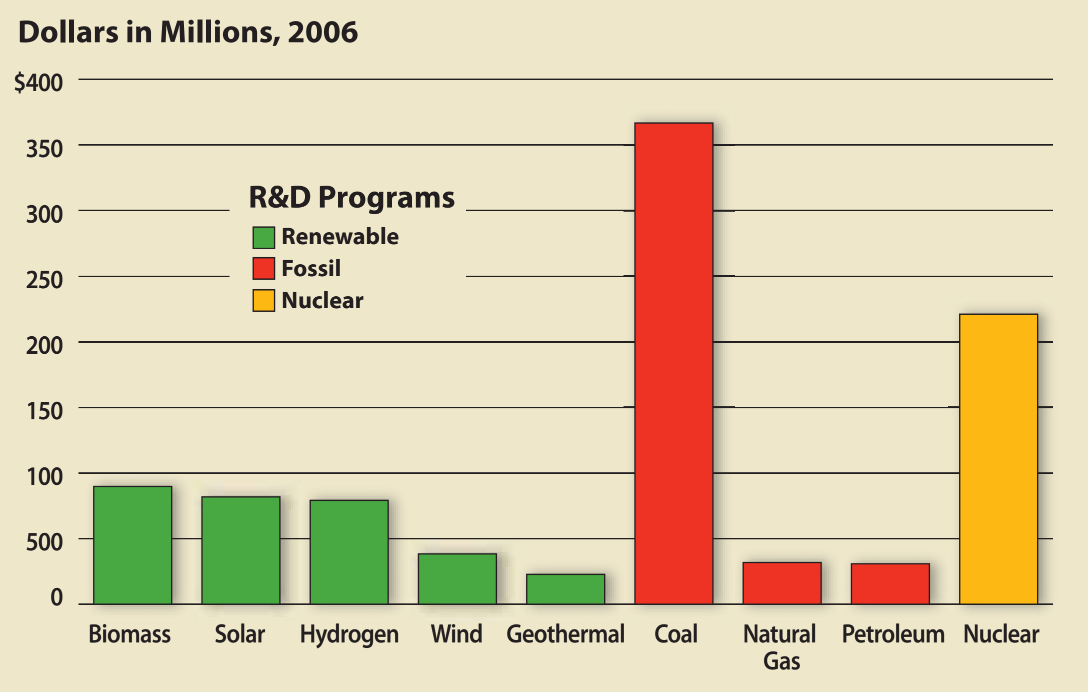
Spending on energy research and development (R&D), whether from the private or public sector, is important for continued innovations in advanced energy technologies.[23] The U.S. Department of Energy's (DOE's) R&D investment in advanced renewable, fossil and nuclear energy technologies fell by 85 percent in real terms between 1978 and 2005, while overall federal government R&D investments rose by about 6 percent annually.[24] The energy sector accounted for 10 percent of all federal government R&D investments in the 1980s, but just 2 percent in 2005.

In 2005, the federal government invested about $1 billion less in energy R&D than ten years before. Furthermore, private investment in the energy sector has declined even more rapidly than public-sector investment. In the 1980s and 1990s, the public and private sectors each accounted for about half of R&D invested in energy, but by 2005 the private sector accounted for only 24 percent.[25]

Of the $982 million that Congress budgeted for energy R&D in 2006, $434 million went for fossil energy, $324 million for renewable energy and $224 million for nuclear energy (**Exhibit 9-3**).[26] Eighty percent of the $324 million budgeted for renewable energy R&D was divided between biomass, solar and hydrogen energy programs.[27] A significant portion of these research dollars went to fund hydrogen fuel cell technologies; the

Exhibit 9-3

Renewable, Fossil and Nuclear R&D by Fuel



Source: U.S. Government Accountability Office.

remaining $65 million went toward wind and geothermal energy programs.

In 2006, President Bush unveiled an Advanced Energy Initiative and a Solar America Initiative to provide additional funds in 2007 for clean-energy technology research at the Department of Energy.[28] The funding for these initiatives would reverse a decade-long decline in federal energy research and development.[29] The ultimate goal of this initiative is to improve the efficiency of renewable energy sources and to reduce their cost, making them more competitive with fossil energy. In his 2008 budget request to Congress, President Bush sought about $1.2 billion to fund research and development for clean and renewable energy programs, an increase of 5 percent from 2007.[30]

State Government Policies

State governments have been important supporters of renewable energy development. State policies used to promote renewable energy sources include renewable portfolio standards, renewable energy credits (RECs), interconnection and net metering rules and financial incentives including exemptions from state taxes. Texas has been aggressive in applying some of these measures.

State policies used to promote renewable energy sources include renewable portfolio standards, renewable energy credits, interconnection and net metering rules and financial incentives including exemptions from state taxes.

The Texas Legislature also has recognized the need for new transmission lines in areas of the state with renewable resources and authorized the Public Utility Commission (PUC) to designate Competitive Renewable Energy Zones (CREZs), areas to be connected to the electrical grid through the construction of additional transmission lines. Thus far, the CREZ areas include only wind energy projects, although all renewable energy sources are eligible.

Renewable Portfolio Standards

Texas' 1999 electricity deregulation legislation — Senate Bill 7 — created a renewable portfolio standard (RPS) for Texas that requires electricity providers engaged in the competitive market to acquire a minimum amount of electricity from renewable energy sources. Municipally owned utilities and cooperatives are excluded from the RPS requirement, but can choose to participate. Renewable resources include solar, wind, biomass, landfill gas, geothermal, hydroelectric, wave and tidal energy. Any of these energy sources can satisfy the RPS goal.

By 2006, Texas had exceeded S.B.7's goal for Texas power generators to install 2,880 MW of generating capacity from renewable energy by 2009. Senate Bill 20 increased the state's RPS to 5,880 MW of electricity from renewable energy sources by 2015, and established a state goal of 10,000 MW by 2025.[31]

In Texas, wind energy has thus far satisfied the majority of the RPS goal because the state has significant wind resources and the cost of wind power is lower than other renewables. For example, today solar energy is much more expensive than wind energy. In 2006, solar photovoltaic (PV) systems generated electricity for about 18 to 23 cents per kWh, while large-scale wind power prices ranged from 3 to 6 cents per kWh.[32]

To encourage the development of renewables other than wind, the 2005 Texas Legislature set a *voluntary* goal specifying that 500 MW of the 5,880 MW should come from a source other than wind. Legislation carving out a *mandatory* set-aside for non-wind generation failed in the 2007 legislative session.

As of February 2008, 25 states and Washington D.C. had implemented an RPS with binding targets for renewable energy sources.[33] Another four states—Missouri, North Dakota, Virginia, and Vermont—had enacted voluntary renewable energy portfolio goals. (**Exhibit 9-4**). Texas' RPS goal is stated as a minimum number of megawatts; other states define their RPS goals as a percentage of total electric production.

The 2015 goal represents about 4 to 5 percent of the state's projected electric annual generation production, and roughly 8 percent of ERCOT's currently installed generation capacity of 72,416 MW. Based on a study of wind's effective load-carrying capability, however, ERCOT determined that next year only 8.7 percent of installed wind capacity in its region can be reliably counted on to serve peak summer demand, a time of year when the wind is typically calm.[34] As a result, and assuming all 5,880 MW is met by wind energy, only 0.7 percent of ERCOT's estimated 75,596 MW of peak summer demand would be served by wind generation.

The 2025 goal of 10,000 megawatts would represent 14 percent of ERCOT's currently installed

Exhibit 9-4

Renewable Portfolio Standards by State, February 2008

State	Amount	Year	Organization Administering RPS
Arizona	15%	2025	Arizona Corporation Commission
California	20%	2010	California Energy Commission
Colorado	20%	2020	Colorado Public Utilities Commission
Connecticut	23%	2020	Department of Public Utility Control
District of Columbia	11%	2022	DC Public Service Commission
Delaware	20%	2019	Delaware Energy Office
Hawaii	20%	2020	Hawaii Strategic Industries Division
Iowa**	1,105 MW	2010	Iowa Utilities Board
Illinois	25%	2025	Illinois Department of Commerce
Massachusetts	4%	2009	Massachusetts Division of Energy Resources
Maryland	9.5%	2022	Maryland Public Service Commission
Maine	10%	2017	Maine Public Utilities Commission
Minnesota	25%	2025	Minnesota Department of Commerce
Missouri*	11%	2020	Missouri Public Service Commission
Montana	15%	2015	Montana Public Service Commission
New Hampshire	16%	2025	New Hampshire Office of Energy and Planning
New Jersey	22.5%	2021	New Jersey Board of Public Utilities
New Mexico	20%	2020	New Mexico Public Regulation Commission
Nevada	20%	2015	Public Utilities Commission of Nevada
New York	24%	2013	New York Public Service Commission
North Carolina	12.5%	2021	North Carolina Utilities Commission
North Dakota*	10%	2015	North Dakota Department of Commerce
Oregon	25%	2025	Oregon Energy Office
Pennsylvania	18%	2020	Pennsylvania Public Utility Commission
Rhode Island	15%	2020	Rhode Island Public Utilities Commission
Texas***	5,880 MW	2015	Public Utility Commission of Texas
Vermont*	10%	2013	Vermont Department of Public Service
Virginia*	12%	2022	Virginia Department of Mines, Minerals, & Energy
Washington	15%	2020	Washington Secretary of State
Wisconsin	10%	2015	Public Service Commission of Wisconsin

*Missouri, North Dakota, Virginia and Vermont have voluntary goals for adopting renewable energy instead of an RPS with binding standards.

**Iowa has had a mandatory RPS goal of 105 MW since 1983. In 2001, the state governor established a secondary voluntary goal of 1,000 MW of wind by 2010.

***Texas' RPS goal of 5,880 MW equates to 4 to 5 percent of total energy production by 2015. Texas may reach this level by the first quarter of 2008.

Sources: U.S. Department of Energy, Energy Efficiency and Renewable Energy and North Carolina State University.

generation capacity. Assuming the SB 20 goal is met by wind generation, the 10,000 MW would represent about 11 percent of ERCOT's estimated 89,883 MW peak summer demand in 2025.

Texas' RPS goals have entailed some costs to taxpayers. The fiscal impact of the renewable energy goal to a residential customer who uses about 1,000 megawatt-hours of electricity was equivalent to roughly 12 cents per month in 2005 and seven cents per month in 2006.[35] This five-cent decline in the monthly impact was due to falling renewable energy credit prices.

Renewable Energy Credits

To facilitate the RPS standards, the Texas Legislature created a system of "renewable energy credits," or RECs, that competitive electricity retailers can purchase or trade among one another to meet their individual requirements. (One REC or credit represents one megawatt-hour of qualified renewable energy generated and metered in Texas.) Any retail electric provider (REP) can meet its renewables requirement either by purchasing power directly from a renewable energy generator or by purchasing RECs from another party that has a surplus of renewable energy credits available to sell.[36]

At present, Texas generates more electricity from renewable sources than the RPS requires.

State law requires REPs to acquire renewable energy based on their market share of electricity sales. For example, a REP that sold 5 percent of all retail electricity in Texas would be responsible for achieving 5 percent of the statewide renewable goal by 2015.[37] It should be noted that they can use renewable energy contracts in place before September 1999 to reduce their requirements. If they do not acquire their required minimum number of RECs, they face an administrative penalty of up to $50 per megawatt-hour of shortfall.

Municipally owned utilities and cooperatives are not required to achieve the renewable energy goals, but those that generate renewable energy can sell credits to REPs who need them. Municipally owned utilities and electric cooperatives that choose to enter the competitive electric market fall under the broad category of "competitive retailer (CR)" and become subject to REC requirements. CR is a broad term that also includes REPs.

In addition to meeting minimum RPS requirements, RECs can be purchased "voluntarily" to substantiate claims made to consumers who choose a "green" or renewable energy plan. In such cases, the REP must acquire (or a co-op or municipally owned utility may generate) sufficient credits to "authenticate" or prove that the electricity sold to these customers was generated from renewable sources.

It should be noted, however, that current Texas law considers "voluntary" and "required" RECs to be two different things. The RPS legislation that passed in 2005, S.B. 20, led some REPs to believe they could use voluntary credits to fulfill their RPS goal. H.B. 1090, approved by the 2007 Texas Legislature, forbids REPs from counting the acquisition of voluntary credits toward their mandatory credit requirement, which should further increase the amount of energy being generated by renewable technologies.

ERCOT manages the renewable energy credit program for PUC. When retail electric providers electronically submit their credits to ERCOT to certify they have met their RPS requirement, the credit is considered "retired." RECs remain active for up to three years, after which they are retired automatically, regardless of whether they were turned in to meet a particular REP's requirement. Thus, if a generator has a surplus of RECs, it may hold on to them for up to three years before selling them.[38]

In another change mandated by 2007's H.B. 1090, large industrial customers can tell their REPs that they choose to "opt out" of the RPS requirement. This may allow such customers to avoid paying higher prices for electricity produced from renewable resources. REPs with customers that opt out in this fashion can reduce their renewable energy requirement by an amount equivalent to the customers' electricity usage. The overall requirement for the state, however, is not reduced. The requirement attributable to an industrial power load that "opts out" thus is spread out among all of the state's REPs.

At present, Texas generates more electricity from renewable sources than the RPS requires, so a surplus of credits is available each year.[39]

Competitive Renewable Energy Zones

While S.B. 7 created state goals for renewable energy generation, it made no provision to ensure that an adequate system of transmission lines would be available to *move* energy from new, renewable energy generators to customers who need the electricity.

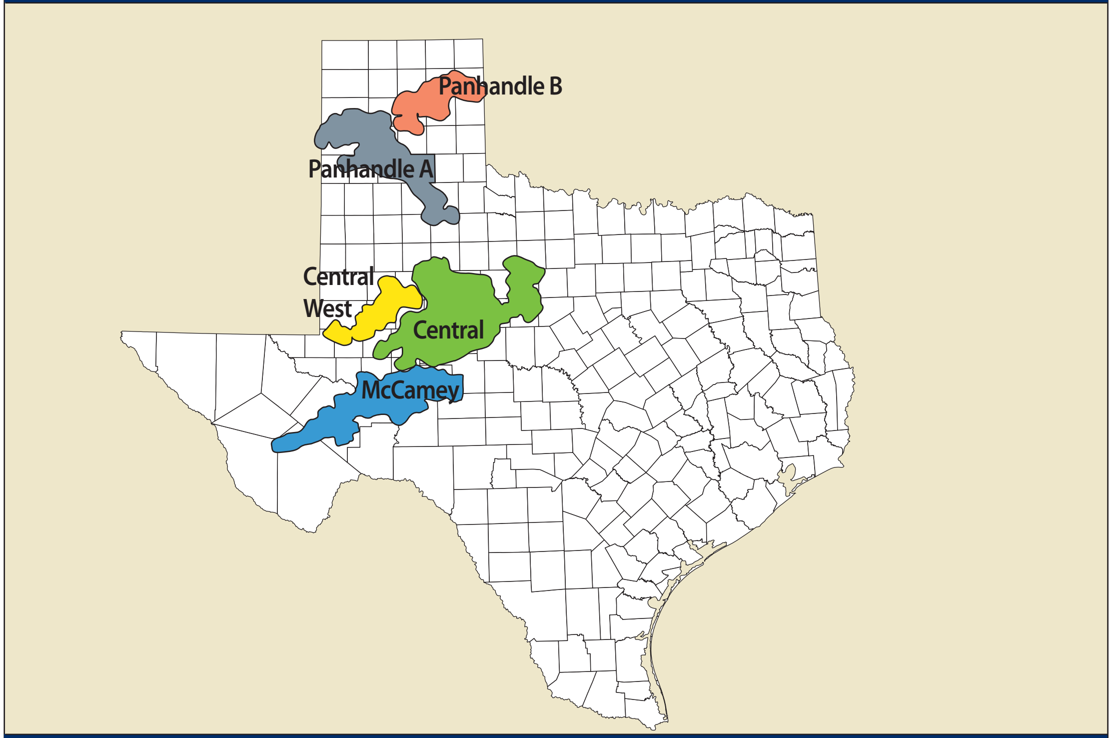
S.B. 20 attempted to alleviate this problem by authorizing PUC to identify areas in Texas most suitable for generating capacity from renewable energy technologies, including solar, wind, biomass, landfill gas, geothermal, hydroelectric, wave and tidal energy. PUC then could pre-designate a need for new transmission lines connecting these areas, based on the existence of the renewable energy resource and demonstrable evidence that generators are committed to developing the areas, which are called "Competitive Renewable Energy Zones" or CREZs.

In Texas, the fastest-growing renewable energy technology is wind power. In 2005, PUC delegated to ERCOT the task of determining which land areas throughout Texas would be most conducive to wind energy, and roughly estimating the cost to build transmission lines to each of those areas. While other renewable energy technologies are eligible for CREZ status (such as solar energy), the current demand for new transmission lines is coming from the wind industry. ERCOT noted that potential wind generators representing about 17,000 MW of electricity, mostly in West Texas, had requested connection to ERCOT's energy grid. That is more than three times the amount of existing wind capacity in Texas.[40]

ERCOT's study identified 25 areas in the state with significant potential for wind development, but lacking the necessary transmission improvements. PUC evaluated ERCOT's findings, weighing wind-resource data and developer commitments against the likely cost of building the needed transmission lines, and selected for further study six major CREZ areas in August 2007 (**Exhibit 9-5**).[41] The CREZs are located in the Panhandle; the McCamey area, south of Odessa; and near Sweetwater and Abilene.

EXHIBIT 9-5

ERCOT Selected CREZ Zones*



*The McCamey Area includes two CREZ areas.
Source: The Electric Reliability Council of Texas.

PUC also was charged with developing a plan to build the transmission capacity needed to move electricity from the CREZ locations to the power grid. The cost of that construction will be charged uniformly to all Texas electricity consumers. A recent ERCOT study estimates that it will cost about $1.5 million per mile to build transmission lines to transport wind generated electricity from West and Northwest Texas to urban areas.[42]

PUC asked ERCOT to study the transmission needs for four different scenarios of CREZ zones and to complete a report for its review.[43] On April 2, 2008, ERCOT finalized its CREZ Transmission Optimization Study. The estimated cost of building new transmission lines to windy parts of the state ranges from $3 billion for 12,053 MW of wind generation capacity to $6.4 billion for 24,859 MW.[44] Each scenario includes 6,903 MW of wind generation that was either in-service or had signed interconnection agreements as of fall 2007.

PUC will issue final designation of transmission solutions for the CREZ areas, and decide which transmission companies will be selected to build transmission lines. The expansion of transmission lines to the CREZ zones would move large amounts of wind power to the state's electric grid.

Net metering is a utility practice that allows owners of qualifying electricity generation resources to capture the value of electric energy they produce beyond their own needs.

Net Metering

Net metering is a utility practice that allows owners of qualifying electricity generation resources — solar energy, wind, geothermal electric, biomass, landfill gas, hydroelectric, tidal energy, wave energy and ocean thermal energy — to capture the value of electric energy they produce beyond their own needs. For example, under net metering, homeowners or businesses with PV solar energy systems or small wind turbines can reduce their use of grid electricity and sell excess electricity they produce back to the utility. Net metering is considered of particular importance to the development of distributed solar energy.

State and utility net metering implementations, both nationally and in Texas, often have differing technical and legal requirements, creating obstacles to growing a market for renewable energy systems.[45] Each state or utility adopts interconnection standards and net metering rules that establish which utilities must participate; which customers of distributed energy are eligible for net metering; the size of an individual system eligible for net metering; the treatment of net excess generation of electricity (whether it is credited to customer's next bill, purchased by the utility monthly at retail rate, etc.), and the process and requirements for interconnection.

As of August 2007, at least some electricity customers in 42 states and the District of Columbia had access to net metering. Several electric utilities in Texas offer net metering to customers, most notably Austin Energy and San Antonio's CPS Energy.[46]

In 1986, net metering was first introduced in Texas in response to federal legislation. PUC adopted rules, applicable to investor-owned utilities (IOUs), allowing customers with renewable electricity generators capable of producing 50 kW or less to have their net energy consumption measured with a single meter capable of spinning forward and backward. This rule is still in effect for investor-owned utilities (IOUs) outside the ERCOT power grid (such as El Paso Electric Company, Entergy Texas, South Western Electric Power Company and Xcel Energy), which currently account for 15 percent of all Texas electricity sold in the state.[47] Municipally owned utilities, electric cooperatives and river authorities are not required to offer net metering, though some have done so voluntarily.

In 1999, however, S.B. 7 deregulated the electric industry within the ERCOT area, creating new distinctions between entities responsible for delivering energy (transmission and distribution service providers, or TDSPs) and selling energy (retail electric provider, or REPs), and making the appropriate application of the PUC's existing net metering requirements unclear.

To reestablish net metering within ERCOT, the Texas Legislature approved H.B. 3693 in 2007. H.B. 3693 directed ERCOT and PUC to establish protocols and rules requiring REPs to offer to purchase net excess generation from schools, and to enable them to voluntarily offer to purchase excess generation from other customers with distributed renewable generation by January 1, 2009.[48]

In October 2007, ERCOT convened a Distributed Generation Task Force to begin addressing H.B. 3693 by presenting options and recommendations to PUC on net metering policy for distributed renewable generation. On January 15, 2008, the

ERCOT Board of Directors asked PUC to clarify the definition of "net metering" since the legislation is ambiguous about the meaning of the term and its intended application in Texas' competitive electricity market.[49]

The most common method of net metering uses a single, bidirectional meter that runs forward and backward; one alternative method requires utilities to separately measure energy in-flows and outflows. The choice of metering method is a technical one, but has important financial ramifications for customers, transmission and distribution service providers, and retail electric providers.[50]

PUC is expected to provide guidance on the definition of net metering in spring 2008, and to complete more detailed net metering rulemaking for IOUs within ERCOT by fall 2008. Full implementation of this measure is expected by January 1, 2009.[51] In other areas of the state, however, Texans will continue to encounter different net metering programs depending on the type and location of utility to which the customer is interconnected.

OUTLOOK

Texas is a state rich in energy resources. In the 20th century, the state tapped into its fossil fuel — oil, gas and coal — reserves and reaped economic benefits. Texas is also rich in renewable energy resources — wind, solar, geothermal and biomass — and can continue to play a major role in the energy economy of the 21st century.

The following chapters examine, in greater detail, these renewable energy resources.

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Chapter 10
Solar Energy

Introduction

Solar energy is an inexhaustible resource. The sun produces vast amounts of renewable solar energy that can be collected and converted into heat and electricity.

Texas, due to its large size and abundant sunshine, has the largest solar energy resources among the states. Several other states, however, lead the nation in terms of *using* solar energy, mostly due to state policies and incentives that encourage the installation of solar energy systems.

California is the nation's largest solar energy market by far, and has effective state initiatives promoting the industry. Other states with notable markets for solar energy include New Jersey, Arizona, Colorado and New York.

Even so, in 2006 solar energy accounted for just 0.01 percent of all U.S. electricity, mainly because of its higher costs compared to other power options.[1] Solar energy plays an even smaller role in the Texas electricity market.

Still, Texas has the sunshine, manufacturing base and research institutions needed to become a leader in the development of solar energy.[2] The state is well positioned to compete with other states and countries in a global solar energy market worth $10.6 billion in 2006.[3] One study estimates that Texas could capture about 13 percent of all new jobs and investments related to solar photovoltaic technologies by 2015, primarily in manufacturing.[4]

History

Humans have harnessed the power of the sun for millennia. In the fifth century B.C., the Greeks took advantage of passive solar energy by designing their homes to capture the sun's heat during the winter. Later, the Romans improved on solar architecture by covering south-facing windows with clear materials such as mica or glass, preventing the escape of solar heat captured during the day.[5]

In the 1760s, Horace de Saussure built an insulated rectangular box with a glass cover that became the prototype for solar collectors used to heat water. The first commercial solar water heaters were sold in the U.S. in the late 1890s, and such devices continue to be used for pool and other water heating.[6]

In the late 19th century, inventors and entrepreneurs in Europe and the U.S. developed solar energy technology that would form the basis of modern designs. Among the best known of these inventors are August Mouchet and William Adams. Mouchet constructed the first solar-powered steam engine.[7] William Adams used mirrors and the sun to power a steam engine, a technology now used in solar power towers. He also discovered that the element selenium produces electricity when exposed to light.

Texas has the sunshine, manufacturing base and research institutions needed to become a leader in the development of solar energy.

In 1954, three scientists at Bell Labs developed the first commercial photovoltaic (PV) cells, panels of which were capable of converting sunlight into enough energy to power electrical equipment. PV cells powered satellites and space capsules in the 1960s, and continue to be used for space projects.[8]

In the 1970s, advances in solar cell design brought prices down and led to their use in domestic and industrial applications. PV cells began to power lighthouses, railroad crossings and offshore gas and oil rigs.

In 1977, solar energy received another boost when the U.S. Department of Energy created the Solar Energy Research Institute. It was subsequently renamed as the National Renewable Energy Laboratory (NREL), and its scope expanded to include research on other renewable energy sources. NREL continues to research and develop solar energy technology.

In the last 20 years, solar energy has made further inroads and now is used extensively in off-grid and remote power applications such as data monitoring and communications, well pumping and rural power supply, and in small-scale applications such as calculators and wristwatches. But solar energy has not yet achieved its potential to become a major contributor to world electrical grids.

Private and government research and development in solar energy technologies have led to continuing innovation over the last 30 years. The conversion efficiency of PV cells — that is, the percentage of sunlight hitting the surface of the cell that is converted to electricity — continues to improve. Commercially available cells now on the market have efficiencies approaching 20 percent.[9] Cell efficiencies achieved in research laboratories recently surpassed 40 percent.[10]

The worldwide PV market has grown by an average of 30 percent annually for the past 15 years.

The worldwide PV market has grown by an average of 30 percent annually for the past 15 years, an increase that has improved economies of scale for manufacturers.[11] As a result, the cost of electricity generated from PV modules has fallen significantly, from more than 45 cents per kilowatt hour (kWh) in 1990 to about 23 cents per kWh in 2006.[12] In 2006 and 2007, a shortage of silicon (a primary component of crystalline silicon PV systems) temporarily increased PV module costs, but prices are expected to decline once again between 2008 and 2011, when silicon plants currently under construction are completed.

Uses

Solar energy has many uses. It can be used to provide heat, light or to generate electricity. *Passive* solar energy refers to the collection of heat and light; passive solar design, for instance, uses the sun's energy to make homes and buildings more energy-efficient by eliminating the need for daytime lighting and reducing the amount of energy needed for heating and cooling. *Active* solar energy refers to storing and converting this energy for other uses, either as photovoltaic (PV) electricity or thermal energy.

Solar Heating

Solar systems that heat water for homes and businesses, and passive solar design for buildings of all sizes, both have the same effect on the electric grid as conservation. They do not generate electricity per se, but reduce the demand for electricity and natural gas.

From 1998 to 2005, the solar water heating market produced about the thermal equivalent of 124,000 megawatt-hours (MWh) annually.[13] Solar pool heating is the most commonly used solar energy in the U.S.[14] In 2005, it accounted for 95 percent of U.S. solar thermal collector shipments. The second-largest end use for solar thermal collectors was water heating, primarily in residential buildings, accounting for about 4 percent of U.S. shipments in 2005.[15]

Solar Electricity

Solar energy technology is used on both small and large scales to produce electricity.

A unique advantage of small-scale solar energy systems is that, if they include storage devices, they may eliminate the need to connect to the electric grid. PV systems power road maintenance and railroad warning signs, flashing school zone lights, area lighting and other devices without expensive power lines or batteries. Offshore oil rigs, navigational aids, water pumps, telecommunication equipment, remote weather stations and data logging equipment also benefit from PV power.[16]

In 2005, small-scale, off-grid PV-powered devices accounted for about 15 percent of PV capacity installed worldwide.[17] In the same year, most installed PV systems — 59 percent — provided electricity to homes and buildings connected to the electrical grid.[18] The remaining PV systems were installed for use in remote off-grid homes and buildings in industrialized countries and the developing world.

On a larger scale, solar technology can produce commercially significant amounts of electrical power. Utility-scale concentrating solar power (CSP) systems, for instance, typically offer capacities of from 50 to 200 megawatts (MW), and could produce enough electricity to power approximately 7,800 to 31,000 homes in Texas, based on average electric use in 2006, when the sun is shining.[19]

SOLAR ENERGY IN TEXAS

In June 2007, the University of Texas at Austin's IC^2 Institute, an interdisciplinary research unit, released a study making a case for supporting the solar industry in Texas.[20] This study notes that Texas has excellent solar resources and should use its high technology infrastructure to build a solar industry that creates high-quality technology and manufacturing jobs. Currently, all of the solar energy generated in Texas accounts for a minute portion of the state's electricity production and comes from distributed PV solar systems on homes and businesses.

Economic Impact

In 2006, global solar industry revenues were $10.6 billion.[21] Texas specific data for solar industry revenues are not available. The IC^2 Institute expects the solar industry to create more jobs and contribute billions of dollars in investment and income to the U.S. economy over the next decade, if long-term incentives are offered to encourage the solar industry.[22] An IC^2 study noted that:

> …since high-tech manufacturing employment in Texas has yet to return to pre-recession levels, the PV manufacturing industry creates an opportunity to generate employment for semiconductor and electric component workers statewide whose jobs have been outsourced offshore.[23]

One study that evaluated the state-by-state impact of an expanding U.S. solar PV market found that California and Texas stand to gain a large share of all new solar PV jobs and investment created between 2004 and 2015.[24] The study assumed that the nation's solar PV capacity would grow from 340 MW in 2004 to 9,600 MW total PV capacity in 2015, with an investment value of $34 billion. According to this study, Texas should gain about 13 percent of all new U.S. solar PV jobs and investment, primarily in manufacturing. This translates into approximately 5,567 new jobs — 93 percent in manufacturing and 7 percent in construction/installation — and represents about $4.5 billion of investment in Texas by 2015.[25]

The Solar Energy Industries Association (SEIA) estimates that "every megawatt of solar power currently supports 32 jobs, with 8 of these jobs in system design, distribution, installation and service created where the systems are installed."[26] The Prometheus Institute, a data source on solar energy initiatives, projects that solar energy will create 22,000 American jobs in manufacturing, distribution and various building trades over the next decade.[27]

Austin Energy, a municipal utility, commissioned a study of the economic benefits of solar energy manufacturing and installation in 2006. This study concluded that construction of a 100 MW solar manufacturing plant in the Austin area could create nearly 300 new jobs and add about $1 billion to the regional economy by 2020.[28] In addition, the city of Austin and Travis County would benefit from an increase in sales tax and property tax revenue.

Texas technology companies have demonstrated an interest in the solar industry. In Austin, HelioVolt has developed a low-cost manufacturing process for applying a thin-film PV coating to building materials.[29] On April 15, 2008, Governor Rick Perry announced that HelioVolt would receive $1 million from the state's Texas Enterprise Fund (TEF) for the construction of a development and manufacturing facility. According to the Governor's office, the project is expected to create about 160 jobs and $62 million in capital investment.

Entech, located in Keller, Texas, provides advanced solar energy technology including high-efficiency solar cells for NASA spacecraft.[30] The company also has invented a new lighting system to illuminate office buildings, schools and stores. In addition, Applied Materials, which has a semiconductor manufacturing plant in Austin, recently acquired a company called Applied Films in order to enter the PV business. Applied Materials plans to use its chip-industry knowledge to drive down manufacturing costs for solar panels.[31]

The IC^2 Institute notes that the solar industry could produce substantial savings for Texas energy consumers in the form of "avoided generation capacity capital costs, avoided fuel costs, avoided CO_2 emissions, the value of fossil fuel price hedging and avoided distribution costs."[32] In California, IC^2 estimated that these savings ranged from eight to 22 cents per kWh in 2005.[33] IC^2 says that further research is needed to estimate similar savings for Texas consumers.

Solar energy also can reduce price volatility related to fluctuating natural gas prices. As utilities begin to charge higher rates for peak load periods, PV systems that generate the most electricity during the hottest time of the day can produce substantial savings on energy costs. Utility companies

In 2006, global solar industry revenues were $10.6 billion.

would benefit because additional peak load power reduces the strain on their systems and the need for additional power plants.

Production

Sunlight can be converted into heat and electricity in a number of ways. A variety of solar technologies are in production, and many companies and researchers are pursuing efforts to develop devices that convert the sun's energy more efficiently.

Photovoltaic Energy

Photovoltaic cells (PV) are used worldwide to convert sunlight into electricity. The PV cell contains two layers of semiconducting material, one with a positive charge and the other with a negative charge (**Exhibit 10-1**). When sunlight strikes the cell, some photons are absorbed by semiconductor atoms, freeing electrons that travel from the negative layer of the cell back to the positive layer, in the process creating a voltage. The flow of electrons through an external circuit produces electricity.[34]

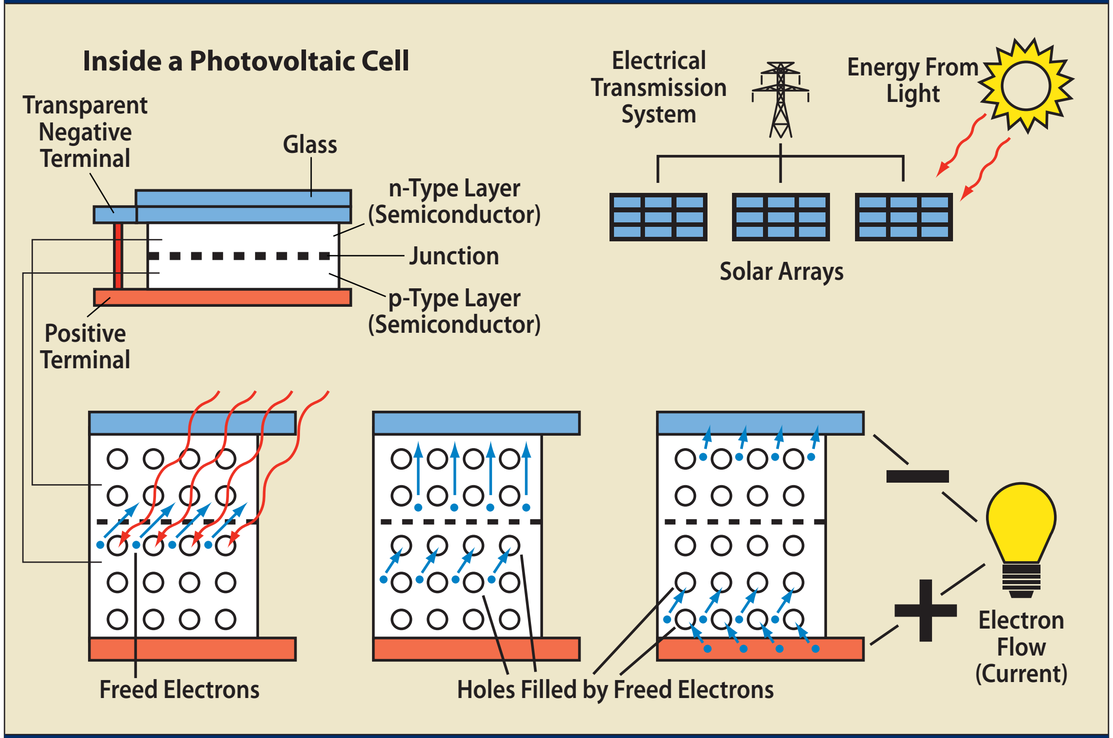
Since individual photovoltaic cells produce little power and voltage — they generate only about one to two watts per cell—they are connected together electrically in series in a weatherproof *module*. To generate even more power and voltage, modules can be connected to one another to form a *solar panel*; solar panels are grouped to form an *array*. The ability to add additional modules as needed is a significant advantage of PV systems.

Several PV technologies are in use or in development. The silicon-based PV cell, made with the same silicon used in the semiconductor industry, has dominated the market and continues to do so. Solar Energy Industries Association (SEIA) reports that 94 percent of PV modules used today are made of crystalline silicon.[35]

Sunlight can be converted into heat and electricity in a number of ways.

Exhibit 10-1

The Photovoltaic Cell



Source: U.S. Department of Energy.

The search for cheaper solar energy systems, however, has spurred the development of thin-film PV cells that have semiconductor layers only a few millionths of a meter thick. Thin-film PV technologies are intended to reduce the amount of expensive materials needed to produce solar cells. For example, new methods are being used to produce solar cells that reduce or eliminate the use of high-priced silicon. The U.S. Department of Energy (DOE) estimates that U.S. production of thin-film solar modules will exceed that of crystalline silicon modules by 2010.[36] While thin-film efficiencies are lower than silicon's, the lower cost may tip the balance in thin film's favor.[37]

Research scientists also are working on a new generation of solar cells that include nanomaterials, multijunction cells and various other research efforts that may produce "leapfrog" technologies, offering considerably higher efficiency at a lower cost.[38]

Nanotechnology, for instance, has attributes that, in theory, may triple the amount of energy produced by photons of sunlight. This technology also could result in PV cells that could be painted on homes and buildings.[39] Research on inverted multijunction cells that capture more of the sun's energy also is ongoing, and already has produced a world-record 39.3 percent conversion efficiency.[40] These emerging technologies have the potential to produce higher efficiencies more cost-effectively.

Some companies are developing faster and more efficient ways to manufacture thin-film solar cells at lower costs. HelioVolt, an Austin-based company, has developed FASST, which it claims is a low-cost manufacturing process for applying copper indium gallium selenide, a thin-film PV coating, to construction materials such as roofing, steel and flexible composites in 80 to 98 percent less time than conventional processes. This would position the company to bring economical building products featuring integrated PV cells to the market. HelioVolt is seeking partners and plans to have some products available by 2008.[41]

The U.S. Army also is interested in lightweight solar panels, since it wants to reduce the need for generators and personal battery packs that soldiers use to power fans, light, radios and laptops.[42] In Texas, the Army's Fort Bliss, in cooperation with the U.S. Naval Postgraduate School and Army Corps of Engineers, is the site for a "Power The Army" project that will conduct large-scale field trials of three new solar energy technologies. The army and others hope that the project will improve solar system efficiencies and lead to lower solar energy costs.[43]

Solar Thermal Energy

Solar thermal energy refers to technologies that use the sun's energy to heat water and other heat-transfer fluids for a variety of residential, industrial and utility applications. Simple and widely used applications of solar thermal energy include solar water heating, swimming pool heating and agricultural drying. In the U.S., solar pool, water and space heating are currently the major applications of thermal energy.

Flat-plate collectors — large, insulated metal boxes with glass or plastic covers and dark heat-absorbing plates — are the most common collectors used for home solar water and space heating (**Exhibit 10-2**).[44] Other common varieties are evacuated-tube collectors and integral collector-storage systems. All three types gather the sun's energy, transform it to heat and then transfer that heat to water, a heat-transfer fluid or air. Flat-plate collectors typically are mounted on the roof. Evacuated-tube collectors are sometimes used to heat water, but also have useful commercial and industrial applications where higher temperatures are required.

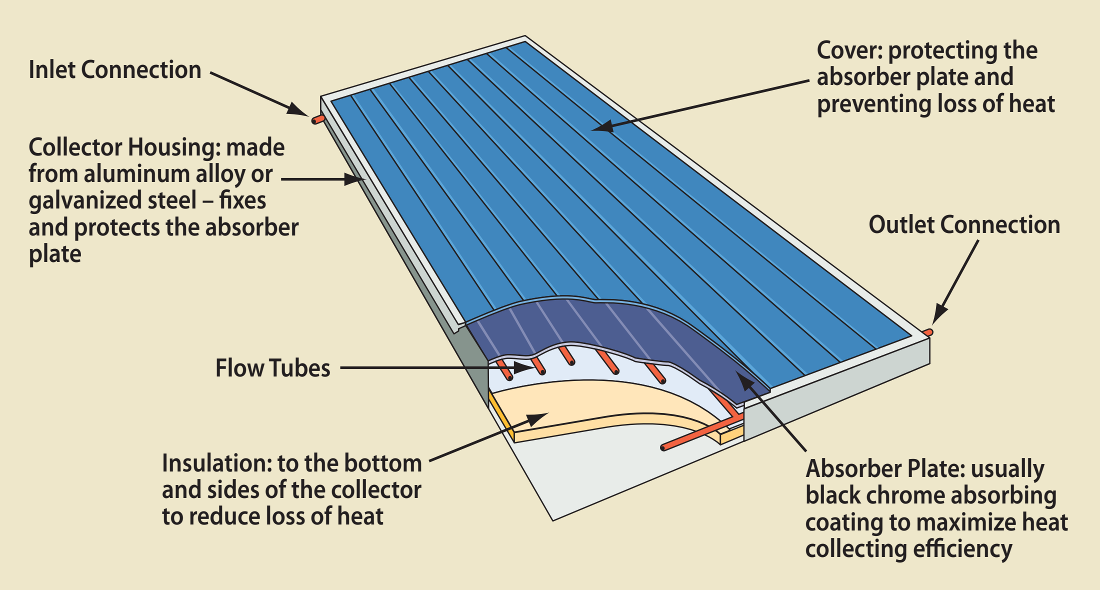
Solar thermal energy refers to technologies that use the sun's energy to heat water and other heat-transfer fluids for a variety of residential, industrial and utility applications.

The most powerful large-scale solar thermal technology, however, is *concentrating solar power* (CSP). While CSP can be PV-based, it generally refers to three solar thermal systems—parabolic troughs, solar dish/engines and power towers—each of which is in use or under development today. These systems use mirrors or reflectors to focus sunlight to heat a fluid and make steam, which then is used to generate electricity.

At present, only *parabolic trough* CSP systems are in commercial use in the U.S., with three installations in three states capable of generating 419 MW of electricity in all.[45] Trough systems consist of a linear, parabolic-shaped reflector that focuses the sun's energy on a receiver pipe, heating a transfer fluid flowing through the pipe; the transfer fluid then generates superheated steam which is

Exhibit 10-2

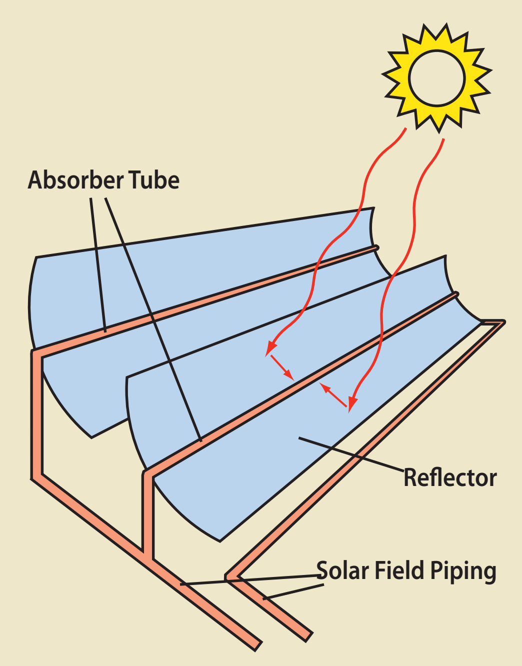
Flat Plate Collector



Source: Green Spec.

Exhibit 10-3

A Parabolic Trough System



Source: Hong Kong Engineer Online.

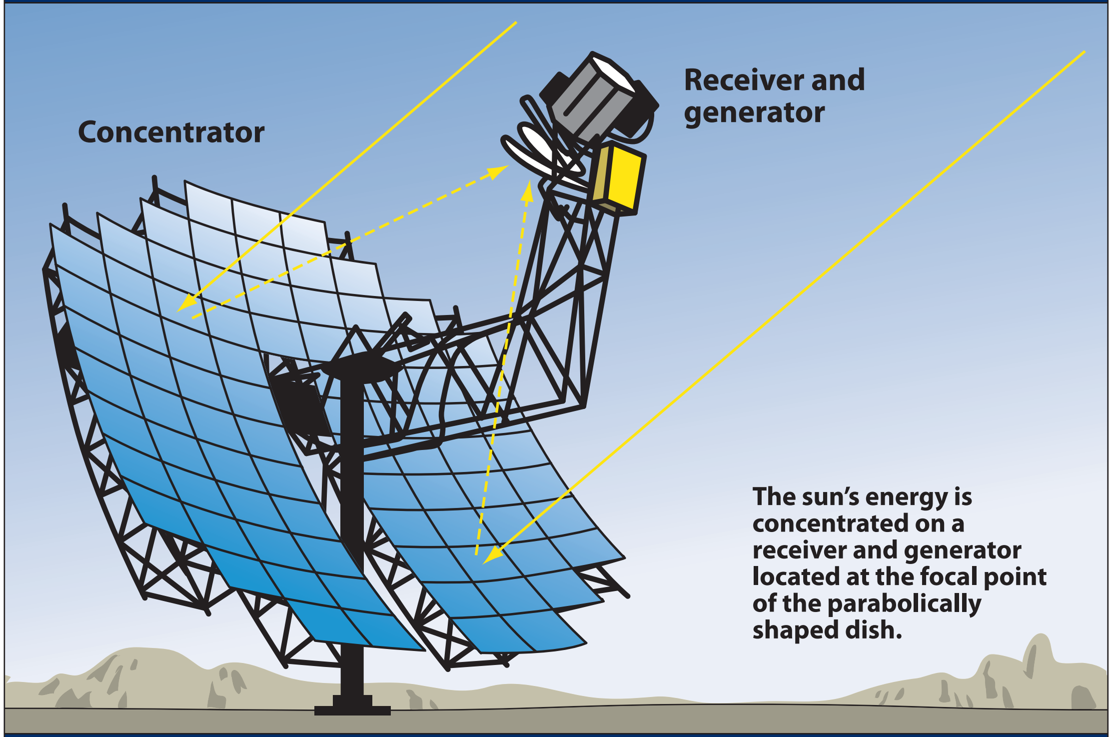
fed to a turbine and electric generator to produce electricity. The troughs track the sun from East to West during the day so that the sun is continuously focused on the receiver pipes (**Exhibit 10-3**).

A *solar dish/engine* system consists of a solar concentrator — glass mirrors in the shape of a dish that reflect sunlight onto a small area — and a power conversion unit that includes a thermal receiver and a generator (**Exhibit 10-4**). The thermal receiver includes tubes for the transfer fluid — usually hydrogen or helium — that transfers heat to a generator to produce electricity. In 2006, Stirling Energy Systems, a Phoenix-based provider of such systems, signed agreements to build two large plants employing the technology in Southern California.[46] This would be the first commercial installation of a solar dish/engine system in the U.S.

Solar *power towers* use a large field of sun-tracking mirrors called heliostats to concentrate sunlight on a receiver located on the top of a tower. The receiver heats a heat transfer fluid such as molten nitrate salt that is then used to generate steam to power a turbine-generator to produce electricity

Exhibit 10-4

Solar Dish/Engine System



Sources: Florida A&M University and Florida State University.

(**Exhibit 10-5**). The molten salt reaches about 1,050 degrees Fahrenheit in the receiver before being stored in a tank where it can retain its heat for several hours.

In the U.S., two large-scale power tower demonstration plants — Solar One and Solar Two located in the Mojave Desert near Barstow, California — have generated 10 MW of electricity each. Solar One operated off and on from 1982 to 1988 and used water as its heat transfer fluid, while Solar Two used molten nitrate salt for heat transfer, operating periodically from 1996 to 1999.[47]

Europe's first commercial solar power tower went online in Spain in late 2006 and currently generates 11 MW of electricity, enough to power just under 6,000 homes.[48] More fields of mirrors are being added to this plant. Solucar, its developer and operator, plans two more power towers at other locations in Spain.[49]

Transmission

Solar energy differs from most energy technologies in that it can be generated on site, reducing or eliminating fuel transportation and electricity transmission and distribution costs. Solar water heating and space heating devices are "stand-alone" systems that are not connected to the electric grid. A PV system provides electric power directly to a user and can be used either as a "stand-alone" power source or connected to the electricity grid (**Exhibit 10-6**).

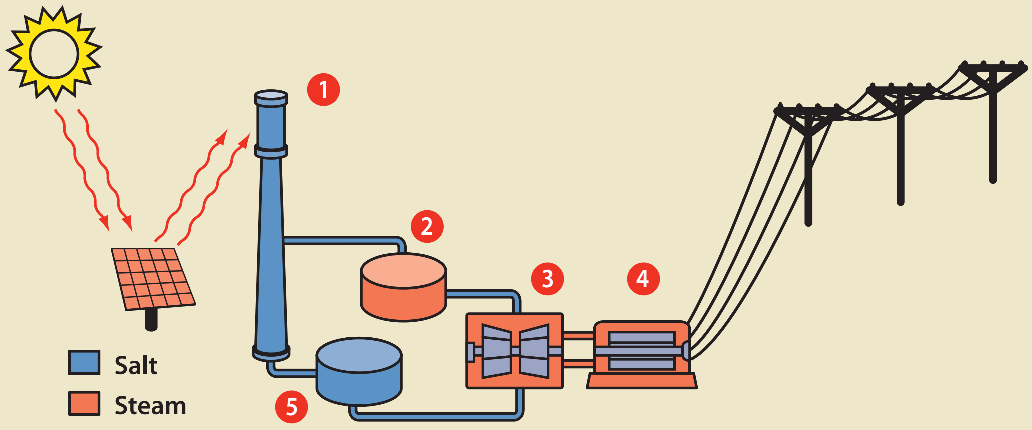
Systems offering this flexibility sometimes are called *distributed* power generators. By contrast, utility-scale concentrating solar power plants use *centralized* power plants and transmission lines to distribute electricity to customers.

In 2005, off-grid PV systems accounted for about 18 percent of all PV installed worldwide.[50] Homes in remote areas can use PV systems for lighting,

Solar energy differs from most energy technologies in that it can be generated on site, reducing or eliminating fuel transportation and electricity transmission and distribution costs.

EXHIBIT 10-5

Solar Power Towers



Schematic of electricity generation using molten-salt storage:

1. **sun heats salt in receiver;**
2. **salt stored in hot storage tank;**
3. **hot salt pumped through steam generator;**
4. **steam drives turbine/generator to produce electricity;**
5. **salt returns to cold storage tank**

Sources: Florida A&M University and Florida State University.

A home or business with a PV system that is connected to the electric grid has the option of supplementing its energy needs with electricity from the local utility company and delivering excess electricity to the grid.

home appliances and other electrical needs, saving the cost of extending power lines to a remote location. These systems require a storage device to store power generated during the day for nighttime use; typically, this is a lead-acid battery bank. Unlike gasoline-powered generators, PV systems do not require fuel deliveries and are clean and quiet to operate.

Distributed, Grid-Tied PV

At night and even on cloudy days, a PV system is not likely to produce enough energy to power a home's needs, while on sunny days it may produce more electricity than needed. A home or business with a PV system that is connected to the electric grid has the option of supplementing its energy needs with electricity from the local utility company and delivering excess electricity to the grid. Grid-tied PV systems thus can reduce strains on the power grid.

Net Metering

Net metering standards allow owners of qualifying solar energy systems to be compensated for the value of electric energy they produce; they have been proven to promote solar energy systems. The IC^2 Institute report that examined opportunities for the development of the Texas PV industry recommended the adoption of retail net metering in the state.[51] Retail net metering credits customers at the utility's full retail rate for each kWh generated rather than at the utility's avoided-cost rate, which is lower (see Chapter 9 of this report for further discussion of net metering).

The grid-connected PV market continues to grow more rapidly than off-grid PV and accounted for about 59 percent of the world PV market in 2005.[52] Between 1995 and 2005, the grid-connected PV market rose by more than 50 percent annually, compared to 29 percent for all solar applications.[53] In the U.S., cumulative installations of grid-tied PV systems surpassed those of off-grid systems in 2005. The Prometheus Institute expects that grid-tied PV systems for homes and businesses in the U.S. will become even more popular in the coming years.[54]

Exhibit 10-6

Types of Photovoltaic Energy Systems

System	Energy Source	Connected to the electricity grid?	Energy storage device in the system?	Examples
Grid-tied* solar system	PV cells	Yes	No	Home system that draws on the electricity grid at night and exports excess power in the day
Stand-alone grid-tied* solar system	PV cells	Yes	Yes (batteries)	Home or business system uninterruptible power (e.g. for computers, servers). Still operates when the grid is down
Stand-alone solar system without energy storage	PV cells	No	No	Water pumping
Stand-alone solar system with energy storage	PV cells	No	Yes (batteries)	Remote homes, lighting, TV, radio, telemetry
Stand-alone off-grid hybrid solar system	PV cells in combination with another energy source (e.g. diesel, wind)	Most often not	No	Remote large-scale communications, industrial uses

* also called "grid-connected."
Source: Solarbuzz.

California accounts for the majority of the U.S. PV market, with a cumulative grid-tied PV capacity of more than 198 MW at the end of 2006 (**Exhibit 10-7**).[55] The second-largest market is New Jersey, with more than 35 MW of grid-tied PV installed capacity.[56] Both California and New Jersey have generous PV incentives that have spurred growth in installations. Texas ranked fifth in grid-tied capacity in 2006, with more than 1.7 MW.[57]

Exhibit 10-7

Grid-tied PV Installed Capacity: Leading States*

State	Capacity Megawatts (MW)
California	198.0 ***
New Jersey	35.5 **
Colorado	4.0***
New York	2.3 **
Arizona	1.7**
Texas	1.7**
Massachusetts	0.5 ***
Nevada	0.5 ***
Oregon	0.3 ***
Connecticut	0.3 ***

*Estimates
**Data from mid-year 2007, does not include all installations.
***California data are through end of 2006. Other data are projected from actual mid-year 2006 capacity.
Source: Texas Comptroller of Public Accounts and Prometheus Institute.

Central Power Generation

Utility-scale concentrating solar power plants usually are connected to the electric grid and often require the construction of new transmission lines. This is because they are generally located in remote areas with high rates of solar radiation, far away from urban centers, rather like wind farms. And, like wind farms, CSP systems can produce significant amounts of electricity.

A 2007 DOE study identified seven southwestern states — California, Arizona, New Mexico, Nevada, Utah, Colorado and Texas — as good candidates for CSP. These states have the combined solar capacity needed to generate up to *16 billion* MWh of electricity.[58] Arizona, New Mexico, California and Nevada account for 87 percent of this potential capacity. West Texas has enough potential solar capacity to generate up to 351 million MWh of electricity.

CSP can supply peak power during summer months, when wind and hydro energy can be scarce.[59] Energy costs for CSP plants are fixed and are not subject to fuel price swings. In addition, CSP plants generate electricity without emitting carbon dioxide and other greenhouse gases.

CSP plants occupy large tracts of land in areas that, as noted above, usually are far away from urban areas, entailing increased transmission costs. A CSP plant needs about five to 10 acres of land to produce 1 megawatt of installed capacity.[60] The recently completed Nevada Solar One CSP plant near Las Vegas can generate 64 MW of electricity and has a collector field that covers 400 acres, which translates into about 6.25 acres of land to produce 1 megawatt (**Exhibit 10-8**).

In the U.S., the largest and longest-operating CSP systems are the Solar Energy Generating Systems (SEGS) parabolic trough plants located in California's Mojave Desert. These plants, built between 1985 and 1991 and covering about 1,000 acres, continue to perform well and can generate a combined total of 354 MW.[61] In 2006, the SEGS plants accounted for more than half of all grid-connected solar power generated in the U.S.[62] The plants generate electricity during the daytime and shut down at night.[63] Located about 155 miles northeast of Los Angeles, the SEGS plants generate enough electricity to power over 100,000 homes.[64]

Technological advances have renewed interest in CSP plants in the U.S. and Europe. In 2006, the Arizona Public Service utility completed a 1 MW CSP power plant, the first parabolic power plant built in the U.S. in 20 years.[65] In June

CSP can supply peak power during summer months, when wind and hydro energy can be scarce.

Exhibit 10-8

Nevada Solar One, CSP Plant

Source: HotWatt Solar.

2007, another parabolic trough power plant went online in Boulder City, Nevada, near Las Vegas, with a generation capacity of 64 MW — enough electricity to power about 15,000 homes.[66] This plant will minimize transmission costs because it was built adjacent to an existing gas power plant and transmission lines.[67] Several other U.S. CSP plant construction projects have been announced (**Exhibit 10-9**).

In Texas, Austin Energy has solicited proposals for CSP power from sites in West Texas, but has not made a final decision on how or whether to proceed.[68] CSP plants must be located in areas with high solar radiation readings, and in Texas such places are particularly common in the western part of the state, much of which lacks an extensive transmission infrastructure.

Extending transmission lines to such areas is expensive. The Electric Reliability Council of Texas (ERCOT) estimates that building transmission lines to transport wind generated electricity from West and Northwest Texas to urban areas will cost about $1.5 million per mile; CSP projects in the same areas would require similar expenditures.[69] Some large landowners, furthermore, may object to Texas utility companies acquiring property and easements as needed through the use of eminent domain.

Availability

Solar energy is available everywhere on Earth, in varying amounts. Solar radiation that reaches the earth's surface in an unbroken line is called *direct*, while sunlight scattered by clouds, dust, humidity and pollution is called *diffused*. The sum of the direct and diffuse sunlight is called *global-horizontal insolation*. Concentrating solar technologies, which use mirrors and lenses to concentrate sunlight, rely on direct radiation, while PV cells and other solar technologies can function with diffused radiation.

Insolation is a term referring to the amount of solar radiation that strikes the planet's surface over some period — a minute, hour, day, month or year. NREL has developed insolation estimates for the U.S. based on solar measurements taken at a number of stations throughout the country, as well as computer modeling that uses meteorological data to predict insolation at a large number of sites.

According to NREL's measurements, the nation's most plentiful solar resources are found in the Southwest. California, Nevada, Arizona, New Mexico, Utah, Colorado and Texas, and they possess some of the best insolation values in the world. According to DOE, "enough electric power for the entire country could be generated by covering about nine percent of Nevada — a plot of land 100 miles on a side — with parabolic trough systems."[70]

In all, the U.S. has a relatively abundant supply of solar resources. A 1 kW solar electric system in the U.S. can generate an average of more than 1,600 kWh per year, while the same system in

Exhibit 10-9

U.S. Completed and Planned CSP Plant Construction

Utility/State	Capacity (MW)	Developer Name/ Complete Dates
Arizona Public Service	1	Solargenix-Acciona/2006
Florida Power & Light SEGS, California	24	Solel/2007
Nevada Power & Light	64	Solargenix-Acciona/2007
Southern California Edison	500	SES/2012
Southern California Edison	350	SES/2014
San Diego Gas & Electric	300	SES/2012
San Diego Gas & Electric	600	SES/2014
Pacific Gas & Electric	500	Luz II/unknown
Total 2006 US CSP Contract Potential	2,339	

Source: Prometheus Institute.

southern Germany (which installs eight times as many PV systems as the U.S.) would be able to generate only about 1,200 kWh per year, due to that nation's weaker insolation. A 1 kW system installed in parts of Nevada, Arizona, New Mexico and far West Texas can produce 2,100 kWh per year. [71]

Texas has abundant solar radiation statewide, but again, the highest insolation readings are in West Texas. West Texas has 75 percent more direct solar radiation than East Texas, making it an ideal location for utility-scale CSP technologies.[72] Virtually all of Texas, however, has adequate to very good solar radiation.[73]

A study commissioned by the State Energy Conservation Office (SECO) in the mid-1990s found that Texas has 250 "quads" of solar energy accessible per year. Given that one quad is *one quadrillion* British thermal units (Btus) of energy — enough to meet the annual needs of about 3 million people — Texas' solar energy potential is enormous.[74] The 2007 Texas Legislature directed SECO to update a 1995 assessment of Texas renewable energy resources. This report, which will be released before the start of the 2009 Texas Legislative Session, will include up-to-date data on the availability of various renewable energy resources.

Virtually all of Texas has adequate to very good solar radiation.

While the U.S. possesses some of the world's best solar radiation values, it accounted for only 8 percent of worldwide PV installations in 2006. Germany was the undisputed leader in that year, accounting for 55 percent of the world market (**Exhibit 10-10**). Japan came in second place, with 17 percent of the PV world market. Spain's PV installations rose by more than 200 percent in 2006, while the U.S. market expanded by 33 percent.[75]

The U.S. was once a leader in the PV market, but over the last decade it has lost ground to Japan and Germany. Both governments offer generous subsidies to stimulate their solar energy markets. The U.S. has not offered similar subsidies at the federal level, and has not established a long-term, consistent strategy in its approach to solar energy at either the state or federal levels, creating periodic uncertainty in the market.

COSTS AND BENEFITS

Both thermal and PV solar systems can produce electricity at significantly lower costs today than in the 1980s, but costs remain high compared to fossil fuel energy sources.

In the U.S., 2006 retail electricity prices for all sectors averaged more than eight cents per kWh, and for residential electricity, the price averaged about 10 cents per kWh.[76] By contrast, parabolic trough-style CSP systems generated electricity at a cost of 12 cents per kWh in 2006, while PV systems generated electricity for about 18 to 23 cents per kWh.[77]

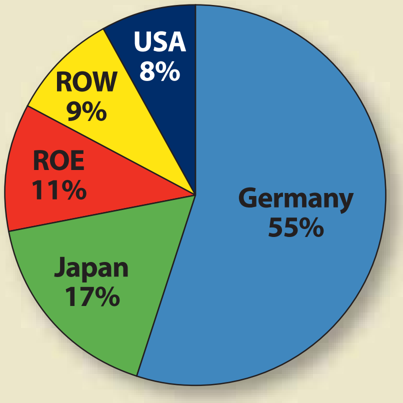
The retail price of electricity during peak hours, however, can rise to between 25 and 40 cents per kWh in some parts of the U.S., making PV systems more competitive during peak periods.[78] PV systems usually generate more electricity during the hottest time of the day, and thus can help to offset the need to add expensive electric generating capacity to satisfy peak demand in warm areas of the country.

PV costs per kWh declined significantly over the last 16 years (from more than 45 cents per kWh in 1990 to about 23 cents per kWh in 2006), due primarily to manufacturing economies of scale as well as improved solar cell efficiency.[79] The Solar

EXHIBIT 10-10

2006 PV Installations By Market

TOTAL: 1,744 MW



(Note: ROW=rest of world; ROE=rest of Europe)

Source: Solarbuzz 2007.

Energy Industries Association (SEIA) notes that "each doubling in cumulative manufacturing has brought prices down by about 18 percent."[80]

In the past five years alone, the world PV industry has grown by an average of 30 percent or more each year. In 2006, the U.S. PV industry expanded by 33 percent, compared to 19 percent for the world.[81] The expansion of federal income tax credits for commercial and residential solar energy projects, and state and utility incentives, particularly in California, fueled the U.S. industry's impressive growth in 2006. These federal tax credits, however, are set to expire at the end of 2008, and were not extended by Congress in 2007.

A shortage of silicon and growing global demand for solar PV modules led to some cost increases in 2006 and 2007.[82] About 90 percent of PV modules today still are made of crystalline silicon (polysilicon), which has been in short supply globally, constraining production and temporarily increasing the cost of solar cells.[83]

Polysilicon supplies are expected to remain tight and prices high until new plants under construction are completed.[84] Solarbuzz, an international solar energy consulting firm, predicts rapid growth in polysilicon capacity through 2011, and a resumption of faster rates of growth for the PV market.[85] Unprecedented investment in manufacturing capacity is expected to result in lower PV costs over the long term.

The cost of solar modules accounts for 50 to 60 percent of the total installed cost of a PV system, with other system parts, materials, assembly and installation accounting for the remainder.[86] PV module costs have declined by about 80 percent over the last decade, but the installation costs have not dropped appreciably in recent years.[87] Installation costs vary depending on available sunlight, the typical energy usage of the home and the availability of experienced installers in the area. Unlike other energy sources, however, 90 percent of the cost of a PV system is incurred up front.[88] Once the system is installed, there are no fuel costs and the system requires little maintenance.

A PV system designed to supply about 60 percent of the energy needs of a home in California costs about $16,000 to $22,000, minus any tax credit or rebate. In San Diego, California, the federal income tax credit (see below) and a California Solar Initiative (CSI) rebate have reduced the total installed cost of a $17,460 residential PV system by $7,000, for a final cost of $10,460.[89] Solarbuzz notes that government incentive programs can lower solar PV system costs to about 10 to 12 cents per kWh, compared to a range of 22 to 40 cents per kWh without incentives.[90]

The PV industry's overarching goal is to improve solar cell efficiency while reducing their cost. Government research labs and private companies have invested in research and development in the expectation of a breakthrough that will make solar energy competitive with other sources of energy.

Solar cell efficiencies have improved significantly since the 1950s, when they had efficiencies of less than 4 percent.[91] Today, solar cell efficiencies range from 15 to more than 30 percent, but most commercial PV systems are about 15 percent efficient.[92] In December 2006, Boeing-Spectrolab Inc., manufacturer of space solar cells and panels, announced that, with DOE funding, it had developed a solar cell with a conversion efficiency of 40.7 percent.[93] This "multi-junction" solar cell uses a new class of semiconducting materials that allows it to capture energy from more of the solar spectrum. This breakthrough may lead to less expensive, more efficient solar cells.

DOE expects significant PV and CSP cost reductions in the next five to 10 years, making these solar technologies more competitive with conventional fuel sources (**Exhibit 10-11**). Improved PV technologies that use cheaper materials, higher-efficiency devices, new nanomaterials applications and advanced manufacturing techniques should reduce the cost of PV-generated electricity to as little as 11 cents per kWh by 2010.[94] DOE also expects CSP-generated electricity prices to decline to 8.5 cents per kWh by 2010. Texas' average residential retail price for electricity was more than 12 cents per kWh in 2006 and 2007.[95]

In addition to cost, however, solar electricity faces other barriers to widespread market deployment. As a new entrant to the power supply market, PV developers face uncertain and inconsistent treatment, both in Texas and nationally, at the hands of regulators and electric utility companies.

In the past five years alone, the world PV industry has grown by an average of 30 percent or more each year.

Exhibit 10-11

Price Trends for Solar Power Through 2015 Photovoltaics and Concentrating Solar Power (CSP)

2006 Status in the United States:

PV	CSP
18 to 23 cents per kWh	12 cents per kWh

Potential for PV and CSP Pricing:

PV	CSP
11 to 18 cents per kWh by 2010	8.5 cents per kWh by 2010
5 to 10 cents per kWh by 2015	6 cents per kWh by 2015

Source: U.S. Department of Energy.

Processes and rules for interconnection and net metering are not consistent throughout Texas, so development of a statewide marketplace for these technologies has proven difficult. Solar industry professionals want clear, consistent market rules to encourage the development of a single market and the jobs and economic benefits that arise from it.[96]

A federally funded study at the University of Massachusetts-Amherst found that experts in solar technology agree that subsidies alone are not enough to support a healthy solar industry; more investment is needed from the manufacturing sector.[97] Recently, the number of private equity firms and venture capitalists investing in the solar energy sector has grown rapidly, as has the number of companies working on various solar technologies.[98]

Recently, the number of private equity firms and venture capitalists investing in the solar energy sector has grown rapidly.

A 2007 report by the IC^2 Institute indicated that California leads the nation in U.S. federal research awards, patents, scientific publications and business establishments related to PV solar energy (**Exhibit 10-12**).[99] Texas ranked fourth among states in its number of federal research awards related to PV — 18 to California's 62 — with half going to industry and half to educational institutions. Texas accounted for 3 percent of the U.S. scientific literature on photovoltaics, behind California, Colorado, Ohio, New York and Massachusetts. In its number of PV-related patents, Texas ranked fourth, again behind California. And Texas ranked fifth in the number of PV businesses located in the state.[100]

The IC^2 study concluded that:

> Texas does have some significant PV technologies and intellectual capital, but the current university, research organization, business and state resources are not sufficient to develop a comprehensive, cohesive and synergistic strategy to achieve sustained success in the global marketplace.[101]

Environmental Impact

Solar energy technologies generate electricity without producing air or water pollution. Solar thermal energy technologies may require cooling water, but most of this water can be recycled. Only small amounts of hazardous materials are produced in the manufacture of photovoltaic cells and CSP equipment and essentially none in other solar thermal applications.

Most PV systems are installed on existing structures such as homes and commercial buildings and require no additional land. CSP plants require large tracts of land, depending on the technology used and the size of the project. For example, a 100 MW CSP plant requires between 500 to 1,000 acres depending on whether thermal energy storage is included. NREL estimates that a CSP plant typically needs about five to 10 acres of land to produce 1 megawatt of installed capacity.[102]

In the US, the largest CSP project covers roughly 1,000 acres in the Mojave Desert and can generate 354 MW, while the recently completed Nevada Solar One CSP plant near Las Vegas covers 400 acres and can generate 64 MW of electricity. California's 354 MW solar plants generate enough electricity to power about 100,000 homes and the Las Vegas 64 MW solar plant produces enough power for about 15,000 homes annually.[103]

According to the U.S. Environmental Protection Agency (EPA), CSP plants do not damage the land, but merely take it out of use for other applications such as agriculture. Wildlife habitat may be displaced from land used for such systems, however.[104]

Solar electricity can reduce carbon emissions by offsetting the need for carbon-producing fuels. For example, Applied Materials has installed solar panels at its manufacturing plant in Austin that will generate about 33.7 MWh annually and

Exhibit 10-12

Productivity in Photovoltaics

State	Number of Federal Research Awards*	Percent of U.S. Total	Number of Scientific Publications**	Percent of U.S. Total	Number of Photovoltaic Patents**	Number of PV Businesses
California	62	15%	261	20%	289	310
Colorado	44	11%	255	19%	63	85
Massachusetts	35	8%	101	8%	73	34
Texas	18	4%	44	3%	68	65
Florida	17	4%	52	4%	30	94
Ohio	15	4%	125	10%	55	14
New York	14	3%	113	9%	83	76
Michigan	13	3%	40	3%	59	29
New Mexico	13	3%	53	4%	27	31
Pennsylvania	13	3%	53	4%	55	22
Virginia	13	3%	41	3%	13	19
Percent of U.S. Total		62%		87%		

*1993-2005
**1991-2005
Source: IC² Institute, The University of Texas at Austin.

eliminate about 54,000 pounds of carbon emissions each year.[105]

EPA reports that PV systems do not generate solid waste in creating electricity. Their manufacture generates small amounts of hazardous materials such as arsenic and cadmium, which must be disposed of properly to avoid harm to the environment and humans. Similarly, CSP plants do not produce solid waste when generating electricity, but the construction and production of plant equipment does produce small amounts of hazardous waste.[106]

State and Federal Oversight

The federal and state regulations that apply to the solar industry are those that apply to other manufacturing facilities as well, such as health and safety and environmental regulations. Solar PV systems also must meet existing electric regulations.

Subsidies and Taxes

The solar energy industry, and in particular the photovoltaics industry, has grown in direct response to federal, state and local tax policies and subsidies.

At the federal level, an important subsidy is a 30 percent federal income tax credit for solar energy equipment offered during 2006 and 2007; this was the first residential tax credit for solar energy established in 20 years. (A tax credit is a dollar-for-dollar reduction of an individual's or business' tax liability.) The tax credit applies to business investments in equipment that uses solar energy to generate electricity, or in solar heating or cooling systems. Homeowners qualify for a residential tax credit up to a maximum of $2,000.

The 30 percent credit originally was set to expire at the end of 2007, but Congress subsequently extended it for another year, through December 31, 2008. The tax credit reverts to 10 percent after that date. Industry analysts say that the federal income tax credit for solar energy has expanded markets for solar products, but note that the limited time

Texas provides businesses with both a franchise tax deduction and a franchise tax exemption for solar energy devices.

period for the credit creates uncertainty in solar industry markets.[107]

State and local initiatives — tax policies, rebate programs, standardized interconnection and net metering rules and renewable portfolio standards — also have encouraged the solar industry's growth in some locations. In Texas, the state provides businesses with both a franchise tax deduction and a franchise tax exemption for solar energy devices. In addition, Texas has a property tax exemption for the appraised value of a solar or wind-powered energy device for on-site energy production and distribution. Thus far, however, these state policies have not resulted in significant growth in Texas' solar market.

Texas' Renewable Portfolio Standard, or RPS (see Chapter 9) has promoted the growth of renewable energy in Texas, but while it has created a market for wind, it has not proven to be an effective driver for the solar market, where higher costs (relative to wind and biomass) outweigh the higher revenues afforded by the ability to create and sell renewable energy credits (RECs).[108] No solar projects have yet been developed in Texas with the primary intent of creating and selling energy and RECs into the Texas energy and RPS compliance markets.[109]

Interconnection policies and practices are also inconsistent throughout the state. Texas has standardized interconnection policies and procedures developed by the Texas Public Utility Commission that apply to investor-owned utilities, but not to electric cooperatives or municipal utilities.[110] These procedures, moreover, are silent on some issues critical to distributed generators, such as definitions of what types of equipment (such as solar panels, wind turbines and inverters, which convert solar-generated electricity into household current) are eligible for interconnection.[111] Texas' net metering policies and practices are similarly inconsistent and depend upon the type of utility to which the distributed generator is interconnected.

Throughout the U.S. and within Texas, state- or utility-sponsored solar rebate or incentive programs have been the primary driver stimulating demand for solar energy.[112]

Austin Energy currently offers solar rebates ranging up to $4.50 per watt. The cost of installing a 1 kW (1,000 watt) solar system in Austin, for instance, ranges from $6,000 to $10,000, and the Austin Energy rebate pays up to $4,500 toward its purchase and installation.[113] San Antonio's CPS Energy, a municipal utility, offers rebates of $3 per watt for PV panels and installation, capped at $10,000 for residential customers and $50,000 for commercial and industrial customers.[114]

The IC² Institute study of the PV industry, however, concluded that "additional incentives are needed to spur non-wind renewables" in the state.[115]

OTHER STATES AND COUNTRIES

California was the third-largest world market for PV systems in 2006.[116] On August 21, 2006, California gave a huge boost to its solar energy industry when Governor Schwarzenegger signed the "Million Solar Roofs" bill, S.B. 1, directing the California Public Utilities Commission and California Energy Commission to implement the California Solar Initiative (CSI), which offers rebates starting at $2.50 per watt for PV systems up to one MW in size.[117] S.B. 1 took effect on January 1, 2007.

The Million Solar Roofs legislation authorized the state to invest $3.3 billion over 10 years toward the goal of creating 3,000 MW of solar-generated electricity in the state by 2017. It also required that homebuilders begin offering solar panels as a standard option; increased the cap on net metering; and required municipal utilities to create their own rebate programs. California state rebates are estimated to cover about a third of installation costs. In the City of Los Angeles, combined state, local federal and utility rebates can reduce the price of a $35,000 solar system to about $17,500, a 50 percent reduction.[118]

New Jersey, which ranked second in PV installations in 2006, has implemented several initiatives to promote solar energy, including specific targets for solar renewable energy in the state's RPS. To meet the RPS goals for solar, New Jersey has offered rebates for solar equipment ranging from $2.00 to $3.80 per watt, depending on the size of the PV system, as well as an exemption from the state sales tax for solar energy equipment.[119]

Due to the high number of applications for its solar system rebates, however, the New Jersey

Board of Public Utilities exceeded its budget and had to create a waiting list soon after the program was initiated. In 2007, the state made $47 million available for small (10 kW) residential and commercial installations, but these funds still are not enough to cover current demand.[120] New Jersey is moving its solar strategy away from rebates and toward performance-based incentives, limiting rebates only to small systems based on their estimated performance, and relying more on Solar Renewable Energy Certificates (SRECs) as the primary financial driver for large solar projects.

In New Jersey, an SREC is issued every time a solar electric system generates 1 MWh of electricity. Businesses and individuals can sell or trade them on New Jersey's on-line market for trading SRECs. Electricity suppliers/providers serving New Jersey's retail customers must use the SREC program to meet their solar RPS requirements. Recently, the price for an SREC has averaged about $200 per MWh generated.[121]

Arizona, Colorado and New York also offer substantial incentives for PV system installations.

Germany is currently the largest PV market in the world, with more than 960 MW of installed capacity.[122] By contrast, the U.S. had 526 MW of installed PV capacity in 2006.[123] In Germany, a "feed-in" tariff for solar electricity is the main driver for the PV market. This tariff requires utilities to buy every solar kWh offered by a utility customer at a fixed price for 20 years; utilities, moreover, must connect PV systems to the grid as they are acquired.[124]

Between 1999 and 2003, Germany's 100,000 Roofs Program, which provided low-interest loans for about 340 MW of installed capacity, also contributed to the dramatic growth of the PV industry. Annual installations of PV capacity in Germany rose from 12 MW in 1999 to 960 MW in 2006.

Japan, the second-largest world market for PV installations, accounted for 17 percent of the market in 2006.[125] Japan's 1995 Seventy Thousand Roofs Program provided a 50 percent subsidy for grid-tied PV systems, reducing the net electricity cost to a level competitive with conventional electric options.[126] In the process, this program expanded the PV market and improved the supply chain of manufacturers and installers. In 2006, Japan manufactured about 39 percent of all solar cells.[127]

The Japanese residential PV program expired in 2005, but the PV market is expected to continue growing because the cost of solar energy has become more competitive with retail electricity prices (Japan has some of the highest retail electricity prices in the world). For example, the cost of a typical PV system in Japan has declined from $16,000 per kilowatt in 1994 to about $6,000 per kilowatt in 2005.[128]

The Japanese are the current world leaders in PV manufacturing, creating 824.3 MW in 2005 and accounting for 45 percent of world market share. Europe is in second place, having manufactured 515.3 MW of PV cells in 2005, with 28 percent of the world market share. The U.S. is a distant third, having produced 154.8 MW in 2005 (a 9 percent world market share), barely ahead of China's 150.7 MW (8 percent market share).[129]

Germany is currently the largest PV market in the world.

OUTLOOK FOR TEXAS

Government subsidies and incentives have played a vital role in promoting the solar energy industry in the U.S. and throughout the world, and will continue to do so for the foreseeable future. Countries with the most favorable programs and research and development support have experienced the most innovation and most rapid growth in their solar energy industries.

In the U.S., the extension of the federal income tax credit spurred rapid growth in the solar energy market. Since the development of PV and CSP plants requires three to six years, industry advocates support the extension of the tax credit for a longer term.

While Texas has implemented some incentives to spur solar energy development — RPS, franchise tax incentives and some net metering guidelines — several other states have implemented far more generous programs. A recent Texas study also recommended the implementation of additional state-level incentives to spur non-wind renewables.[130]

In November 2006, the President's Council of Advisors on Science and Technology (PCAST) reported that, while the council:

> …do[es] not believe that solar power will provide the bulk of the Nation's electrical energy requirements in the next few decades, the level of entrepreneurial activity suggests that solar power, particularly for distributed applications, will continue to grow at a rapid rate — perhaps over 50 percent per year — in the near term. Thus, predicting its ultimate place in the electricity generation hierarchy is difficult.[131]

PCAST also noted that some startup companies believe that solar PV will be able to supply power at 10 cents per kWh within five years, allowing solar to compete directly with conventional energy sources.[132]

The IC^2 Institute concluded that Texas has the solar resources and the research institutions needed to achieve significant market share in the global solar energy market.

The IC^2 Institute concluded that Texas has the solar resources and the research institutions needed to achieve significant market share in the global solar energy market, but lacks a cohesive strategy to achieve success.[133] Its report noted that there are many competitors in the global PV industry, and that:

> …for Texas to acquire and maintain a competitive advantage, it must create opportunities to align research, development, commercialization, and alliance-building strategies necessary to gain a substantial and sustainable foothold in the global marketplace.[134]

The solar energy industry is developing rapidly. Whether Texas becomes a major player in solar energy will depend on decisions made by both public and private entities.

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CHAPTER 11
Wind Energy

INTRODUCTION

Wind energy is among the world's fastest-growing sources of energy. During the last decade, wind energy growth rates worldwide averaged about 30 percent annually.[1] In the last three years, the U.S. and Texas wind energy markets also have experienced a rapid expansion of capacity. In 2007, for example, U.S. wind power capacity grew by 43 percent, while Texas' rose by 57 percent.[2]

This growth has been driven by a variety of factors including government subsidies and tax incentives, improved technology, higher fossil fuel prices and investor concerns about potential federal action to reduce carbon emissions, which could make electricity from fossil fuels more expensive.[3]

Wind power is an abundant, widely distributed energy resource that has zero fuel cost, zero emissions and zero water use. Wind's challenges are largely related to its variable nature — wind speed and direction can change by the season, day, hour and minute. For electricity grid operators the variability of wind — sometimes too much wind is blowing and at others too little — makes it difficult to integrate wind into a grid that was not designed for fluctuations. Moreover, surplus wind power cannot be stored, given current technology.

Many Texas landowners have willingly leased their lands to wind developers, but others oppose the industry. The siting of wind turbines can be problematic, due to opposition to their appearance, noise and potential hazard to wildlife. Some landowners complain that without a permitting process for wind projects, they have no way to protect their property rights.

Transmission is another significant hurdle, since the best sites for wind energy development often are far away from urban centers and the wire networks that provide them with power. Some landowners object to transmission lines traversing their ranches and farms, claiming they will lower their property values. Other critics say that wind energy, like other forms of alternative energy, is not really economically viable without substantial government subsidies and incentives.

Still, wind power can provide economic value to some property owners. Property owners leasing land for wind turbine development receive a steady income (although landowners with transmission towers and lines passing through their land receive only a one-time payment). And wind projects, like other energy projects, create construction and operation jobs and expand the local property tax base.

History

For centuries, people have used the wind to sail ships, grind grains, run small sawmills and pump water from wells. Today, however, wind power increasingly is used to generate electricity.

Rural areas used small windmills to produce electricity in the early years of the twentieth century. The widespread electrification of rural areas in the 1930s led to a decline in the use of windmills for this purpose. In the 1970s, however, an oil shortage led to renewed interest in renewable energy sources, including wind energy.[4] Lower fossil fuel prices during much of the late 1980s and 1990s made wind energy less competitive and slowed its growth.

Wind power came back strongly in 1999, spurred by factors such as government incentives, growing environmental concerns, improved wind turbine technology, declining wind energy costs, and energy security concerns. Among the most significant factors behind the growth of utility-scale wind energy is the federal production tax credit, currently 2 cents per kilowatt-hour (kWh).[5] More recently, higher fossil fuel costs and the expectation of future carbon regulation have also contributed to the growth of wind energy.

Texas' installed wind capacity rose from 180 megawatts (MW) in 1999 to 2,739 megawatts in

In the last three years, the U.S. and Texas wind energy markets have experienced a rapid expansion of capacity.

2006, an average annual increase of 48 percent (**Exhibit 11-1**). In 2006, Texas surpassed California to lead the nation in wind-generating capacity and in that year accounted for almost a third of new installed wind capacity in the U.S. Texas now has the world's largest onshore wind farm in the Sweetwater area.

In 2006, Texas surpassed California to lead the nation in wind-generating capacity.

By the end of 2007, U.S. installed wind capacity had grown to 16,596 MW, enough to power about 5 million homes based on their average household consumption in 2006. In 2007, Texas had installed wind capacity of 4,296 MW, enough to power about 1 million homes, based on average electric use in 2006.[6] It should be noted that Texas homes tend to use more electricity than the average U.S. home, since electricity rather than fuel oil and natural gas supplies most of the state's residential and commercial-sector energy. In addition, hot Texas summers increase the amount of electricity used for air conditioning.[7] Consequently, in Texas a megawatt of wind energy powers about 230 homes, compared to the U.S. average of 300 homes.[8]

At least 1,557 additional MW of installed wind capacity projects came on line in West Texas in 2007, with an additional 1,396 MW currently under construction in Texas.[9] Other states with at least 200 MW of installed wind capacity at the end of 2007 included California, Minnesota, Washington, Iowa, Colorado, Oregon, Illinois, Oklahoma, New Mexico, New York, Kansas, North Dakota, Pennsylvania and Wyoming (**Exhibit 11-2**).

EXHIBIT 11-1

Installed Wind Capacity, 1999-2007 (In Megawatts)

Year	Texas	California	U.S.
1999	180	1,646	2,500
2000	181	1,646	2,566
2001	1,096	1,714	4,261
2002	1,096	1,822	4,685
2003	1,293	2,043	6,374
2004	1,293	2,096	6,740
2005	1,995	2,150	9,149
2006	2,739	2,376	11,575
2007	4,296	2,439	16,596

Source: U.S. Department of Energy.

As of 2007, all of Texas' utility-scale wind projects were in the western parts of the state. The McCamey area, south of Odessa and Midland, saw the first wave of wind development in Texas. West-Central Texas, encompassing the Sweetwater/Abilene area (Taylor and Nolan counties), is home to Texas' largest concentration of wind development, including three of the nation's largest wind projects.[10] The area continues to experience rapid growth and is home to the largest single wind farm in the world, FPL Energy's 735 MW Horse Hollow site, with 428 wind turbines covering about 47,000 acres of Nolan and Taylor counties.[11]

Along the Texas Gulf Coast, plans are under way to build wind farms both on land and offshore. Phase I of the Peñascal Wind Power project in Kenedy County, on land belonging to the Kenedy Ranch Trust, will generate 200 MW after its projected startup in 2008.[12] Construction on Phase I of the Peñascal project has begun, but the Coastal Habitat Alliance, a nonprofit organization dedicated to protecting the Texas Gulf Coast, sought an injunction in March 2008 to block construction of the project. It could take several months for the federal court to make a decision on this case.

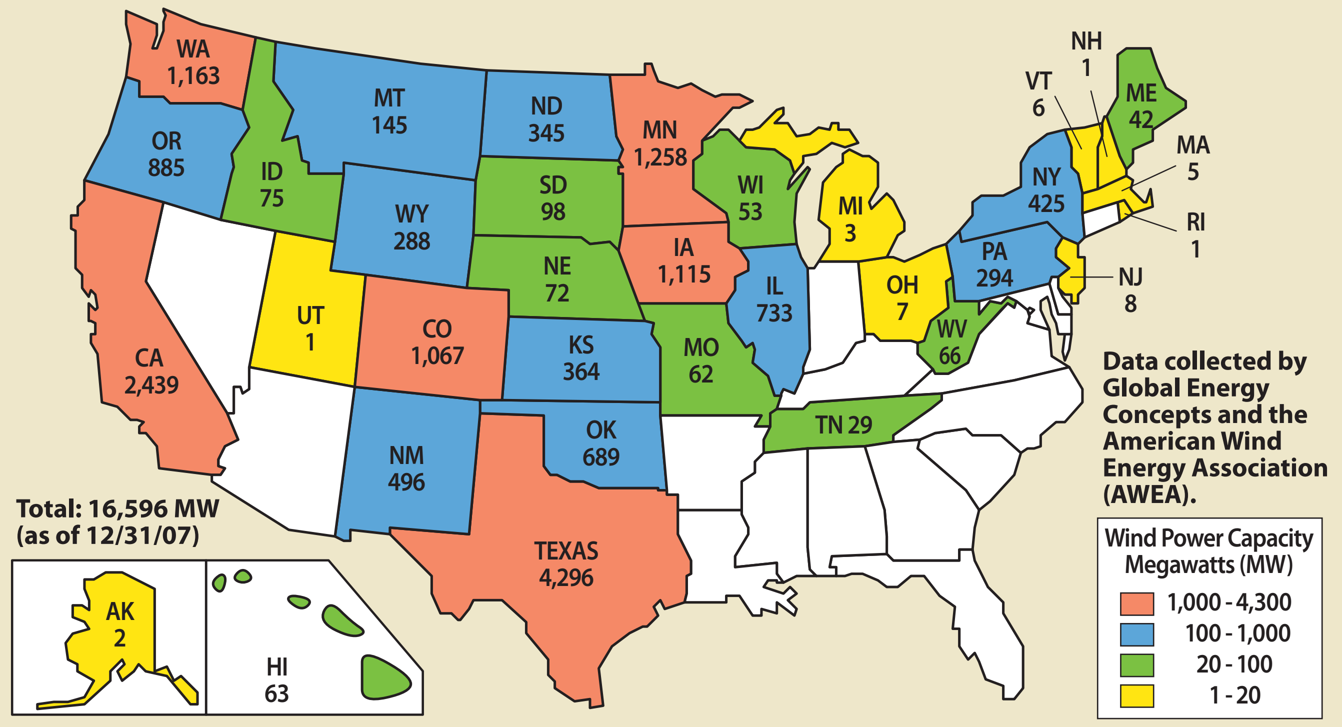
To date, only European nations have built offshore wind farms, although Massachusetts, Texas, Delaware, New Jersey, New York and Georgia have active offshore project proposals.[13] The Texas offshore proposals would be only about eight miles from the electric grid, minimizing transmission expenses. But offshore wind energy development faces obstacles such as hurricane exposure, waves, seabed instability and a more difficult service environment.[14] Additional obstacles to the development of offshore wind farms include concerns about the impact to birds, marine wildlife, navigation and tourism.

Uses

Wind can be used to provide mechanical energy; Texas ranchers still use windmills to provide well water for cattle. But wind's ability to generate electricity without using water is by far its most important and promising aspect.

Exhibit 11-2

2007 Year End Wind Power Capacity (MW)



Total: 16,596 MW (as of 12/31/07)

Data collected by Global Energy Concepts and the American Wind Energy Association (AWEA).

Source: U.S. Department of Energy.

In West Texas, where wind is abundant and water is in short supply, desalination systems powered by wind can be used to develop brackish water sources for consumption. Wind also can be used to power desalination plants along coastal areas. These desalination plants require a constant power supply and use a lot of electricity.[15] Texas Tech University and GE Global Research are working to develop a desalination test plant at Reese Technology Center in Lubbock that will be powered by wind energy.[16]

WIND POWER IN TEXAS

While wind power represents only a small portion of Texas' overall electricity production (about three percent), the state's wind capacity is growing rapidly. High wind speeds, improved wind technology, and government subsidies and tax incentives have contributed to the growth of wind power in the state. With new transmission lines planned by the Public Utility Commission of Texas (PUC) to serve parts of Texas with strong winds, wind's share of overall state capacity is likely to continue to grow in the coming years.

Economic Impact

The wind energy industry can provide economic benefits to some landowners and local communities. In West Texas, landowners have formed associations and selected "steering committees" to hire attorneys to contact wind developers and negotiate wind leases. In 2005, community leaders in the area formed the West Texas Wind Energy Consortium to educate landowners about the economic benefits of wind development.

The biggest benefits go to landowners who receive compensation year after year for turbines sited on their property. Adjacent landowners, however, do not receive ongoing royalty payments. Landowners who have electric transmission towers and lines pass across their land are offered a one-time payment (based on the land's fair market value) plus damages to compensate for other effects to property values. Some landowners complain that land marred by transmission towers and lines drops in value and that the available compensation is insufficient.

For landowners with wind turbines on their property, some wind leases provide bonuses and installation payments, but the primary form of payment is in the form of royalties, also called rent, operating fees or monthly production payments, usually paid to the landowner quarterly. In 2007, the standard royalty was about 4 percent of gross revenues but the amount a landowner receives can depend on many factors, including the number and size of wind turbines installed; the area's wind capacity; the turbines' annual hours of operation; the availability of transmission lines; and the price the electric utility company pays per kWh.[17]

Wind plant construction, maintenance and operations all create jobs, which in turn generate income for local businesses and communities. The National Renewable Energy Laboratory (NREL) estimates that six to 10 permanent operations and maintenance jobs are created for every 100 megawatts of installed wind capacity. One hundred MW of installed wind capacity also creates about 100 to 200 short-term construction jobs.[18]

In October 2006, Texas Governor Rick Perry announced commitments from wind energy companies to invest $10 billion in wind projects in the state. These projects would increase installed Texas wind capacity by about 7,000 MW.[19] The investment, however, is contingent on the construction of additional transmission lines to windy areas of the state. The Electricity Reliability Council of Texas (ERCOT) has identified more than 17,000 MW of possible wind energy projects.[20]

In June 2007, the U.S. Department of Energy (DOE) chose the Lone Star Wind Alliance, a coalition of universities, state agencies and private industry, to receive up to $2 million in equipment to test large wind blades.[21] BP has donated the land and $250,000 for this project, which will be located at Ingleside, north of Corpus Christi. The construction of the blade test facility is expected to attract wind turbine and blade manufacturers to Texas.[22]

And wind-related manufacturing is growing in Texas (**Exhibit 11-3**). In 2006, TECO/Westinghouse and Composite Technology Corporation announced plans to manufacture wind turbines in the state.[23] Supply-chain companies that fabricate wind turbine towers, tower flanges and bolts and other wind turbine components are moving to Texas or expanding their operations. The growth of wind power in Texas also creates service jobs in various fields including engineering, legal and financial services and transportation.

The rapid growth in wind power that Texas has experienced since 2005 would likely slow if the federal production tax credit (PTC), which is scheduled to expire on December 31, 2008, is

EXHIBIT 11-3

Texas' Wind Business is Growing (a few examples)

Manufacturing Specialty	Manufacturing Company	Location
Nacelles*	TECO-Westinghouse	Round Rock
Wind Turbine Towers	Trinity Industries	Dallas/Fort Worth
Tower flange, bolts etc.	CAB Inc.	Nacogdoches
Steel fabrication	Wind Clean	Coleman
Carbon Fiber for Blades	Zoltek	Abilene
Blades	MFG	Gainesville
Bolting Services	Aztec Bolting	League City

* The Nacelle sits atop the wind tower and houses the gear box, shafts, generator, controller and brake.
Source: American Wind Energy Association.

not extended. (The PTC is a federal subsidy that currently provides a 10-year corporate income tax credit of 2.0 cents per kWh, effectively reducing the cost of wind power.) The American Wind Energy Association (AWEA) warns that wind energy developers and manufacturers will stop making investments in equipment and facilities if the PTC is not extended. They also note that wind energy companies are already reporting a decrease in wind energy investment due to the current uncertainty over the extension of the PTC.[24]

Supporters of wind argue that there is another economic benefit of wind energy — reduced dependence on fossil fuels. The American Wind Energy Association (AWEA) estimates that in the U.S., "by the end of 2006 wind energy use will save over 0.5 billion cubic feet (Bcf) of natural gas each day, relieving some of the current supply shortages."[25] By reducing natural gas demand, wind energy can limit the impact of natural gas price hikes to residential and commercial consumers. Critics, however, contend that wind's variability mitigates this advantage.

Consumption

ERCOT, which manages the state's largest power grid, reports that wind energy accounted for 2.1 percent of electricity generated in its region in 2006, compared with just 1.1 percent in 2004.[26] In the U.S., by contrast, wind power provided just 0.8 percent of electricity at the end of 2006.[27] By 2007, wind energy accounted for 2.9 percent of electricity generated in the Texas ERCOT region.[28]

Since ERCOT is responsible for ensuring the reliability and adequacy of the electric grid, it makes capacity calculations to determine if it will have sufficient generating capacity on the grid. Wind power is variable and ERCOT historical wind generation data reveals that there is often less wind blowing on summer afternoons that coincide with peak electrical demand. For planning purposes, ERCOT determined that next year, it can count on just 8.7 percent of its installed wind capacity to alleviate Texas' peak summer demand. It also notes that conventional generation must be available to meet forecast load and reserve requirements.[29]

According to NREL, wind energy can supply 20 percent of the nation's electricity by 2030.[30]

Production

Wind turbines convert the wind's kinetic energy into mechanical power that a generator, in turn, converts into electricity. There are two main types of wind turbines, the horizontal-axis and vertical-axis models (**Exhibit 11-4**). Most modern wind turbines have a horizontal axis, with blades resembling airplane propellers. Vertical-axis units have blades that resemble an eggbeater's. Horizontal-axis units account for almost all utility-scale turbines — 100 kilowatts or several megawatts — in the U.S. and other countries.[31]

Both small and large wind turbines can be used to generate electricity. Small turbines with a capacity to generate less than 10 kilowatts of electricity typically are used to power single homes or farms in remote or "off-grid" locations. Intermediate-sized systems, with a capacity of between 10 and 250 kilowatts, can power a village or a cluster of homes and buildings. Large, utility-scale turbines can generate several megawatts and usually are grouped together into power plants often called "wind farms," and connected to the electrical utility grid; their power is sold to utility customers.[32]

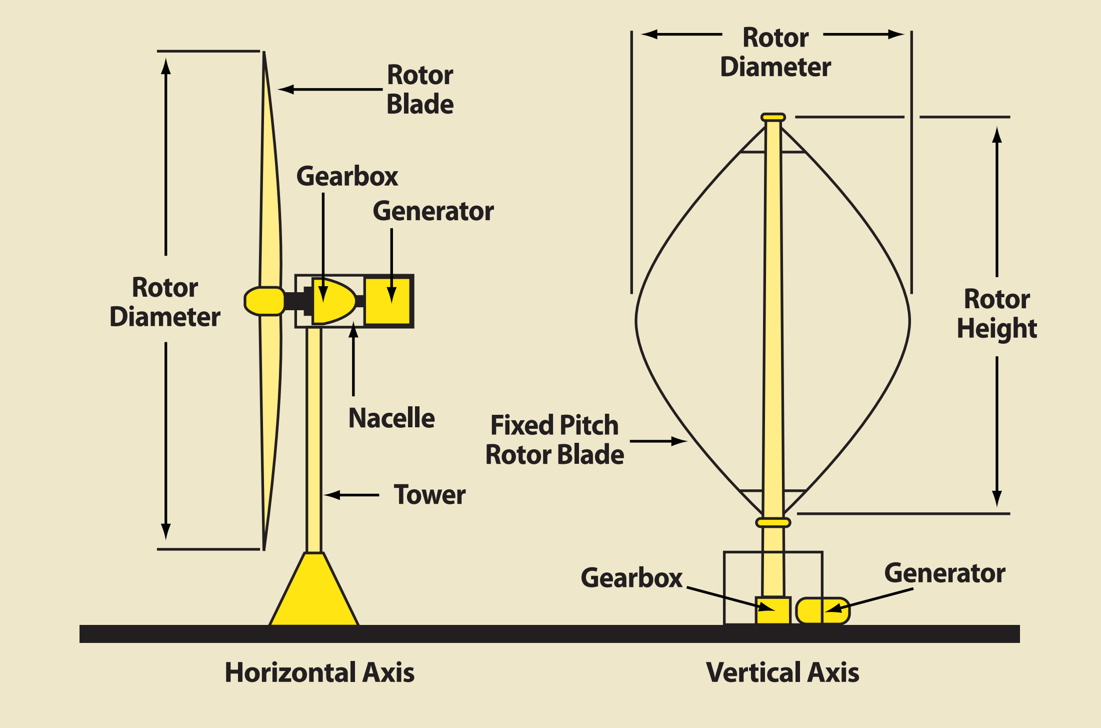
Demand for wind turbines has outstripped global supply.[33] The total development timeline of a wind farm, from initial wind assessment through construction, can require from two to five years and involves many steps.[34] Wind developers must locate sites and negotiate lease options that provide the wind company with a sufficient amount of time to allow for wind measurement, land surveys and studies including avian, environmental, geotechnical, foundation and soil tests to determine if the site is suitable for development.[35]

A wind energy lease is different from an oil and gas lease because it involves only the land surface and not the mineral rights. The average term of a wind energy lease can range from 30 to 50 years, but typically is about 35 years.[36] These long lease periods reflect the fact that creating a wind farm is a complex and expensive project with costs that can run into the hundreds of millions of dollars.[37] Furthermore, wind turbines have a lifespan of more than 20 years.[38] Wind farms are large and often encompass land from several landowners, thus requiring separate leases from each. In West Texas, most wind farms range from 2,000 acres to more than 100,000 acres.[39]

ERCOT reports that wind energy accounted for 2.9 percent of electricity generated in its region in 2007, compared with just 1.1 percent in 2004.

Exhibit 11-4

Horizontal-Axis and Vertical-Axis Wind Turbines



Source: American Wind Energy Association.

The wind farm development and pre-construction phase involves numerous steps, such as title research, permitting, financing, equipment purchases, the development of a power sales strategy and connection to the electrical grid. The construction phase consists of assembly and installation of the wind turbines, transmission lines, substations, roads and other improvements as required. The operational phase of power production typically lasts about 25 years.[40] However, the operational phase may be "repowered" with new equipment, as has been done recently in California, where wind projects have replaced equipment originally installed in the early 1980s.

While wind farms may extend over thousands of acres, the wind turbines themselves occupy only a small percentage of the land — generally 3 to 8 percent (one to two acres per turbine, mostly for the unit itself and associated service roads). This allows farmers and ranchers to use most of the land for other activities.[41] The land occupied is often referred to as the wind turbine's "footprint."

A wind farm also requires substantial acreage for open space between turbines, however, to maximize their efficiency in capturing the wind and to avoid turbulence that can impede airflow (**Exhibit 11-5**). The size of the turbine, land characteristics — plains, hills, ridges, plateaus and mountains — and the direction of the prevailing winds determine the distance needed between wind turbines and turbine rows. One study noted that on a flat site with a single prevailing wind, each turbine requires 26.7 acres, while a site with two prevailing winds requires 59 acres per turbine.[42] At present, neither the federal government nor the state has any spacing regulations for wind turbines.[43]

The kinetic energy of moving air provides the motive force that turns a wind turbine's generator. The wind turns the rotor blades; this motion spins

Exhibit 11-5

West Texas Wind Farm

Source: Cielo Wind Power.

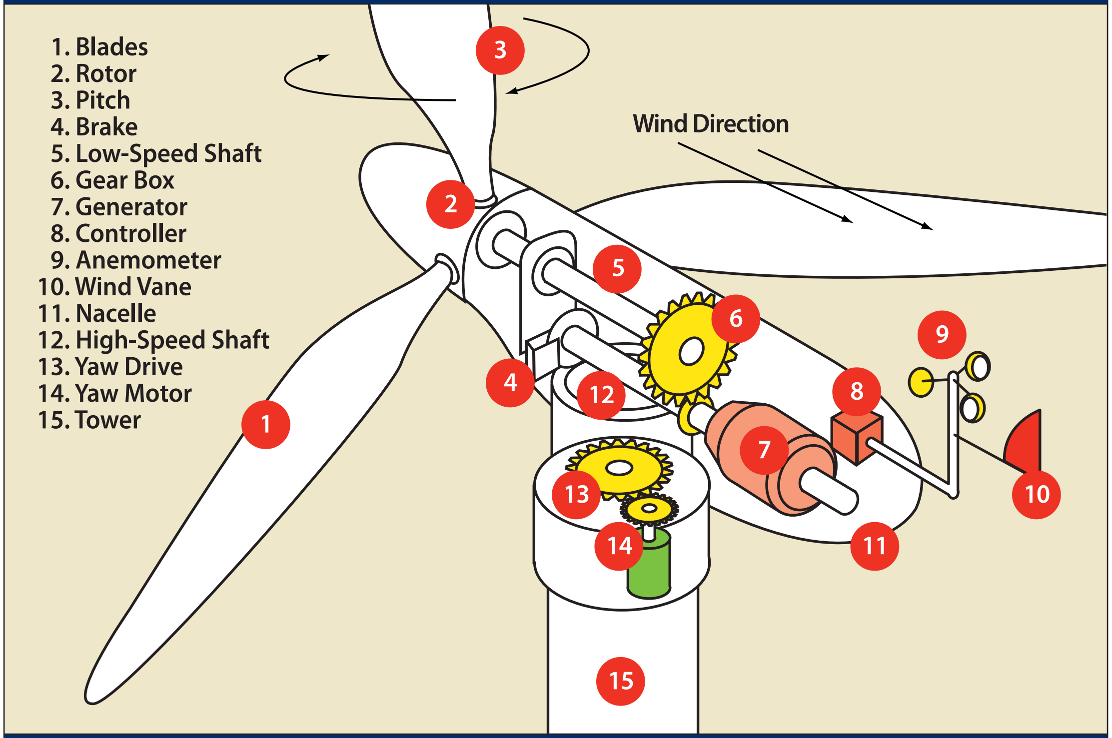
a drive shaft that in turn spins the turbine of a generator to make electricity. A gear box located along the drive shaft increases speed to match generator requirements and optimize power generation (**Exhibit 11-6**). Some wind turbines have a large generator and no gearbox. Longer rotor blades mean a larger "rotor swept area," the total area covered by spinning blades, increasing the energy that can be captured and generating more electricity.

Other factors including wind speed, the height of the wind turbine and air temperature also determine power output. The stronger the wind, the more power is available. A doubling of wind speed increases power output by a factor of eight.[44] Utility-scale wind farms generally require a minimum annual average wind speed of 13 miles per hour.[45]

Wind turbines often are located along hilltops and mountain ridges because a five-fold increase in the height of a wind turbine above the prevailing

Exhibit 11-6

Components of an Energy-Generating Windmill



Source: Alliant Energy.

terrain can result in twice as much wind power. While actual wind characteristics are site-specific, in general, raising the height of a wind turbine increases available wind power. Air temperature also affects wind power generation, with cold, relatively dense air generating about 5 percent more power than hot air.[46]

Today's wind industry has increased output and reduced generation costs by building taller wind turbine towers with longer blades. Both wind turbine size and output have increased steadily since the early 1980s (**Exhibit 11-7**). At that time, the tallest wind turbines were about 56 feet tall; today, some of the larger wind turbines reach heights of nearly 400 feet. The output of wind turbines also has increased steadily, rising from 50 kW in the early 1980s to 500 kW in the mid 1990s and more than 3 MW in 2006.[47]

Today, some of the larger wind turbines reach heights of nearly 400 feet.

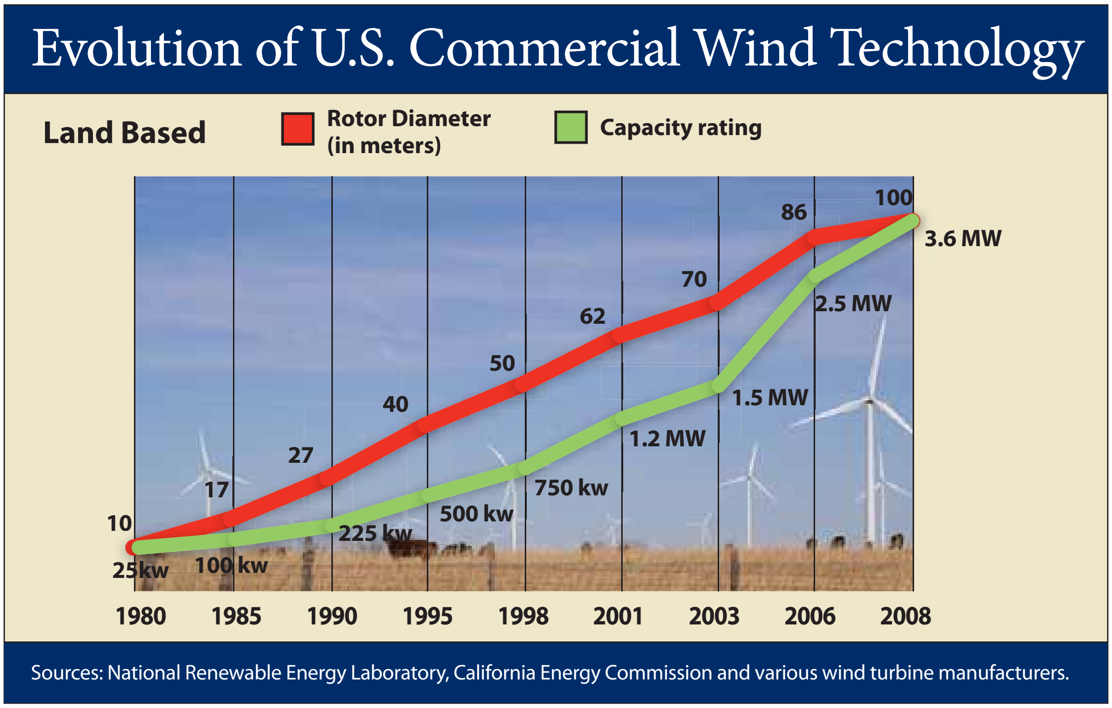
Most wind turbines currently planned for installation in West Texas wind farms are 1 MW to 2.3 MW units. Again, a 1 MW wind turbine can generate electricity for about 230 Texas households.[48]

Capacity factor is a measure of the energy production of a power plant. Since wind is variable, blowing strongly at times and not at all at others, a wind turbine's capacity factor compares actual power produced over time with the power that would be produced by the same turbine operating at maximum output 100 percent of the time. For example, wind turbines at most locations run about 65 percent to 80 percent of the time, but during some of this time they generate at less than full capacity, further lowering their capacity factor.

Utility-scale wind turbines typically operate with a capacity factor ranging from 25 to 40 percent, though they may exceed these amounts during windy months.[49] A recent U.S. Department of Energy (DOE) study noted that taller wind turbines, improved siting and improvements in wind turbine technology all have contributed to continuing improvements in capacity factors. For example, DOE found that capacity factors for projects installed before 1998 average 22.5 percent, compared to 36 percent for those installed in 2004 and 2005.

In Texas, the average capacity factor of wind farms installed in 2004 through 2005 is 39 percent, compared to 32 percent for projects installed between 2000 and 2001 and 19.6 percent for those

Exhibit 11-7



Evolution of U.S. Commercial Wind Technology

Sources: National Renewable Energy Laboratory, California Energy Commission and various wind turbine manufacturers.

installed before 1998.[50] The West Texas wind farms that generate power for the city of Austin's utility company, Austin Energy, have capacity factors ranging from 35 percent to 40 percent.[51]

Sometimes wind production can drop suddenly. On February 26, 2008, wind production in the Electric Reliability Council of Texas (ERCOT) dropped from over 1700 MW down to 300 MW within a three hour period.[52] Traditional power plant operators, who would normally provide more power on short notice, failed to provide power as promised. ERCOT was able to avoid blackouts by asking large industrial customers to cut back on power use. These demand-response customers get reduced electric rates in exchange for cutting power on short notice.

Too little wind is a problem on some days, but on other days heavy winds can generate too much power. When the wind blows hard and wind turbines produce more electricity than the grid can accommodate, the producers in West Texas shut down the wind turbines.

Another measure, the *availability factor*, gauges the reliability of power plant equipment. This measure is expressed as a percentage of the year in which the power plant is available to produce electricity. Like most complex devices, wind turbines are out of service at times, either for maintenance and repairs (a scheduled outage) or when they break down unexpectedly (unplanned outages). Wind turbine technology has improved over the last two decades, and today's machines can have an availability factor of more than 98 percent.[53] In comparison, the availability of large coal and nuclear plants average in the 90 to 95 percent range.

Transmission

Wind energy faces transmission obstacles. As noted above, some of the best wind sites are in remote areas far from population centers, making them dependent on long-distance transmission. Unlike fossil fuels and biomass, which can be transported by pipeline, road or rail, wind energy is produced on site and can only be transported to customers over electric transmission lines.

Extending transmission lines to windy areas is expensive. A recent ERCOT study estimates that building transmission lines to transport wind generated electricity from West and Northwest Texas to urban areas will cost about $1.5 million per mile.[54]

Before they can build the transmission lines, Texas utility companies must lease or buy easements from landowners. For landowners adjacent to wind farms, the expansion of wind energy to their area may mean the construction of what they view as unsightly transmission lines on their farm or ranch land, without any of the economic benefits that accrue to landowners with wind turbines on their property. Again, landowners receive only a one-time payment for the easement, which includes both the transmission lines and towers.[55]

If a landowner is unwilling to sell the land easement or thinks the amount offered is too low, the utility company can initiate an eminent domain proceeding at the county court level to settle the matter. There is growing opposition to private businesses using eminent domain to force individuals to sell their land.[56] Opposition to high-voltage transmission lines also is strong, in part because of aesthetics, property value issues and concern over any potential health problems.

Since wind is a variable source of energy production, wind power plants typically cannot control their power delivery times as precisely as do plants powered by fossil fuels. The electric system already must be capable of responding to swings in electrical usage by customers — swings of as much as 25,000 MW in a single day. Nonetheless, as previously noted, wind's variability posed a problem in February 2008, when ERCOT had to ask large industrial customers to reduce their electricity use. Advances in wind forecasting (the prediction of wind strength ahead of time) should allow wind power to be integrated with conventional resources in an optimal way.[57]

In fact, transmission constraints are the main obstacle to wind development nationwide. This is certainly true in Texas; the Panhandle is the state's most wind-rich area, but it lacks the lines needed to fully exploit this resource. Nationally, investment in new transmission infrastructure over the past 15 to 20 years has not kept pace with growth in electricity consumption.[58]

Furthermore, the existing network was not designed to accommodate variable forms of power. Inadequate transmission capacity near McCamey

Since wind is a variable source of energy production, wind power plants typically cannot control their power delivery times as precisely as do plants powered by fossil fuels.

from 2002 through 2004, for instance, often forced producers to curtail energy production to avoid overloading the transmission lines.[59] More lines were added to alleviate this problem, but some difficulties persist. Beginning in 2006, there was a resurgence of curtailment problems in West Texas as the pace of transmission development lagged the pace of new wind construction.

In some circumstances, as when some transmission lines are down for maintenance or when the power supply exceeds demand, some wind providers will offer wind power at no cost or even pay to have their electricity moved on the grid, a response commonly referred to as "negative pricing."

Wind providers have an incentive to sell power even at negative prices because they still receive the federal production tax (PTC) credit and renewable energy credits; they might lose more money if they simply stopped producing power. (At times of low power demand, some combined cycle gas turbine plants also offer negative pricing to avoid the expense involved in shutting down and then restarting a plant, although such situations are rare.)[60]

Wind is an inexhaustible but variable energy source, since there are seasonal variations in wind production; even windy areas have some days that are windier than others.

State legislation approved in 2005 should provide greater access to transmission lines and increase wind energy development. The 2005 Texas Legislature's Senate Bill 20 increased the state's Renewable Portfolio Standard (RPS) to 5,880 MW of electricity from renewable energy sources by 2015, and set a target of 10,000 MW by 2025. The new law also required the Public Utility Commission of Texas (PUC) to designate Competitive Renewable Energy Zones (CREZs), areas of the state identified as having the best renewable energy resources, and requiring the transmission infrastructure needed to deliver that energy to customers. (For a detailed discussion of renewable portfolio standards and Competitive Renewable Energy Zones, see Chapter 9.)

PUC asked ERCOT to study the potential for Texas wind development and necessary transmission improvements. The primary potential areas for wind capacity expansion identified in the study include the Texas Panhandle; the McCamey area south of Odessa; areas near Sweetwater and Abilene; and the Gulf Coast south of Corpus Christi.[61] PUC used ERCOT's study to decide which areas are most suitable for the extension of transmission capacity.

In July 2007, after evaluating about 25 areas in the state for wind power generation, PUC designated six CREZ zones as the best sites for ERCOT to develop transmission plans for between 10,000 MW and 25,000 MW of proposed wind capacity, with the costs to be covered by all Texas consumers through fees built into the cost of electricity.

On April 2, 2008, ERCOT released the CREZ Transmission Optimization Study, which provides transmission plans for four scenarios of wind generation. The estimated cost of building new transmission lines to windy parts of the state ranges from $3 billion for 12,053 MW of wind generation capacity to $6.4 billion for 24,859 MW.[62] Each scenario includes 6,903 MW of wind generation that was either in-service or had signed interconnection agreements as of fall 2007. PUC will issue final designation of transmission solutions for the CREZ areas, and decide which transmission companies will be selected to build transmission lines.

Several companies have formed partnerships to build transmission capacity for the CREZs.[63] Another company has filed a proposal with PUC to build an 800-mile transmission loop in the Texas Panhandle to connect 8,000 MW, mostly of wind power, to the ERCOT electric grid.[64]

Availability

Wind is produced by the uneven heating of the earth's land, water and atmosphere, which causes air masses to move around the planet. Wind is an inexhaustible but variable energy source, since there are seasonal variations in wind production; even windy areas have some days that are windier than others. Wind is in greatest supply along mountain and ridge tops, but other windy areas include mountain passes, hilltops, mesas and flat, wide-open areas such as open plains and shorelines.

The Pacific Northwest Laboratory (PNL), a federal research center, created a national wind resource assessment for DOE in 1986. PNL classifies wind power by class, with Class 1 consisting of very light winds and Class 7 comprising the strongest winds. PNL ranked Texas second among states for wind potential, just behind North Dakota.[65]

The Alternative Energy Institute (AEI) at West Texas A&M University has refined PNL's wind resource data, using updated information to construct an improved wind map of Texas. AEI identified three areas of Texas with significant wind power potential: the Great Plains, the Gulf Coast and specific areas in the Trans-Pecos region (**Exhibit 11-8**).[66]

Many factors including hills and trees can affect wind patterns, causing actual wind measurements to vary from those on the wind maps. Consequently, wind development companies perform their own long-term measurements with an anemometer to assess the true potential of a site.

In 1995, the State Energy Conservation Office (SECO) released a study that evaluated Texas' renewable energy resource base. This study included a thorough assessment by West Texas A&M University's Alternative Energy Institute that concluded that Texas has 524,800 MW of potential wind power capacity, enough to power about 121 million homes (**Exhibit 11-9**).[67]

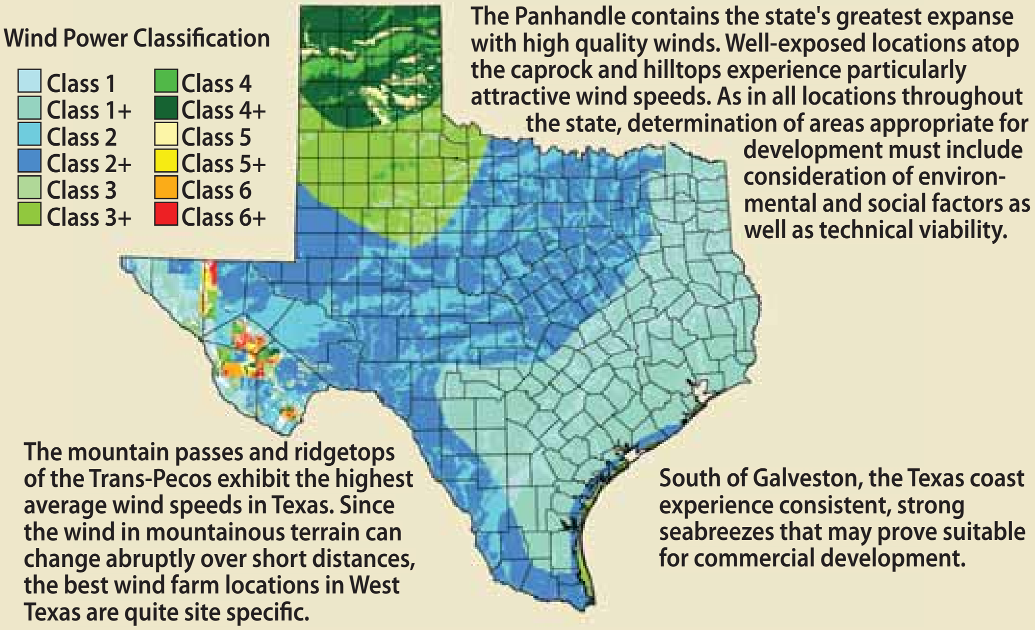
Most of Texas' potential wind capacity falls in class 3, which is characterized by wind speeds of between 15.7 mph to 14.3 mph. Even so, the state had enough class 4 wind (16.8 mph to 15.7 mph) to meet 100 percent of its electric needs in 1995. The 2007 Texas Legislature directed SECO to update the 1995 assessment of Texas renewable energy resources. This report, which will be released before the start of the 2009 Texas legislative session, will include up-to-date data on the availability of various renewable energy resources.

More recent studies also have highlighted Texas' wind potential. In December 2006, ERCOT released a report on wind generation and transmission that concluded: "there is significant potential for development of wind resources in Texas."[68] AWS Truewind, the company ERCOT hired to identify areas of the state with the best wind resources, reported that annual capacity factors of between 30 to 45 percent were common in Texas' windiest sites.[69]

Abundant, renewable and non-polluting, wind energy has been the leading renewable electric

Exhibit 11-8

Texas Wind Power Potential



The Panhandle contains the state's greatest expanse with high quality winds. Well-exposed locations atop the caprock and hilltops experience particularly attractive wind speeds. As in all locations throughout the state, determination of areas appropriate for development must include consideration of environmental and social factors as well as technical viability.

The mountain passes and ridgetops of the Trans-Pecos exhibit the highest average wind speeds in Texas. Since the wind in mountainous terrain can change abruptly over short distances, the best wind farm locations in West Texas are quite site specific.

South of Galveston, the Texas coast experience consistent, strong seabreezes that may prove suitable for commercial development.

Source: Alternative Energy Institute, West Texas A&M University.

Exhibit 11-9

Texas Wind Power: Potential Electricity Production*

Wind Power Class	Area (km2)	Percent of State Land	Potential Capacity (MW)	Potential Production (Billion kWh)	Percent of Texas Electric Consumption
3	143,400	21.13%	396,000	860	371%
4	29,700	4.38	101,600	231	100
5	5,000	0.74	21,600	48	21
6	300	0.04	1,600	4	2
Total	**178,400**	**26.29%**	**524,800**	**1,143**	**493%**

*Data is from a 1995 study of Texas Renewable Energy Resources that is currently being updated and is scheduled for release before the 2009 Texas Legislative Session.
Source: Texas State Energy Conservation Office.

resource in Texas for the past few years, and is currently attracting significant investor interest as a power plant option in ERCOT's competitive wholesale market.[70] In Texas, an additional 1,618 MW of wind generation came on line by the end of 2007 (**Exhibit 11-10**). Potential developers of another 17,000 MW of wind generation have requested an analysis of transmission capabilities.

Cost and Benefits

In the last 22 years, wind power prices per kilowatt-hour, calculated using the federal production tax credit (PTC), have declined by about 80 percent.[71] Currently, the PTC reduces the price of wind power by about 2.0 cents per kWh, making wind more attractive to electric utilities and investors.[72]

Wind energy has been the leading renewable electric resource in Texas for the past few years.

For example, in 1984 U.S. wind farms generated electricity for about 30 cents per kWh, but by 2005, prices in some areas of the nation had declined to as little as 3 cents per kWh.[73] In 2006, U.S. wind power prices ranged from 5 to 8.5 cents per kWh, *independent* of the federal production tax credit (PTC), depending on site-specific factors such as the strength of the wind resource, turbine size and development and installation costs. When the PTC is factored into the price, wind prices are even lower. For example, the 2006 U.S. wind power price, *including* the PTC, ranged from 3 to 6 cents per kWh. Texas is at the competitive end of the U.S. wind power price range.[74]

A 2007 DOE report on the wind industry concluded that Texas and the Plains states are among the nation's lowest-cost wind regions due to higher performance and lower development and installation costs. The report notes that performance depends on the strength of the wind resource, while development and installation costs "depend on a region's physical geography, population density, or even the regulatory processes."[75] Lower costs translate into lower wind power prices. Wind development costs are higher in California, the Great Lakes and along the Eastern coast.[76]

The development of taller wind turbines with larger rotor blades has contributed greatly to increased output and lower costs. Improved monitoring and analysis of wind resources have led to better siting and increased performance, while electronic monitoring of turbines and controls has helped to lower costs.

In California, 139 wind turbines from the 1980s that collectively generated about 11 megawatts of power recently were replaced with four new ones generating the same output with greater reliability.[77] In 2006, almost 17 percent of the wind turbines installed in the U.S. could generate more than 2 MW each, and the most frequently installed unit was a GE 1.5 MW wind turbine.[78]

The cost of wind-generated electricity varies depending on the site's average wind speed. In 2005, the American Wind Energy Association (AWEA) reported that, all other things being equal, a wind turbine at a site with average wind speed at the hub height (the axis of the turbine around which the blades spin) of 16 miles per hour (mph) can generate electricity for about five cents per kWh;

Exhibit 11-10

Texas Wind Power Projects Completed in 2007

Project Name	Location (County)	Quarter of Initial Operation	Total Capacity (in MW)	Number of Turbines	Turbine Size (in MW)	Project Developer
JD Wind IV	Hansford	Q1	10	8	1.25	John Deere Wind
Camp Springs	Scurry	Q2	130.5	87	1.5	GE Energy
Lone Star 1	Shackelford	Q2	72	36	2	Gamesa
Sweetwater IVa	Nolan	Q2	135	135	1	Mitsubishi
Sweetwater IVb	Nolan	Q2	105.8	46	2.3	Siemens
Wildorado	Potter, Oldham & Randall	Q2	161	70	2.3	Siemens
Buffalo Gap 2	Nolan & Taylor	Q3	232.5	155	1.5	GE Energy
Capricorn Ridge 1	Coke	Q3	117	78	1.5	GE Energy
Capricorn Ridge 2	Coke	Q3	144.9	63	2.3	Siemens
Lone Star 1	Callahan	Q3	110	55	2	Gamesa
Camp Springs 2	Scurry	Q4	31.5	21	1.5	GE Energy
Capricorn Ridge	Coke	Q4	97.5	65	1.5	GE Energy
Capricorn Ridge	Coke	Q4	4.6	2	2.3	Siemens
Lone Star 1	Shackelford	Q4	18	9	2	Gamesa
Lone Star 2	Shackelford & Callahan	Q4	44	22	2	Gamesa
Snyder	Scurry	Q4	63	21	3	Vestas
Sweetwater 5	Nolan	Q4	80.5	35	2.3	Siemens
Whirlwind Energy Center	Floyd	Q4	59.8	26	2.3	Siemens
2007 Total			**1,617.60**			

Source: American Wind Energy Association.

at 18 mph, it can generate electricity for about 3.6 cents per kWh; and at 21 mph the cost is about 2.6 cents per kWh.[79]

It should be noted that wind energy prices have increased since 2005, primarily due to higher costs for wind turbines. Even so, AWEA's figures illustrate that the same piece of wind equipment sited in a windier location will produce electricity at a substantially lower cost. Existing Texas wind projects are almost all within the 18 to 21 mph range at hub height. With its abundance of good sites, locations with wind speeds below 18 mph are generally considered inadequate for development in Texas.[80]

Wind energy cost also is affected by the size of the wind farm and the cost of financing. Larger wind farm projects appear to benefit from economies of scale.[81] Since wind energy is capital intensive, the cost of financing also has an impact on wind power costs. An increase in the number of banks and other investors willing to lend for wind projects in 2006 led to cheaper capital, mitigating higher wind turbine costs.[82]

After declining for several years, wind power prices rose in 2006 due to a variety of factors that include a shortage of, and higher prices for, wind turbines and components; rising steel, copper and energy costs; rising lease and royalty costs; and a weaker dollar in relation to the Euro.[83] Europe manufactures most wind turbines and components, although some foreign turbine manufacturers have begun to locate in the U.S. such as Gamesa (Spain) in Pennsylvania, Suzlon (India) in Minnesota and DeWind (Germany) in Round Rock, Texas. GE, a leading supplier of wind turbines worldwide, continues to maintain a significant manufacturing presence in the U.S. as well as in Germany, Spain, China and Canada.[84] Also, a new U.S.-based manufacturer, Clipper Windpower, is in the process of expanding in Iowa.[85]

A recent DOE study expects wind power prices to rise further in 2008 because more recent wind turbine cost increases are not reflected in 2006 prices.[86]

After declining for several years, wind power prices rose in 2006.

Environmental Impact

Wind power does not produce waste products that require disposal or gas emissions that contribute to air pollution and global climate change. It does not consume or pollute water.

Other Risks

The whirling blades and tower of wind turbines can pose a risk to migratory birds and bats, killing them if they fly into the blades. This was discovered in 1994 at the Altamont Pass wind farm in California, which experienced large numbers of such deaths.

Consequently, several studies were conducted to determine how avian deaths could be reduced, and the lessons learned were incorporated into later wind projects. Bird deaths also prompted the wind energy industry to join with other stakeholders—environmental groups, government entities and utilities—to form the National Wind Coordinating Collaborative (NWCC) in 1994. NWCC supports the development of markets for wind power that are environmentally, economically and politically sustainable.

A 2005 study by the U.S. Forest Service found that wind turbines had a low overall impact on birds and that far more are killed by collisions with buildings/windows, high-tension lines and automobiles, and by house cats and pesticides.[87]

More recently, a 2007 National Academy of Sciences (NAS) report on the environmental impacts of wind energy projects found no evidence of significant impacts on bird populations at current levels of installed wind capacity. This study noted that of about 1 billion birds killed annually in 2003, only 20,000 to 37,000 died as a result of collisions with wind turbines. They note, however, that the continued rapid expansion of wind energy over the next 20 years may affect some species of birds and bats.

To avoid future ecological threats, the NAS study recommended the use of systematic pre- and post-construction studies to determine the impact on wildlife and to generate information for improved wind farm siting. The report also noted that the impact to forested areas, where vegetation is cleared to build wind turbines and roads, should be evaluated more thoroughly.[88]

More studies of the flight patterns of migratory birds are under way; these should discourage the placement of wind turbines in areas that interfere with bird flight paths. The wind industry also has joined with NREL, Bat Conservation International and the U.S. Fish & Wildlife Services to identify and quantify effects on bats and study ways to lessen the impact on them as well.[89] The Texas Parks and Wildlife Department is providing funds for a four-year study on bird-migration corridors along the Texas coast. The Caesar Kleberg Wildlife Research Institute at Texas A&M University at Kingsville is conducting this study and has established the Merlin Avian System — a radar system that takes vertical and horizontal measurements tracking the movements of migratory birds 24 hours per day, seven days per week — on the King Ranch, which is located in South Texas between Corpus Christi and Brownsville.[90]

Birds follow migratory routes called “flyways.” Texas is part of the continent’s Central flyway, which funnels migratory birds along the lower southeast Texas coast. In South Texas, opposition to wind development has arisen in large part due to concern for birds and bats. Critics of wind energy development in south Texas also say that it will have a negative impact on ecotourism. South Texas is a birding “hotspot,” attracting thousands of birders to the region every year.[91]

The proposed Peñascal Wind Project on the Kenedy ranch is located along the lower Texas Gulf Coast, in the Central flyway. A Kenedy ranch representative says they have studied the avian issue carefully and have quantitative data indicating that wind development will not have a negative impact on wildlife in the area.[92] The wind developer had avian studies performed of the site that concluded that the planned wind turbines will not interfere with bird migratory patterns.[93]

The Coastal Habitat Alliance (CHA), a nonprofit organization dedicated to protecting the Texas Gulf Coast, commissioned EDM International, Inc. to conduct its own review of the potential impact of wind turbines on avian populations. Their study reached a different conclusion. EDM claims that the wind developer's avian studies of the proposed wind sites are "fatally flawed" and concluded that, if all the sites proposed for possible wind installations on the Kenedy Ranch were developed, the project could have a significant impact on birds.[94] PPM Energy responded that EDM's study "contains factual errors, and is scientifically deficient."[95] PPM notes that the teams the wind developers used to conduct on-site bird studies over nearly three years are scientists based in Kingsville and Corpus Christi, while EDM, a Colorado consulting firm, made its review without direct on-site knowledge.

Another risk of large wind turbines is the danger of ice falls from spinning blades. Utility-scale wind turbines usually are sited at least 650 feet away from homes and public roads to minimize these situations.[96] Newer wind turbines shut down when ice builds up.

Aesthetic and Noise Impact

One of the most common complaints about wind farms is that they spoil the view. Critics say large wind turbine towers clustered into wind farms are an eyesore. Some landowners worry that locating wind turbines in pristine settings, especially where unspoiled views are the attraction, will reduce property values and have a negative impact on tourism. In 2007, a National Academy of Science (NAS) study noted that several studies have been unable to find a correlation between wind farms and lowered property values within a 10-mile radius of their sites.[97]

Technological advancements have resulted in utility-scale wind turbines that are quieter than the earlier models, but they still produce some noise. At a distance of 750 to 1,000 feet, a modern wind farm is said to produce about as much noise as a kitchen refrigerator (**Exhibit 11-11**).[98]

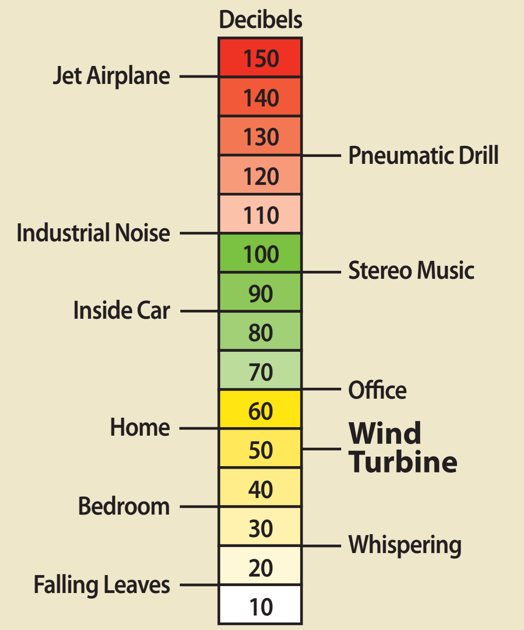
According to a 2002 NREL study, more efficient rotor blades, vibration damping and improved mechanical design have reduced wind turbine noise. This study also reported that much of the sound wind turbines emit is masked by ambient sounds or the sound of the wind itself. Finally, the NREL study pointed out that, "because of the wide variation in the levels of individual tolerance for noise, there is no completely satisfactory way to measure the subjective effects of noise or the corresponding reactions of annoyance and dissatisfaction."[99] Consequently, NREL concluded that noise should be a primary siting constraint for wind turbines.

Property Values and Property Rights

More than 100 Texas counties, cities and various economic development corporations from the Panhandle and South Plains regions have passed resolutions supporting renewable wind energy and the proposed Panhandle Loop transmission

Exhibit 11-11

Wind Noise Measurements (In Decibels)



Source: American Wind Energy Association.

lines.[100] In areas valued for their natural beauty, however, some fear that wind turbines will reduce property values and affect tourism. This is the case in the Texas Hill Country, where on December 20, 2007, the Gillespie County Commissioners Court passed a resolution saying that they "oppose the construction and installation of industrial wind farms in Gillespie County and the surrounding Hill Country area."[101] The Fredericksburg and the Llano city councils have passed similar resolutions.

Critics of wind power also argue that landowners' property rights may be violated when their neighbors lease land to wind developers, since the large wind turbines are visible from their land and in some cases may be close to their property lines. Furthermore, they are concerned about the lack of state regulations for wind farm siting and decommissioning (the removal of wind turbines at the end of their useful lives). Texas, like many other states, does not regulate wind farm siting and decommissioning.

In Texas, there are no state guidelines for wind turbine siting.

This lack of regulatory guidance means that landowners are solely responsible for ensuring that their contracts cover issues such as the dismantling of retired wind turbines. Wind contracts typically specify only that the wind developer will post a bond to cover the costs of decommissioning. Removal generally is limited to the wind turbine structure and up to four feet of the concrete and steel pad upon which it rests. The remaining hole is filled with soil. Since the wind industry is relatively new, however, some landowners wonder whether wind developers will have the resources needed to dismantle wind turbines in the decades to come.

Some critics of wind power say that, until the government adopts wind siting regulations, the only way they can stop wind development is to file lawsuits. In Texas, landowners have filed several lawsuits in an attempt to stop the construction of wind turbines in their communities. So far the courts have ruled in favor of landowners who want to lease their land for the development of wind power. One judge noted that it is a property rights issue; individual property owners have the right to lease for oil, wind or other uses of their land.[102] More recently, The Coastal Habitat Alliance filed a lawsuit in federal court to prevent the construction of wind projects in South Texas "until a thorough environmental review with genuine public input is performed."[103]

State and Federal Oversight

Wind energy facilities in the U.S. usually are approved by local zoning boards and state regulatory authorities.[104] A 2007 survey of state fish and wildlife agencies and independent research revealed that at least six states — California, Minnesota, North Dakota, Oregon, South Dakota, and Vermont — have wind specific siting authority.[105] Federal involvement is limited, although wind turbines are subject to Federal Aviation Administration requirements; they cannot be located where they could adversely affect air traffic or radar systems.

In Texas, there are no state guidelines for wind turbine siting.[106] Counties can discourage but cannot prohibit power plant development. The Texas Parks and Wildlife Department will review a wind energy project against a draft set of guidelines for wildlife protection, if asked. The 2007 Texas Legislature considered a bill — HB 2794 — that would have required a permitting process for wind energy projects, but it did not pass.

Subsidies and Taxes

Most energy technologies benefit from government incentives, and wind energy is no exception. The U.S. wind power industry has relied heavily on the federal production tax credit, which was first adopted in 1992 and currently provides a two-cent per kilowatt-hour (kWh) credit against the corporate income tax for electricity generated in the first 10 years of a wind turbine's operation.[107]

The sensitivity of wind industry's growth to changes in government policy is apparent from the history of the PTC. Congress has allowed the credit to expire three times in seven years before extending it for only one or two years at a time. As can be seen in (**Exhibit 11-12**), each time the credit expired, growth in wind capacity slowed considerably.

Wind development companies and wind equipment manufacturers have complained that these interruptions create uncertainty in the market, discourage investment and may contribute to rising costs. Furthermore, this uneven government support for wind has discouraged manufacturers from investing in new factories in the U.S., opting instead to import product as needed.[108]

The uninterrupted PTC from 2005 to the present and an expanding market for wind power now are attracting wind component manufacturing to the U.S.[109] In December 2006, Congress extended the PTC through the end of December 2008. The wind industry continues to lobby for a lengthier extension of the PTC to encourage long-term investment in the industry.

Texas' Renewable Portfolio Standard also is credited with encouraging the growth of the state's wind energy industry. The RPS creates demand for all renewable energy sources — such as wind, solar, biomass, hydropower and geothermal power — by requiring companies that sell electricity to retail customers to support renewable energy generation.

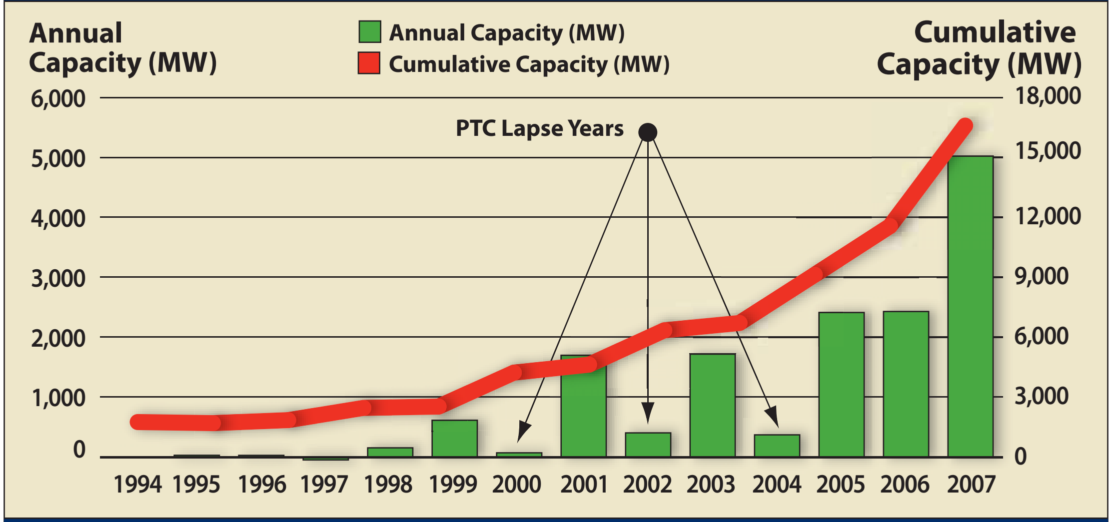
Texas established its RPS in 1999, and as noted earlier, the 2005 Texas Legislature increased the state's total renewable-energy mandate to 5,880 MW by 2015 and a target of 10,000 MW in 2025.[110] To meet the RPS targets, utility companies may buy or trade renewable energy credits (RECs). One REC represents one MWh of qualified renewable energy generated and metered in Texas. ERCOT administers the REC market for the state of Texas. As of February 2008, 25 states and Washington D.C. had implemented an RPS, while four states had enacted voluntary renewable portfolio goals. (see Chapter 9 of this report for further discussion of the RPS and REC).

Other incentives also have helped the industry grow. For example, Texas exempts wind-powered energy devices generating electricity for on-site use from the property tax.[111] Furthermore, the 2001 Legislature authorized school boards to reduce the property value of large renewable electric energy projects such as wind farms. Since this incentive became law, Texas school districts have approved more than 70 wind energy projects for reduced property values.[112]

Whether county governments and school districts can continue to grant abatements and property value limitations is in question, however, due to a January 29, 2008, Texas Attorney General opinion concerning Section 312.402(a) of the Tax Code. The opinion concluded that "fixtures and improvements owned by the wind turbine company as personal property would not be 'real property' that may be the subject of a tax abatement agreement under section 312.402(a)."[113] On February 27, 2008, the Texas Comptroller of Public Accounts raised a different issue with respect to school district tax limitation agreements under Chapter 313 of the

Exhibit 11-12

U.S. Annual Wind Energy Capacity Additions



Source: U.S. Department of Energy.

Tax Code, which could also affect wind farms. The Office of the Attorney General has until August 26, 2008, to respond to the Comptroller's request for an opinion on this matter.

More information on subsidies for wind can be found in Chapter 28.

OTHER STATES AND COUNTRIES

Texas is the largest market for installed wind capacity in the U.S.

Texas is the largest market (with 4,296 MW by the end of 2007) for installed wind capacity in the U.S. California is second, with 2,439 MW of installed wind capacity, followed by Minnesota with 1,258 MW, Washington with 1,163 MW and Colorado with 1,067 MW.[118] Only 15 states had more than 200 MW of wind capacity at the end of 2007. Texas added over 1,500 MW of installed wind capacity in 2007, more than any other state.[119]

At the end of 2007, the world's total installed wind energy capacity was 94,123 MW, up from 74,141 MW in 2006.[120] Europe accounted for 57,136 MW of this capacity. Germany uses the most wind power, with an installed capacity of 22,247 MW; U.S. is second, with 16,596 MW. The addition of just over 5,000 MW of installed wind capacity in 2007 moved the U.S. ahead of Spain — with 15,145 MW — to become the second-largest producer of wind energy.[121]

While the U.S. ranks as one of the nations with the most total installed wind capacity, wind energy accounted for slightly less than 1 percent of all U.S. power generation in 2006 (**Exhibit 11-13**).[122] In Denmark, by contrast, wind energy accounted for more than 20 percent of the nation's total power requirements. Spain and Germany produced about 9 percent and 7 percent of their electricity from wind, respectively.

In some parts of Spain, wind energy consistently supplies 20 percent of electric loads. On March 20, 2007, Spain's electricity network authority, Red Electrica, reported that during a particularly gusty period the country's wind energy generation had reached an all-time high, producing 27 percent of its total power requirements.[123] Similarly, wind supplies 35 percent or more of northern Germany's power.[124]

According to the Global Wind Energy Council, more than 48 countries had policies or laws promoting renewable energy in 2006.[125] The two main types of incentives used to promote renewable energy are minimum price systems and quota systems. *Fixed-price systems* include tax credits and feed-in tariffs, which guarantee that a utility or grid operator will pay a minimum price per unit of electricity to a private generator of renewable electricity. In the *quota system*, the government simply determines the amount and quantity of electricity that a utility must buy from renewable energy sources.

Most European countries, including Germany, Spain, France and Portugal, have adopted feed-in tariffs. In Germany, the 8.53 cents per kWh tariff decreases to 5.39 cents after several years, depending on the quality of the site. Spain's wind power producers can choose between a fixed feed-in tariff — 6.3 to 7.0 cents per kWh based on capacity — or a variable tariff that has a fixed-price component and also factors in the average market price of electricity. France has a fixed tariff price of 8.36 cents per kWh for the first five years that drops thereaf-

Austin Energy Committed to Renewable Energy

Some electric utilities offer "Green Pricing" programs, an optional service that provides the consumer the choice of supporting renewable energy sources such as wind and solar, often by agreeing to pay a premium on their electric bill. Austin Energy, the city of Austin's utility, offers a GreenChoice program that initially charged a slightly higher rate but then keeps the rate fixed for up to 10 years since, once built, the cost of wind power is very predictable due to the fact that utilities acquire it via fixed-price purchase contracts.

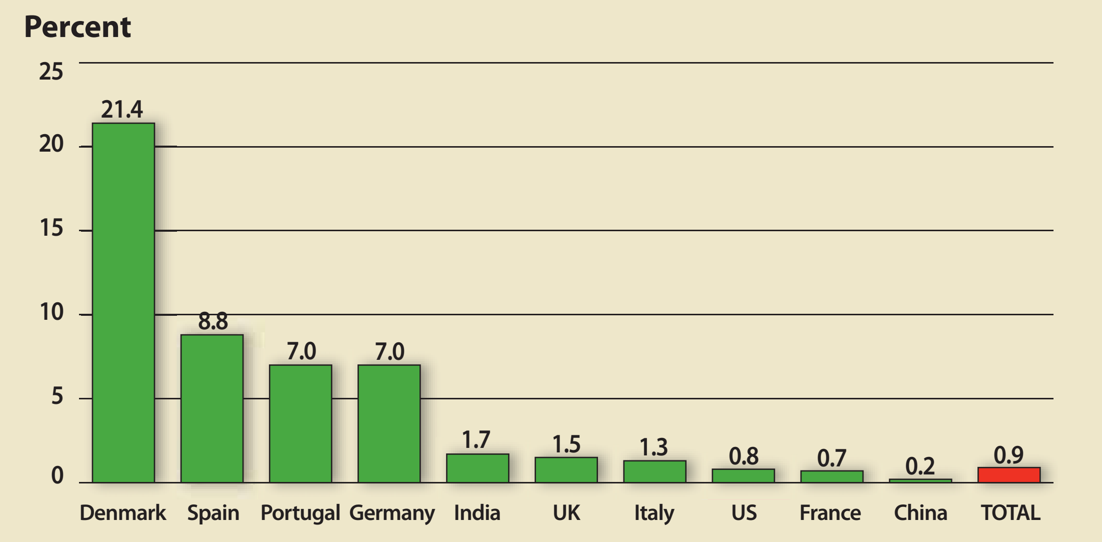
In January 2006, higher natural gas prices and escalating coal delivery costs meant that, for the first time, the green power charge was lower than the fuel charge paid by consumers who did not subscribe to the GreenChoice program.[114]

NREL has ranked Austin Energy's green power program as first in the nation among utility programs for renewable energy sales, for five consecutive years.[115] Austin GreenChoice sales of mostly wind-generated power reached 580 million kWh in 2006.[116] Other Texas utilities, including CPS Energy in San Antonio and El Paso Electric, offer similar "green pricing" programs.[117]

Austin Energy also has net metering standards that have made it easier for owners of small-scale wind turbine projects and solar energy systems to sell excess electricity back to the utility and buy more power only as they need it. Austin Energy net metering allows these customers to use the electric grid, in effect, as a storage battery, since any excess electricity is fed back to the utility grid.

Exhibit 11-13

Approximate Wind Power as a Percent of Electricity in Countries with the Most Installed Wind Capacity, 2006



Source: Berkeley Lab estimates.

The federal production tax credit has been the main driver behind wind energy expansion.

ter. Portugal's feed-in tariff has rates between 7.5 and 7.9 cents per kWh for 15 years. Britain and Italy have a quota system. In 2004 and 2005, the price of wind electricity was 15.5 cents per kWh in Italy and 10.1 cents per kWh in Britain.[126]

Outlook for Texas

Texas' wind industry has benefited from substantial wind resources and significant federal and state incentives. Furthermore, higher fossil fuel prices and more efficient wind turbines have made wind power more competitive with conventional power sources.

The state's wind industry is prospering, but it faces several potential hurdles. Another lapse in the extension of the federal production tax credit could slow the industry's growth, as could a continuing shortage of wind turbines. Furthermore, inadequate investment in new transmission lines, siting and permitting issues and opposition to wind development all could slow the rapid pace of the industry's growth.

The federal production tax credit has been the main driver behind wind energy expansion. The growth of wind power has paralleled the availability of the PTC, slowing in the years (2000, 2002 and 2004) in which the credit was allowed to lapse.[127] The wind industry is asking the U.S. Congress to extend the PTC — currently set to expire in 2008 — for five or more years. Industry advocates say the PTC is important for the continued development of the wind energy industry and the expansion of wind turbine manufacturing in this country.[128] Property tax breaks for wind projects in Texas also have contributed to the industry's growth here.

At this writing, a wind turbine shortage has driven up prices and caused lengthy delays in wind projects. In the last year, Pennsylvania, Iowa and Minnesota successfully attracted foreign companies to build wind turbine factories in their states.[129] Even so, it will take several years for these new factories to ease the current shortage.

Local opposition to wind power usually centers on the danger posed to birds and bats, noise, aesthetics, land values, economic impact on tourism and landowners' property rights. A decline in support for the wind industry at the state and local levels could impede its expansion.

At the national level, the wind industry opposes any legislation that would require federal approval for each wind turbine in the U.S. According to AWEA, such a requirement could bring wind project development to a halt.[130]

Transmission continues to be perhaps the most significant barrier to wind energy development in parts of West Texas, including the Panhandle. PUC is designating CREZs that will develop additional transmission infrastructure.

Texas has abundant wind resources. Its Renewable Portfolio Standard goals and the selection of CREZs to expedite transmission improvements should continue to drive the growth of wind energy in the state.

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Chapter 12

Biomass: Overview

Biomass is any plant or animal matter used to produce energy. Many plants and plant-derived materials can be used for energy production; the most common is wood. Other sources include food crops, grasses, agricultural residues, manure and methane from landfills.[1]

As an agricultural state, Texas has many resources for biomass energy production. Crops used to produce biomass energy — cotton, corn and some soybeans — are all grown in Texas.[2] Texas has 21 landfill gas energy projects and the potential to develop more.[3] Forests in East Texas also provide fuel for energy production. And Texas has significant quantities of manure (feedlot biomass), especially in the High Plains area where there are numerous feedlots.

As an agricultural state, Texas has many resources for biomass energy production.

While cattle manure has the most potential for power use, other forms of agricultural waste have significant possibilities, too. These include poultry litter, rice straw, peanut shells, cotton gin trash and corn stover. In fact, a recent report from the Houston Advanced Research Center estimated that Texas agricultural wastes have the potential to produce 418.9 megawatts of electricity, or enough to power over 250,000 homes, based on average Texas electric use in 2006.[4]

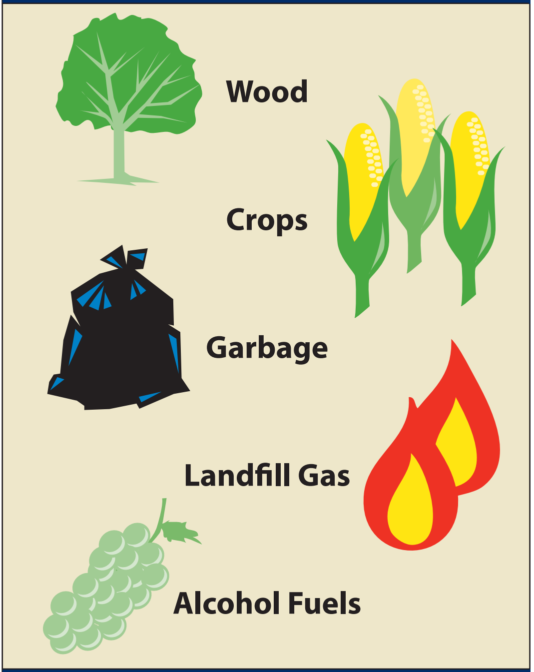
In the U.S., the primary biomass fuels are wood, biofuels and various waste products. Biofuels include alcohols, synfuels and biodiesel, a fuel made from grain and animal fats. Waste consists of municipal solid waste, landfill gas, agricultural byproducts and other material (**Exhibit 12-1**). Most biomass energy used in the U.S. — 65 percent — comes from wood.[5] Another 23 percent of biomass energy used comes from biofuels while the remaining 12 percent comes from waste energy.

Energy generated from biomass is the nation's largest source of renewable energy, accounting for 48 percent of the total in 2006. The U.S. consumed 3,277 trillion British thermal units (Btu) of biomass energy in 2006 (**Exhibit 12-2**).[6] The next largest source of renewable energy is hydroelectric power, with 2,889 trillion Btu consumed in 2006.

In 2005, Texas consumed 73 trillion Btu of biomass energy from wood and waste, and 2.4 trillion Btu from ethanol.[7] Currently, biomass energy accounts for less than one percent of electrical power production in Texas.[8] Texas ranked 22nd in ethanol consumption (691,000 barrels), well behind California (21,864,000 barrels), which was ranked first.[9] Two ethanol plants opened in Texas this year and others are currently under construction and will be in production by 2008. Texas is the largest producer of biodiesel in the nation.[10]

Exhibit 12-1

Types of Biomass

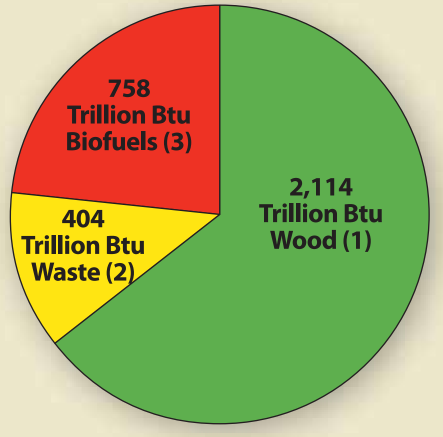


Source: U.S. Energy Information Administration.

The Texas Agricultural Experiment Station expects the use of biofuels to grow more rapidly than other forms of biomass energy.

EXHIBIT 12-2

U.S. Energy Consumption from Biomass, 2006 (in Trillions of Btu)



Notes:
1) Wood includes wood and all derived fuels.
2) Waste includes municipal solid waste, landfill gas, sludge waste and agricultural byproducts.
3) Biofuels include ethanol and biodiesel.

Sources: Texas Comptroller of Public Accounts and U.S. Energy Information Administration.

In the U.S., most renewable energy is used primarily to generate electricity, but biomass energy is an exception. In 2005, about 63 percent of biomass energy was used for heating, 26 percent for electricity generation and 11 percent as transportation fuel.[11]

Biomass energy consumption varies by sector of the economy and by state. Industry uses most of the biomass energy available in the U.S., accounting for 55 percent of total biomass energy consumption in 2006 (**Exhibit 12-3**).[12] In Texas, this pattern is more pronounced with industry accounting for 72 percent of total biomass energy consumption in 2005, the most recent data available (**Exhibit 12-4**).[13] The industrial sector, particularly the paper, chemical and food processing industries, often uses the biomass it produces in its operations to generate electricity, heat and steam that it uses on site.[14]

At the national level, the transportation sector is the second-largest user, accounting for another 15 percent of the nation's biomass energy consumption. In comparison, Texas' transportation sector only accounts for 3 percent of biomass energy consumption in the state. The second-largest user of biomass energy in Texas is the residential sector, which accounts for 18 percent of consumption.

The electric power sector — electric utilities — accounts for about 14 percent of the nation's biomass energy consumption, compared to just 4 percent in Texas. The commercial sector accounts for 3 percent of biomass energy consumed in the U.S and Texas.[15]

While biomass energy accounts for the majority of renewable energy production and consumption in the U.S., it is growing at a slow rate. Between 2001 and 2006, total biomass energy production and consumption both rose by an average of about 4 percent annually. Within the biomass energy category, biofuels experienced the fastest average annual growth in consumption — 24 percent — while wood and waste energy consumption expanded by an average of 1 percent and 2 percent, respectively.[16]

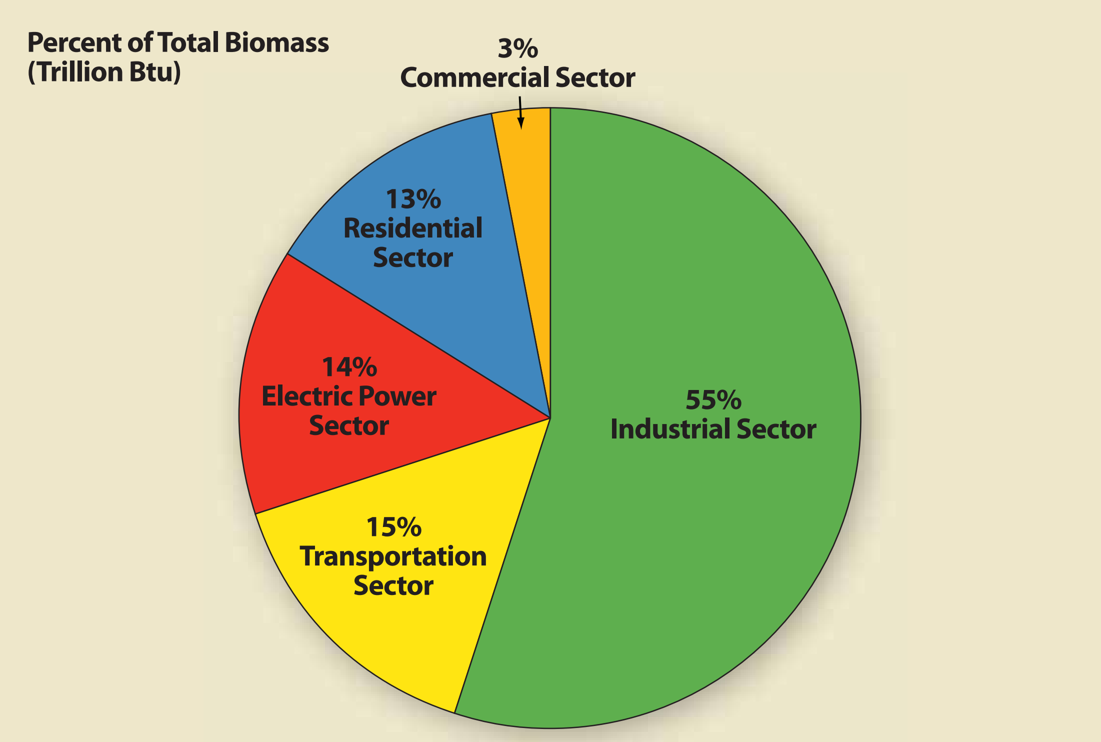
Federal subsidies of $0.51 per gallon of ethanol and $1.00 per gallon of biodiesel have contributed to their recent dramatic production growth. For a complete discussion of subsidies, see Chapter 28.

This growth trend in consumption may continue. The Texas Agricultural Experiment Station expects the use of biofuels to grow more rapidly than other forms of biomass energy.[17] In the U.S., ethanol made from corn currently accounts for the majority of biofuel consumption in the transportation sector. In the future, however, "lignocellulosic" biofuels made from crop residue, grasses, wood products, sorghum, "energy cane" and agricultural waste are expected to supplement corn ethanol. These are commonly referred to by the shorthand term "cellulosic." Public and private funding for new research in cellulosic biofuels is increasing. Corn ethanol requires significant amounts of fertilizers, pesticides, energy and water to grow; cellulosic biofuel production promises to be much more efficient.

The amount of energy needed to produce corn ethanol is a subject of ongoing debate. Improved corn production practices and better ethanol plants, however, have led to a more efficient process. The production of cellulosic ethanol and other biofuels is expected to be significantly more energy-efficient than producing corn ethanol. At present, cellulosic

Exhibit 12-3

U.S. Biomass Energy Consumption by Sector, 2006*



*The industrial sector does not include ethanol heat on co-products from the production of fuel ethanol and biodiesel.

Source: U.S. Energy Information Administration.

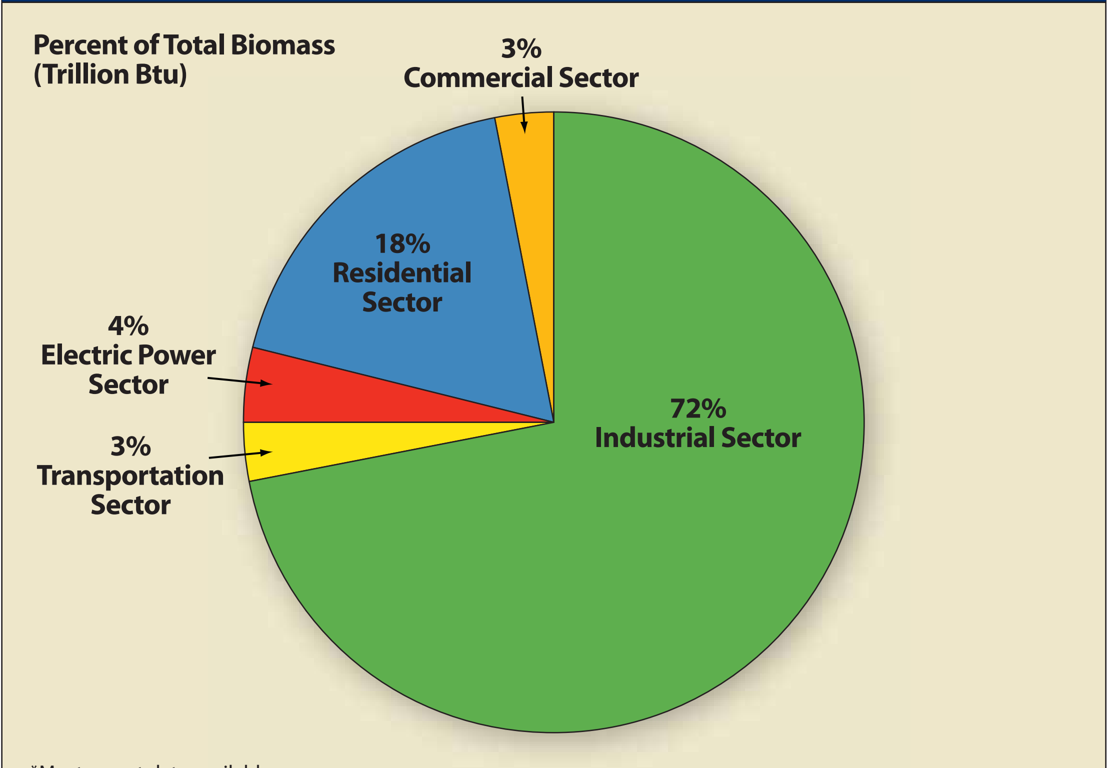
ethanol is cost-prohibitive, but at least eight companies are working on technologies that may make it competitive with other fuels within five years.[18]

The rapid expansion of ethanol has resulted directly in increased corn production and higher prices. In 2006, 20.1 percent of the U.S. corn crop went to ethanol production, rising to 23.7 percent in 2007. The effect of using food crops for fuel has resulted in economic effects beyond corn, however. According to the U.S. Department of Agriculture, other field crops, livestock production costs, and food prices have been affected by corn ethanol as well. For example, higher corn prices led some soybean producers to plant more corn, reducing the amount of soybeans available. At the same time demand for soybean oil increased to make biodiesel, thereby increasing soybean prices. Also, cotton plantings were reduced by 4 million acres in 2007.

Though rising energy prices have also been a factor, the result of these trends is that animal feed prices for cattle, hogs, and poultry have risen and ultimately consumer food costs have risen, too. About 55 percent of the U.S. corn crop is used for animal feed. The effects of higher grain prices on animal feeders vary somewhat depending on the ability of some species to use a byproduct of ethanol production – distiller's grains. Beef and dairy cattle can digest this product better than hogs or poultry, for example. Ultimately, USDA projects higher farm income and retail food prices as a result of these trends and reduced profitability for livestock producers. In fact, Pilgrim's Pride, Inc., based in Pittsburg, Texas, announced that it would close a chicken processing plant in Siler City, North Carolina, and 6 of its 13 distribution centers. The company said record high prices for corn and soybean meal combined with an oversupply of chicken made it necessary to cut costs, resulting in elimination of 1,100 jobs.[19]

Exhibit 12-4

Texas Biomass Energy Consumption by Sector, 2005*



*Most recent data available.

Source: U.S. Energy Information Administration.

Higher food prices have been moderated somewhat by price competition by grocery retailers and the fact that for some food products the value of the agricultural commodity is low compared to packaging, advertising, processing, transportation and other costs.[20]

An upcoming study of the potential of all renewable resources, including biomass, mandated by the Texas Legislature, is expected to be released by the State Energy Conservation Office by early 2009.

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Chapter 13

Ethanol

Introduction

Ethanol (ethyl or grain alcohol) is a renewable fuel used to power vehicles and other internal combustion engines. Ethanol is currently made from feedstock crops such as corn, barley and sugarcane that contain significant amounts of sugar, or materials that can be converted into sugar, such as starch.

About 90 percent of ethanol in the U.S. is made from corn, due in large part to federal subsidies to encourage the production and consumption of corn-based ethanol.[1] Cellulosic ethanol, by contrast, is produced from wheat straw, corn stalks (called stover), sawdust, rice hulls, paper pulp, wood chips, energy cane, sorghum, miscanthus grass and switchgrass, all of which contain cellulose and hemicellulose, which can be converted into sugars and then fermented into ethanol.

At present, corn is much easier and cheaper to process into ethanol than cellulosic biomass. However, compared to corn, cellulosic biomass crops require less energy, fertilizer, pesticide and herbicide to grow.[2] Cellulosic ethanol production may not become economically feasible for a number of years, although the basic technology has existed for more than a hundred years.

Ethanol can be used as an alternative to gasoline and could help reduce America's dependence on imported oil. In early 2007, President George W. Bush announced his goal to reduce U.S. gasoline consumption by 20 percent in 10 years. Furthermore, the 2007 federal energy bill sets a goal that the U.S. will produce 15.2 billion gallons of renewable fuels annually by 2012 and 36 billion gallons by 2022.[3] In addition to the Renewable Fuel Standard (RFS), ethanol production also benefits from federal tax credits.

In addition to federal policies encouraging ethanol production, relatively low grain prices and high crude oil prices contributed to the industry's growth. In January 2007, corn sold for $3.05 a bushel, although by March 2008 increased demand for corn to produce ethanol had driven the price up to $4.83 a bushel, a 58 percent increase in just over a year.[4]

Like all industries, ethanol production can spur job growth and increase local tax revenues. Ethanol production can contribute to local economies.

History

Ethanol has been used as a source of energy for almost 200 years. The 1908 Ford Model T was designed to run on a mixture of gasoline and alcohol. Ethanol use increased during the 1970s and 1980s when gasoline supplies decreased and became more expensive.[5] Currently, ethanol is used as a gasoline additive in mixes of up to 85 percent ethanol.[6]

Uses

Ethanol can be used as an engine fuel by motor vehicles as well as some lightweight aircraft.

It can be blended with gasoline to produce a fuel called E85 — 85 percent ethanol and 15 percent gasoline. This fuel has a high oxygen content, and burns cleaner than other motor vehicle fuel. But ethanol has a lower energy content than gasoline and thus is less efficient; vehicles running on ethanol get fewer miles per gallon. On average, a vehicle consumes 1.4 gallons of E85 for every gallon of regular gasoline.[7]

E85 is used in flexible fuel vehicles (FFVs) that are specifically designed to use it. (All cars built after 1970 can run on E10, a fuel that is 90 percent gasoline and 10 percent ethanol.) Except for minor engine and fuel system modifications, FFVs are identical to gasoline models. FFVs have been produced since the 1980s, and many models are available, though there remain few filling stations that sell E85.

Ethanol also can replace Methyl Tertiary Butyl Ether (MTBE), a fuel additive derived from natural gas used to increase gasoline's octane rating and prevent

About 90 percent of ethanol in the U.S. is made from corn, due in large part to federal subsidies to encourage the production and consumption of corn-based ethanol.

engine knocking. In 2006, several major oil companies announced that they would replace MTBE with ethanol in all of Texas' "non-attainment" cities — areas that have failed to meet federal standards for ambient air quality. These include Dallas-Fort Worth, Houston-Galveston-Brazoria, Beaumont-Port Arthur, San Antonio and El Paso.[8] MTBE replacement alone will create a demand in the state for 400 to 500 million gallons of ethanol per year.[9]

MTBE is being replaced with ethanol because MTBE is water-soluble, is not biodegradable and has been found leaking into some groundwater supplies.[10]

ETHANOL IN TEXAS

At this writing, Texas has two operational ethanol plants, and two more under construction with others planned. Texas has a limited number of fueling stations for E85. Ethanol thus has only a limited impact on Texas and much of the discussion that follows focuses on ethanol's impact nationally, with some discussion of the existing or potential impact on Texas.

At this writing, Texas has two operational ethanol plants.

Economic Impact

According to the Renewable Fuels Association, the ethanol industry created 147,000 jobs in all sectors of the U.S. economy in 2004, and provided more than $2 billion in tax revenue to all levels of the government. The U.S. Department of Energy (DOE) estimates that for every 1 billion gallons of ethanol produced, 10,000 to 20,000 jobs will be added.[11]

A Texas ethanol plant producing 100 million gallons per year could create about 1,600 new jobs in all sectors of the economy. These jobs may be created in other states, since feedstocks for producing ethanol could come from outside Texas.[12]

Consumption

In 2006, the U.S. demand for ethanol was about 5.4 billion gallons. U.S. production of ethanol that year was only 4.9 billion gallons, prompting the nation to import 653 million gallons.[13] The U.S. Energy Information Administration has estimated that Texas motorists used 29 million gallons of ethanol in 2005. Leading the nation, Californians used 918 million gallons of ethanol in the same year.[14] Some states are requiring oil companies to replace the MTBE in gasoline with ethanol, and some companies are doing so voluntarily; this is expected to increase national demand for ethanol.

The U.S. Department of Agriculture (USDA) estimates that by 2010, 30 percent of U.S. corn production will be required to meet the increased demand for ethanol. Even at this rate, USDA estimates that only 8 percent of the nation's annual gasoline consumption will be displaced.[15] The long-term survival of the ethanol industry depends upon a continuing supply of low-cost feedstocks such as corn, or a transition to cellulosic ethanol, using sources such as sorghum, switchgrass or wood.

Production

One bushel of corn (56 pounds) can produce up to 2.8 gallons of ethanol.[16]

As of April 2008, the U.S. had 147 operating ethanol plants, 55 plants under construction and 6 existing plants undergoing expansions.[17] The majority of these plants are located in the Midwestern Corn Belt (**Exhibit 13-1**). Texas has two operating ethanol plants. The U.S. has no commercial cellulosic ethanol plants, but DOE has funded six pre-commercial scale plants for demonstration, none of which are in Texas.

U.S. ethanol production has increased rapidly over the past five years. In 2007, U.S. ethanol production reached 6.5 billion gallons (**Exhibit 13-2**).

EXHIBIT 13-1

Top U.S. Ethanol Producing States, 2007

State	Number of Facilities	Production Capacity (millions of gallons)
Iowa	28	1,862.5
Nebraska	18	1,017.5
Illinois	7	881.0
South Dakota	13	607.0
Minnesota	16	604.6

Source: National Corn Growers Association.

Extraction/Collection

Ethanol can be made from corn by either of two processes: *dry milling* and *wet milling*. Ethanol plants also yield a number of other commercially valuable co-products, such as livestock feed and carbon dioxide.

Dry milling works by grinding the corn into flour and then adding water to create mash. The mash then is mixed with enzymes to convert the starches to sugars. At this point, yeast is added to convert sugar to ethanol and carbon dioxide. Dry mills also produce distillers' dried grain with solubles (DDGS) and carbon dioxide. The livestock industry uses DDGS as a high-value feed, and the carbon dioxide can be sold to beverage makers for carbonation (**Exhibit 13-3**).[18]

In *wet milling*, corn is soaked in water and acid to separate the various grain components. Grinders then separate the corn germ from the fiber, gluten and starches. The starch and water from the mash are converted into ethanol. Other components of the corn can be used to produce corn gluten meal, corn gluten feed, cornstarch, corn syrup and corn oil (**Exhibit 13-4**).

Cellulosic Ethanol

Three primary polymers exist in the walls of plant cells — cellulose, hemicellulose and lignin. To convert cellulose to ethanol, the chains of cellulose molecules must be broken into sugars and then fermented into ethanol using yeasts (**Exhibit 13-5**).

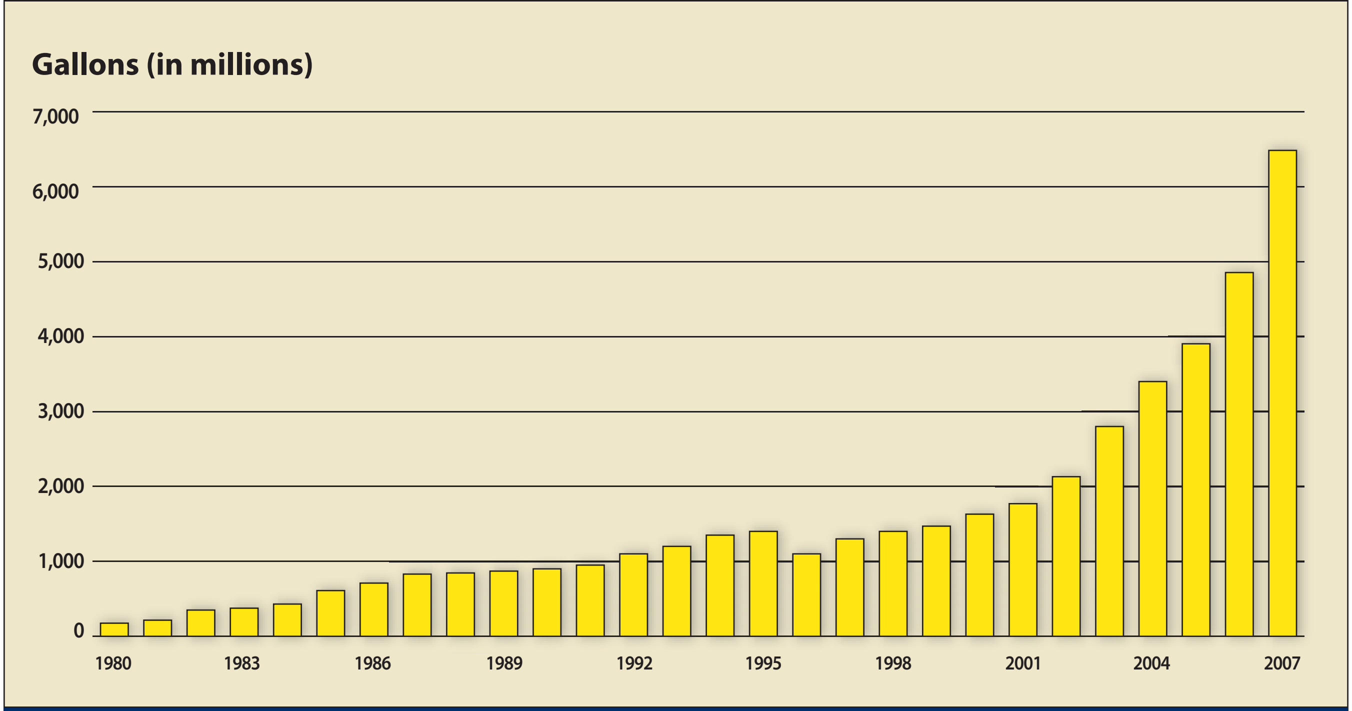
Cellulose can be converted into ethanol by two different methods — the sugar process or the thermochemical process. Acid hydrolysis and enzymatic hydrolysis, in turn, are rival processes used to produce ethanol via the sugar process.

Sugar Process:

In this process, biomass is processed at the ethanol plant. Biomass is ground up resulting in smaller

Exhibit 13-2

U.S. Ethanol Production, 1980-2007

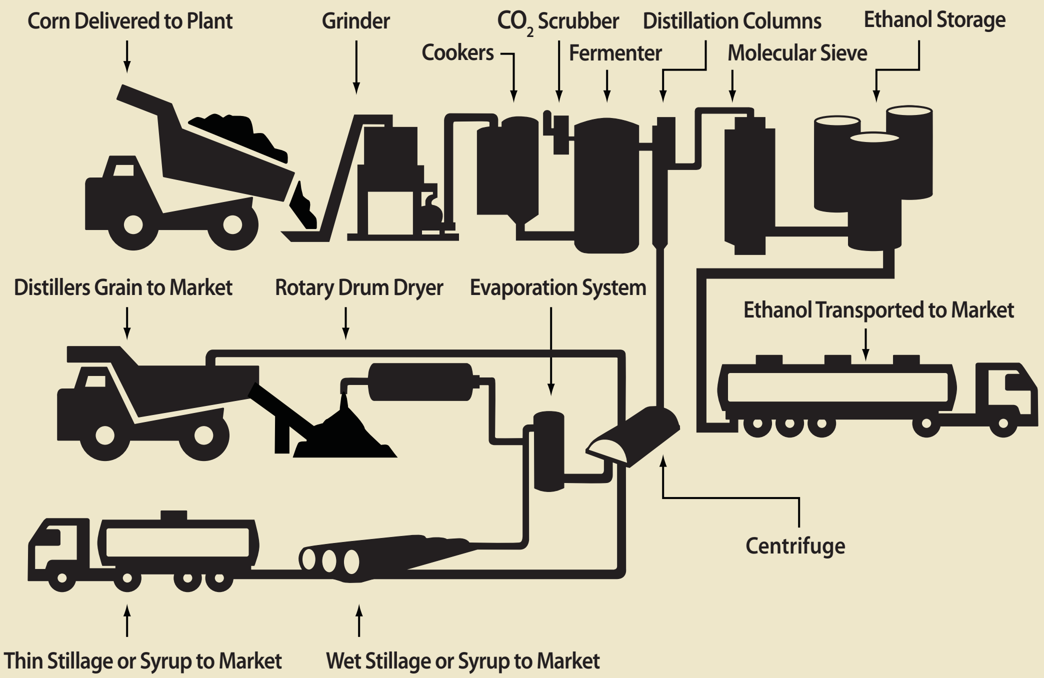


Source: Renewable Fuels Association.

Exhibit 13-3

Producing Corn Ethanol: Dry Milling

The ethanol production process starts by grinding up feedstock so that it can be processed more easily. Once ground, the sugar either is dissolved out of the material or the starch is converted into sugar. The sugar then is fed to microbes that use it for food, producing ethanol and carbon dioxide in the process. A final step purifies the ethanol to the desired concentration. Finally, the ethanol is stored in above-ground tanks until it can be transported.



Source: Renewable Fuels Association.

pieces. Pretreatment is needed to separate the cellulose from lignin in order to make the cellulose available for hydrolysis. Some pentose sugar molecules are freed during pretreatment. Pentose can be fermented into ethanol in limited quantities. The cellulose is hydrolyzed using either acids or enzymes.

Acid Hydrolysis

In this process, two different types of acid are used: dilute acid and concentrated acid. To produce ethanol from plants, a "traditional" process using acid was developed in the 1930s.[19] This process has several drawbacks, however, since the acid must be recycled, and the high processing temperatures can degrade the sugar and lower the ethanol yield.[20]

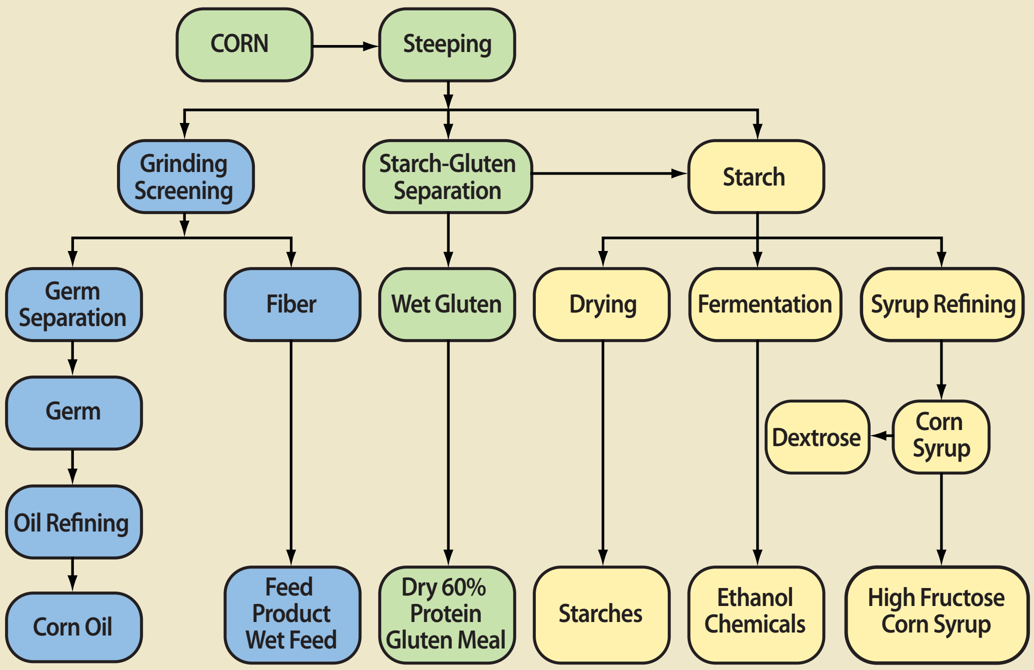
Enzymatic Hydrolysis

Before the enzymes can work to break down the molecules, a pretreatment process breaks down their crystalline structure. The enzymes can come from many sources, such as elephant dung and termite or cow intestines. This process appears to have promise if prices for the enzymes continue falling.

Exhibit 13-4

Producing Corn Ethanol: Wet Milling

Most large ethanol producers use this process, which also yields products such as high-fructose corn sweetener.



Source: Renewable Fuels Association.

The hydrolysis of cellulose results in the formation of glucose — a sugar. Glucose is then fermented into ethanol by yeast or bacteria.

Thermochemical Process:

In this process, biomass is gasified into synthesis gas, or "syngas." The gasification process employs different combinations of temperature, pressure, water and air to convert the cellulosic matter into gas. The syngas then is passed over a catalyst and converted to ethanol.[21] Research at several laboratories across the country is attempting to use thermo-catalytic processes to produce higher-value fuels more closely resembling gasoline and diesel.

Producing ethanol from cellulosic material currently is more expensive than corn-based ethanol, since it can involve many different enzymes as well as genetically engineered organisms (**Exhibit 13-6**). The enzymes used in the sugar process are expensive, although their price has dropped considerably in the past five years. In 2001, the enzyme cost per gallon of ethanol produced was about $5; by 2005, this cost had fallen to between 10 cents and 18 cents per gallon.[22] Many ethanol companies are working with major chemical companies to genetically engineer new types of enzymes and microorganisms, such as bacteria or fungi, for ethanol production.

Another economic barrier to commercial production of cellulosic ethanol is the fermentation step. Currently, the yeasts used for this step cannot process some of the sugars (five-carbon sugars) generated by the breakdown of hemicellulose. Research is being conducted to increase ethanol yields by overcoming this challenge.[23]

Status and Summary of Texas Ethanol Plant Projects

At the time of this report, Texas has two operational ethanol plants. Two other ethanol production facilities are under construction, and 12 more facilities are being planned.[24]

White Energy, Hereford — Deaf Smith County *(completed)* and Plainview — Hale County *(under construction)*

100 million gallons/year at each facility

Feedstock: corn and milo

Hereford facility completion: January 15, 2008, operational

Plainview facility completion: 2008

The Hereford facility was completed in January 2008 and the Plainview facility is under construction. Each plant will add 40 full-time jobs to the local community and support 350 jobs during construction. Each facility is expected to generate about $100 million annually in the local economy. These facilities expect to provide distillers wet grain as feed to local livestock producers.[25]

Panda Ethanol, Hereford *(under construction)*

115 million gallons/year

Feedstock: corn and milo

Completion: 2008

When completed, this plant will be the largest biomass-fueled ethanol refinery in the U.S. About 500 to 600 workers will be needed during its construction. Once operational, it will employ 61 full-time employees. The $120 million facility will be located on a 383-acre site. The steam used in the processing will be generated by gasifying cattle manure.[26]

Levelland/Hockley County Ethanol *(completed)*

40 million gallons/year

Feedstock: corn

Operational: first quarter of 2008

Ground breaking on this facility occurred in October 2006 and construction began in January 2007. Opened in February 2008, the plant is located on a 223-acre site three miles from Levelland, Texas. The plant will process about 15 million bushels of corn annually and employ 30 to 35 employees. The plant is expected to produce 130,000 tons of wet distillers grain and dried distillers grain each year for sale to local livestock producers.[27]

Panda Energy, Sherman County *(planned)*

115 million gallons/year

Feedstock: corn

This facility will refine 38 million bushels of corn annually and generate energy by gasifying 1 billion pounds of cattle manure per year. The site is located on 1,200 acres about three miles from Stratford. This facility is expected to create 138 jobs and generate more than $220 million in the Sherman County economy over the next 10 years.[28] As of this writing, permits for the plant are still pending with TCEQ.

Panda Energy, Muleshoe — Bailey County *(planned)*

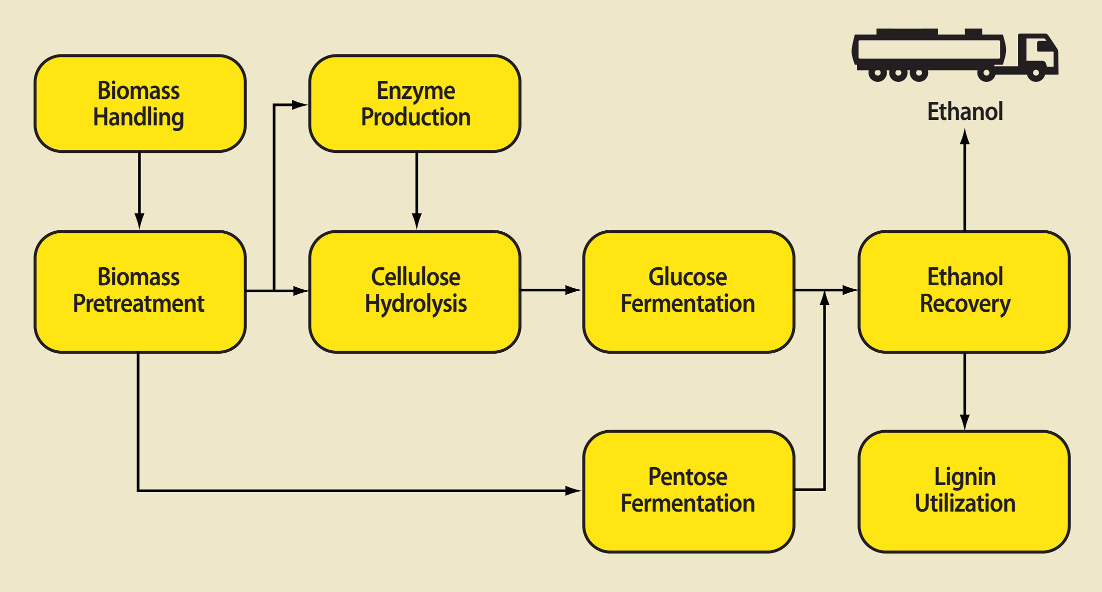
115 million gallons/year

Feedstock: corn

This facility will be one of the nation's most fuel-efficient ethanol facilities. The site is located on 305 acres about eight miles from Muleshoe, Texas. This facility is expected to produce distillers grain, carbon dioxide and ash as co-products.[29] The steam used in the processing will be generated by gasifying cattle manure. At this writing, permits for the plant are still pending with TCEQ.

Exhibit 13-5

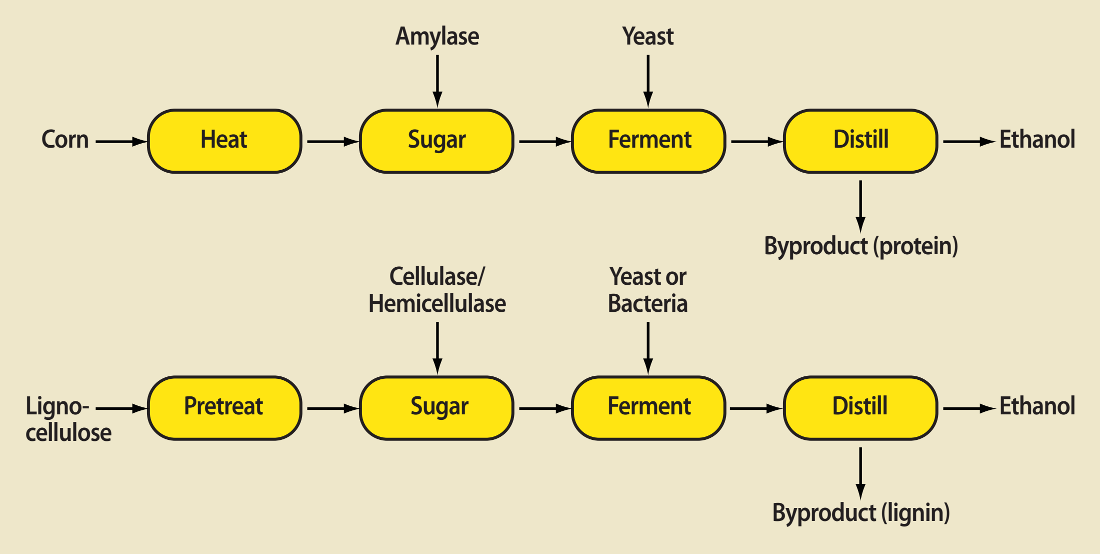
Cellulosic Ethanol Production Process



Sources: U.S. Department of Energy and Renewable Fuels Association.

Exhibit 13-6

Ethanol Production, Corn vs. Lignocellulosic Material



Sources: Dr. Mark Holtzapple, Texas A&M University and Texas Comptroller of Public Accounts.

Ethanol from Sugarcane

Producing ethanol from sugar removes the starch-to-sugar step from the production process, thus making it a more efficient feedstock. Currently, no U.S. ethanol plants use sugarcane, but sugar producer Gay & Robinson of Hawaii plans to build the nation's first sugarcane-to-ethanol plant, using sugar juice and molasses as raw material.[30] The plant could open as early as mid to late 2008.[31]

Production of ethanol from sugarcane makes economic sense in Hawaii because the state produces a large amount of sugar cane and its gasoline prices are much higher than on the mainland.

The U.S. imports some sugarcane-based ethanol from Brazil. American-made, corn-based ethanol is cheaper, however, due in large part to a high import tariff on Brazilian ethanol and a blender credit of 51 cents per gallon available in the U.S . In the continental U.S., moreover, sugarcane can be grown only in the southernmost regions of Texas, Louisiana, Florida and California because it is intolerant to cold weather. Texas ranks fourth in the nation for sugarcane production.[32]

Sugarcane production is strictly controlled by a market allotment system for food use, but no such system is in place for nonfood uses such as biofuel. In addition, the federal government controls the price of sugar, keeping it at twice the price available on world markets, due to high import tariffs.[33] Because of these factors, Texas sugarcane growers can make more money selling their cane to sugar refineries than to ethanol distilleries.

Texas A&M's Agri LIFE Research is crossing sugarcane with miscanthus, a tall perennial grass, to extend its geographical range for lignocellulosic biofuels production. Research also is being conducted to increase the sucrose content of sugarcane and the sugarcane-miscanthus hybrids.

Cellulosic Ethanol From Sorghum

Texas A&M University's Texas Agricultural Experiment Station (TAES) is working on a high-yield variety of sorghum to be used in producing cellulosic ethanol. This variety of sorghum can yield 15 to 20 or more dry tons per acre planted; traditional forage sorghums produce about 10 to 13 dry tons per acre. TAES has estimated that its version of high-yield sorghum would cost between $42 and $50 per dry ton to deliver to a local facility, compared to $50 to $60 per dry ton for traditional forage sorghums and grasses.

The high-yield sorghum being grown by Agri LIFE Research is drought-tolerant, an important trait in Texas. It also uses the same amount of water as corn while producing 33 percent more biomass.[34]

The U.S. Department of Energy (DOE) is pursuing the world's most aggressive cellulosic ethanol initiative. On February 28, 2007, DOE announced funding of up to $385 million in all to construct six cellulosic ethanol plants expected to produce more than 130 million gallons of ethanol per year. None of these DOE-funded plants are in Texas. The funding will last through fiscal 2010. These facilities are expected to produce commercial quantities of ethanol once completed.

Transportation

Ethanol cannot travel in pipelines because it is water-soluble, and as a result will mix readily with any water present in a pipeline. Water often enters pipelines at the terminals, and ethanol that absorbs too much water during transport is unsuitable for use. As a result, ethanol must be transported by truck, train or barge, resulting in higher transportation costs. Most ethanol plants, therefore are situated near major highways or rail lines to ensure efficient movement.

Transportation of corn also can entail costs, and most ethanol plants are located near areas where corn is grown. (To date, the majority of ethanol plants are located in the Midwest because of this constraint.)

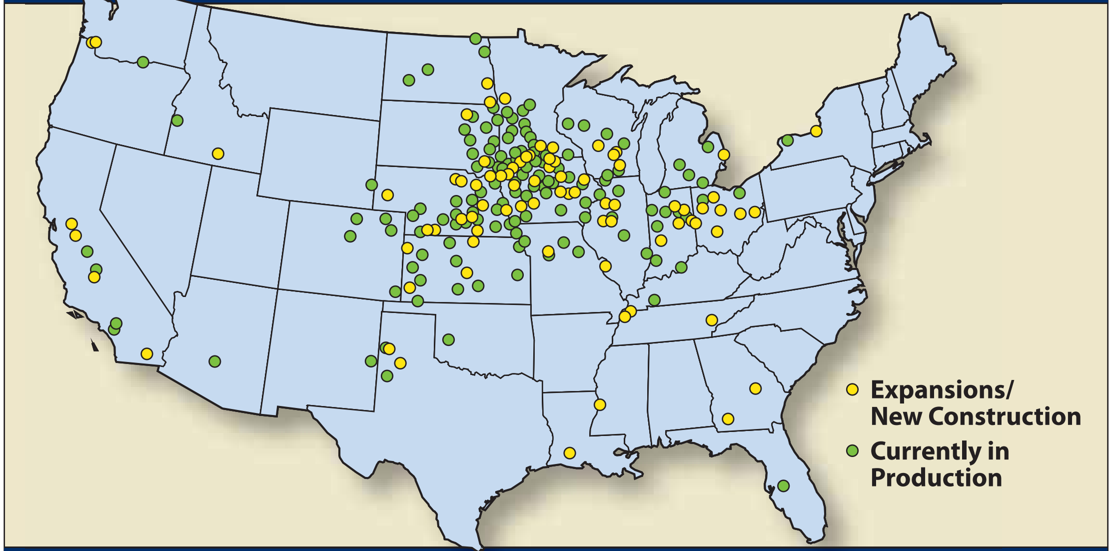
The largest corn-producing states are Iowa, Illinois, Minnesota and Nebraska. While Texas produces a significant amount of corn, it is not in the top tier for production, ranking 11th nationwide in 2007, with 296 million bushels of corn grown.[35] In fact, Texas is a net corn importer, using more corn than is grown.

Some ethanol plants, called "destination plants," are located close to feed yards and dairies, because the by-products of milling (distiller's wet grain and dry distiller's grain) are then fed to livestock. Manure from feed yards also can be used as fuel for the plant, as with the plant currently under construction in Hereford, Texas.

The largest ethanol plants planned for Texas will be located in the Panhandle, close to feedyards and as

EXHIBIT 13-7

Ethanol Plants in the U.S.



Sources: Iowa State University, Center for Agricultural and Rural Development and Texas Comptroller of Public Accounts.

close as possible to Midwestern corn farms (**Exhibit 13-7**). There are more than 1 million head of cattle and 100,000 dairy cows within a 100-mile radius of Hereford, the current home of one completed ethanol plant and one under construction, which could benefit from grain residue.[36]

Storage

Currently, storage of the corn feedstock is becoming a concern due to the extraordinarily large corn harvest expected this year in the U.S. This will be an ongoing problem until more permanent storage sites can be constructed. Once the ethanol is produced, it is stored in above-ground storage tanks where it waits to be transported to a blender.

Availability

In Texas, ethanol (E85) is available to the public as a motor fuel at only 26 locations.[37]

E85 is available at the H.E. Butt Grocery Company (H-E-B) at eight public E85 fueling sites in Schertz, Austin, Killeen, Buda, Waco, Kyle, Mission and Laredo. The Kroger Co., a supermarket chain, operates 17 E85 fueling sites located across Texas. CleanFuel USA, a fueling equipment manufacturer has one E85 fueling site in San Antonio.

In addition, some federal facilities such as military bases in Amarillo, Houston, San Antonio and Wichita Falls have E85 pumps, but these are not open to the public. The Texas Department of Transportation is a national leader for alternative fuel vehicle use in fleet management and is considering using E85 in some of its vehicles. **Exhibit 13-8** shows E85 fueling stations in Texas.[38]

Cellulosic ethanol could greatly increase the volume of ethanol fuel that can be produced and made available to consumers. A 2005 report conducted by the U.S. Department of Energy and the U.S. Department of Agriculture determined that the U.S. could have more than 1.3 billion dry tons of available biomass potential each year by 2030, about 27 percent of it from forest resources and the remaining 73 percent from agricultural resources. If all of this were used to produce biofuels, about a third of the country's transportation fuel needs would be met.[39]

COSTS AND BENEFITS

Ethanol fuel (E85) costs less per gallon *at the pump* than gasoline, due to the federal ethanol blender tax credit of 51 cents per gallon, but it is less efficient because, as noted earlier, it contains less energy than traditional gasoline. Thus a gallon of E85 cannot take a vehicle as far as conventional gasoline would, and depending on current market prices, it can be more expensive to use.

Both the price of E85 and motor gasoline have risen dramatically since 2000. In April 2000, the price of E85 was $1.44 per gallon ($1.80 in gallon of gasoline equivalents). Since then, the national average price has risen to $2.51 per gallon ($3.55 in gallon of gasoline equivalents). The price of E85 has been consistently higher than the price of motor gasoline (**Exhibit 13-9**).[40]

Typically, the price of building an ethanol plant depends largely on the amount of ethanol it will produce. In other words, the larger the production capacity of the facility, the more it costs to build. For example, a plant that could produce 220 million gallons of ethanol per year would cost about $300 million.[41] A plant that could produce 115 million gallons of ethanol per year would cost only $120 million.[42]

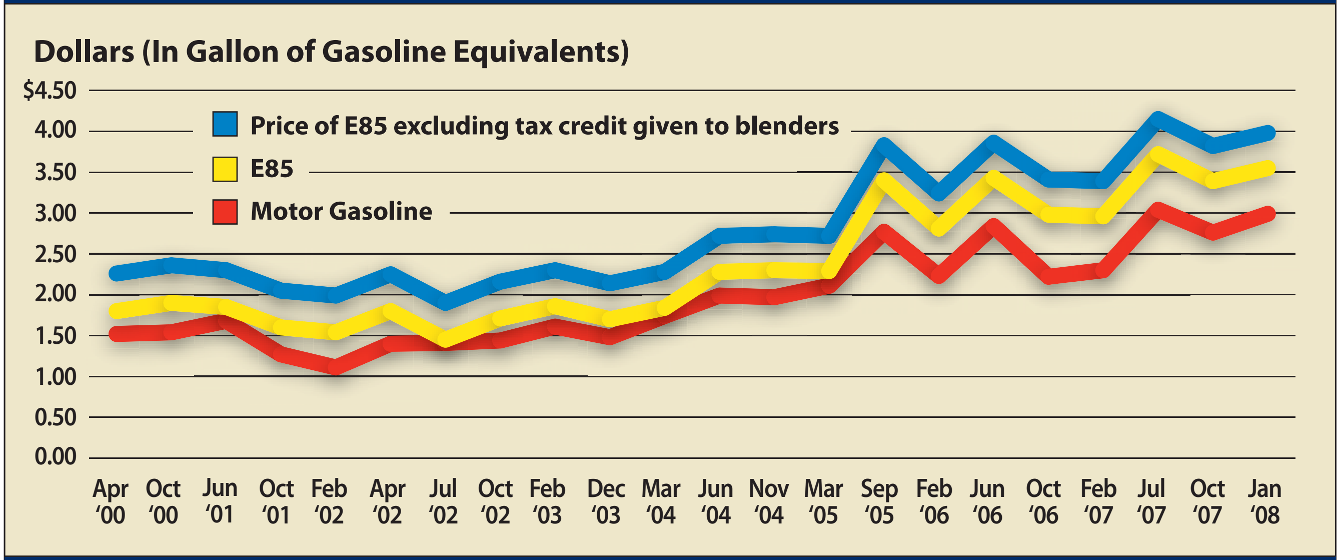
Exhibit 13-8

E85 Fueling Stations in Texas

Source: U.S. Department of Energy.

Exhibit 13-9

Average Price at the Pump in the U.S.
E85 vs. Motor Gasoline 2000-2008



Source: U.S. Department of Energy.

Ethanol and Corn Prices

Due to increased demand, in March 2008, the price of corn reached a 10-year high at $4.83 per bushel.[43] The average annual corn price has been volatile since the 1980s, but has risen steadily and rapidly since the Renewable Fuel Standard was established in 2005. Oil and gasoline prices also have risen during this period. The average annual farm price for corn reached $4.30 per bushel in 2007. In 2007, 23.7 percent (3.1 billion bushels) of the domestic corn crop was used for ethanol production; this is up from 0.5 percent (35 million bushels) of the corn crop in 1980 (**Exhibit 13-10**).[44]

Production Costs

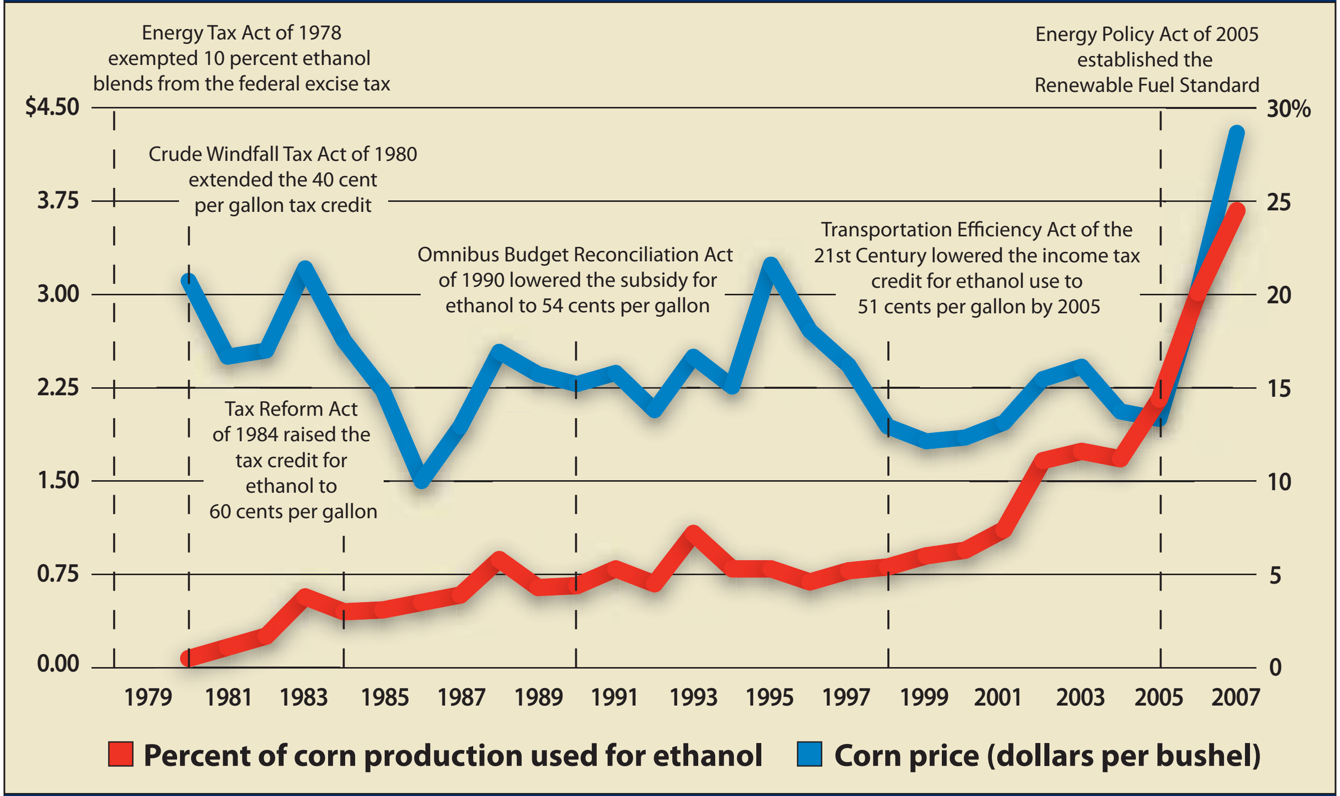
Many factors enter into calculating the production costs of ethanol. In 2005, Dr. David Pimentel, a

Cellulosic Ethanol in Texas

Verenium, an enzyme production and ethanol refining company, has plans to build a cellulosic ethanol facility in the Beaumont area. The company anticipates that the 30 million gallon per year facility will cost between $150 and $180 million and could create 250 construction-related jobs. Once complete, the facility could employ 50 people and have a $750 million impact to the Texas economy over a 20-year period. The facility would use sugar cane, energy cane, and/or sorghum as feedstocks. Given the technology available, with high yields per acre, the company expects that they could generate 2,000 gallons of ethanol for every acre of biomass used. The company plans to submit permit applications in spring 2008, with construction beginning in spring 2009.[45]

Exhibit 13-10

Percentage of U.S. Corn Used to Produce Ethanol and Price per Bushel, 1980-2007



Sources: U.S. Department of Agriculture–Economic Research Service and U.S. Energy Information Administration.

Ethanol's Effect on Crop Prices

The rapid expansion of ethanol production has resulted in both increased corn production and higher corn prices with consequences for other agricultural commodities, animal feed prices and human food prices as well. As **Exhibit 13-10** shows, corn prices have been rising rapidly in recent years.

About 55 percent of the U.S. corn crop is used for animal feed. Less than 10 percent of the crop is used for corn-based human foods.[46] The effects of higher grain prices on animal feeders vary somewhat depending on the ability of some species to use the byproducts of ethanol production - distiller's grains - as feed. Ruminants like beef and dairy cattle can digest this product better than hogs or poultry, for example.

Livestock and poultry feeders across the country are feeling the effects of higher feed prices. The nations' biggest meat and poultry producers have announced cutbacks in production related to rising costs. The largest hog producer in the U.S., Smithfield Foods Inc., based in Smithfield Virginia, announced it will cut production by 5 percent, or 1 million animals, because of high feed costs. Tyson Foods Inc., the largest U.S. meat company, said it will close a beef plant in Kansas resulting in 1,800 lost jobs. The company, based in Springfield, Arkasas, cited a $500 million increase in grain costs and a 40 percent drop in profit.[47]

Texas based companies are reacting, too. Pilgrim's Pride, Inc., based in Pittsburg, Texas, announced that it would close a chicken processing plant in Siler City, North Carolina, and 6 of its 13 distribution centers. The company said record high prices for corn and soybean meal combined with an oversupply of chicken made it necessary to cut costs, resulting in elimination of 1,100 jobs.[48]

Using food and feed crops for fuel also has resulted in economic effects beyond corn prices and livestock production costs. According to the U.S. Department of Agriculture, other field crops and food prices have been affected by rising demand for corn ethanol. Farmers previously cut cotton and soybean plantings, raising prices for those commodities, too.[49]

Soybeans compete most directly with corn in terms of acres planted, particularly in the Midwest where they are planted in rotation with corn. While higher corn prices led some soybean producers to reduce plantings, the demand for soybean oil to make biodiesel increased at the same time. Biodiesel uses 15 percent of U.S. soybeans.[50] Like corn, soybean prices have risen dramatically, from $6.37 a bushel in January 2007 to $11.00 in January 2008.[51] Until 2008 spring planting is complete, it will not be clear what competing crops farmers will choose to plant, a decision some make at planting time in response to commodities futures prices.

DOE-Funded Cellulosic Ethanol Projects

Abengoa Bioenergy Biomass of Kansas, LLC

Plant site: Colwich, Kansas

Source of fuel: Corn stover, wheat straw, milo stubble, switchgrass and other feedstocks

Production: 11.4 million gallons per year

DOE Funding: Up to $76 million

Alico Inc.

Plant site: LaBelle, Florida

Source of fuel: Yard waste, wood waste, citrus peels and vegetations

Production: 13.9 million gallons per year

DOE Funding: Up to $33 million

BlueFire Ethanol, Inc.

Plant site: Southern California

Source of fuel: Assorted green waste and wood waste from landfills

Production: 19 million gallons per year

DOE Funding: Up to $40 million

Brion Companies

Plant site: Emmetsburg, Iowa

Source of fuel: Corn fiber, cobs and stalks

Production: 31 million gallons per year

DOE Funding: Up to $80 million

Iogen Biorefinery Partners, LLC

Plant site: Shelley, Idaho

Source of fuel: Wheat straw, barley straw, corn stover, switchgrass and rice straw

Production: 18 million gallons per year

DOE Funding: Up to $80 million

Range Fuels

Plant site: Soperton, Georgia

Source of fuel: Wood residues and wood-based energy crops

Production: 40 million gallons per year

DOE Funding: Up to $76 million

Source: U.S. Department of Energy.

professor of entomology at Cornell University, and Dr. Tad Patzek, a professor of civil and environmental engineering at the University of California at Berkeley, estimated that it costs about 42 cents per liter, or about $1.59 per gallon, to make ethanol from corn. These costs include costs of corn feedstock, transportation, electricity to run the plant and the cost of waste disposal, among others. They, however, do not include the value of co-products, the market value of which might reduce the net costs of ethanol production.[52] It also should be noted that Pimentel and Patzek used a corn price of 28 cents per liter of ethanol produced. This equates to about $3 per bushel, assuming 2.8 gallons of ethanol produced per bushel of corn. At this writing, corn prices are $4.83 per bushel. This increased feedstock cost would add about 67 cents per gallon to the cost estimated by Pimentel and Patzek.

In 2005, Dr. Hosein Shapouri, an agricultural economist at the USDA, and Dr. Paul Gallagher, a professor of agricultural economics at Iowa State University, estimated that it cost about $0.96 per gallon to make ethanol from corn in 2002. Unlike the Pimentel and Patzek study, these costs include money made from the sale of co-products.[53] Similar to Pimentel and Patzek's study, the feedstock cost is much lower than current costs. In this study, the cost of corn was assumed to be $2.14 per bushel. As noted above, corn prices are $4.83 per bushel at this writing. This increased feedstock cost would add about 96 cents per gallon to the cost estimated by Shapouri and Gallagher.

Demand for ethanol and biodiesel crops has driven up the price of commodities such as corn, palm oil and sugar, contributing to food-price inflation, including beef, eggs and soft drinks.[54] In the U.S., food-at-home prices rose 4.2 percent in 2007, although it is difficult to determine exactly how much of this increase is attributable to ethanol's impact on corn.[55] Many other factors contribute to the cost of food, including transportation, advertising and other costs associated with the food industry. The increased demand for corn for ethanol has affected the livestock industry as well, by increasing feed prices and cutting into livestock feed supplies.

Cellulosic Ethanol

In the absence of any commercial cellulosic ethanol plant, it is not possible to estimate the cost per gallon of ethanol from this process. Experts such as Dr. Bruce Dale, a professor of chemical engineering and materials science at Michigan State University, believe that cellulosic ethanol can be produced for about $2.50 per gallon today. In about five years, using advancements made through DOE funding, Professor Dale anticipates that the price of producing cellulosic ethanol could fall to $1.20 per gallon.[56]

Environmental Impact

Supporters of the ethanol industry say that its use helps the environment by reducing air pollutants. No conclusive studies have shown this to be the case, however. And while alternative fuels, such as ethanol, can reduce America's dependence on foreign oil, the U.S. simply does not have enough acres of farmland to replace most of its gasoline with corn ethanol.

Air Quality

Ethanol supporters also say that its production and consumption are carbon-neutral (**Exhibit 13-11**).

A report by DOE's Lawrence Livermore National Laboratory identified several environmental concerns regarding the use of ethanol as a substitute for MTBE in gasoline:

- When ethanol replaces MTBE, the major concerns are the production of acetaldehyde (a toxic air contaminant) and peroxyacetyl nitrate (an eye irritant).
- Ethanol is shipped by truck or rail. Additional transportation needs could slightly increase the nation's total emissions due to heavy-duty truck and train engines.

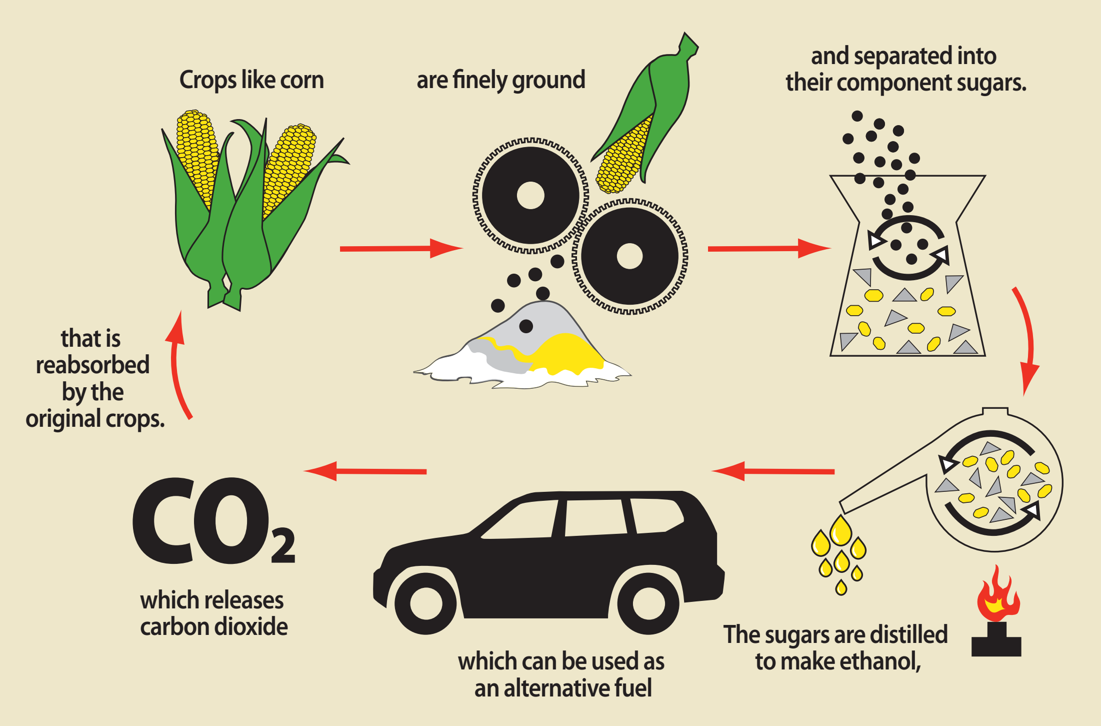
Even so, areas of the country with air pollution problems are focusing on ethanol to help meet the Environmental Protection Agency's (EPA's) clean air standards. According to the Texas State Energy Conservation Office, adding ethanol to gasoline helps it to burn more completely and significantly reduces vehicle emissions. Carbon monoxide emissions are cut by up to 30 percent, Volatile Organic Compounds by about 12 percent and particulates by about 25 percent.[57]

In October 2002, the EPA, U.S. Department of Justice and state of Minnesota settled with 12 Minnesota ethanol manufacturing plants for al-

Demand for ethanol and biodiesel crops has driven up the price of commodities such as corn, palm oil and sugar.

Exhibit 13-11

The Carbon Cycle



Source: U.S. Energy Information Administration.

Growing corn requires a significant amount of water, fertilizer and pesticides.

leged Clean Air Act violations. The New Source Review provisions of the Clean Air Act require such sources to install pollution controls and undertake other pre-construction obligations to control air pollution emissions. The Minnesota plants were required to install air pollution control equipment to reduce emissions of harmful VOCs, carbon monoxide, nitrogen oxides, particulate matter and other hazardous air pollutants produced during the manufacturing process.[58]

Water Use

Growing corn requires a significant amount of water, fertilizer and pesticides, which can have a negative impact on the environment. On average, farmers use about 134 pounds of nitrogen fertilizer per acre of corn each year.[59] Each irrigated acre of corn also requires about 1.2 acre-feet of water (391,021 gallons). By comparison, wheat requires 1.5 acre-feet of water per acre and soybeans require 0.8 acre-feet.[60]

According to a March 2007 *Wall Street Journal* article, critics of ethanol say, "Ethanol plants deplete aquifers, draw heavy truck traffic, pose safety concerns, [and] contribute to air pollution."[61]

According to the U.S. Department of Energy, depending upon climate conditions, corn-based ethanol requires between 2,500 gallons and 29,000 gallons of water per million Btu of energy produced, primarily for crop irrigation; cellulosic crops require significantly less water.[62] A study by the U.S. Department of Agriculture found that water use to irrigate corn averaged 784.6 gallons of water per gallon of ethanol, which equates to more than 9,000 gallons of water per million Btu of energy produced.[63] By comparison, crude oil production and refining can require between one gallon and 2,500 gallons of water per million Btu of heat energy produced, depending primarily on how much water was required to extract crude oil from underground sources.[64] In 2002, water use at ethanol plants averaged 4.7 gallons per gallon of ethanol produced.[65] Biodiesel production typically requires less water than ethanol.

Land Use

Since cellulosic ethanol can be made from any type of plant material, some critics fear that wider use could affect the environment due to tree cutting and additional water use to grow cellulosic materials. It should be noted that some potential cellulosic energy crops can be drought-tolerant and use less water than corn. In 2003, almost 16 percent of the nation's cropland in the U.S. was not being cultivated. This amounts to 58 million acres of land that could be used to grow low-input, drought-tolerant crops for making cellulosic ethanol.[66]

Ethanol is biodegradable, so accidental spills pose few risks to the environment.

To date, the EPA has not studied the overall environmental impact of both producing and consuming ethanol. A March 2007 DOE study found that greenhouse gas emissions from corn-based ethanol are 18 to 28 percent lower than those from gasoline, while cellulosic ethanol greenhouse gas emissions are 87 percent lower. This study did not take into account the environmental effects of producing ethanol, however.[67]

Other Risks

Ethanol corrodes rubber, steel and aluminum, and most vehicles are not designed with this in mind. Ethanol has a higher freezing temperature than gasoline and cannot travel in pipelines because it absorbs water.

A diverse and growing group of detractors, from ranchers to some environmentalists, oppose expanded use of corn-based ethanol, prompting a "food versus fuel" debate as the cost for corn spirals upward due to high demand. The National Cattlemen's Beef Association, National Chicken Council, National Turkey Federation and National Pork Producer's Council all testified before Congress in March 2007 to end corn ethanol subsidies.[68] In August 2007, the National Cattlemen's Beef Association sent a letter to Congress in opposition of increasing the Renewable Fuel Standard.[69]

The National Corn Growers Association maintains that:

- increased demand is being met with increased production, which should allow corn growers to satisfy both domestic and export demand;
- the ethanol process creates useful livestock feed and food products; and
- corn demand has no noticeable impact on food prices.[70]

Tyson Foods, however, the world's largest processor and marketer of chicken, beef and pork, has warned that ethanol-driven corn prices will push up the cost of chicken and beef for American consumers.[71]

In Texas, Dr. David Anderson, a Texas Cooperative Extension economist, stated that as ethanol production grows, livestock producers should consider the following possibilities:

- higher feed costs;
- feeder cattle and calf prices adjusted to the price of corn;
- reduced production in terms of cattle weights and profitability; and
- a livestock industry that is less competitive in the world market.[72]

The food versus fuel debate has generated increased interest in cellulosic ethanol. Due to the complexity of the process, however, only relatively small-scale production has been possible to date. Cellulosic ethanol research continues to be conducted in Texas.

The food versus fuel debate has generated increased interest in cellulosic ethanol.

State and Federal Oversight

The federal Clean Air Act and Clean Water Act both affect ethanol plants.

On April 12, 2007, EPA set emissions rules for ethanol plants. Ethanol plants that use carbohydrate feed stocks such as corn are not required to count "fugitive" emissions (those not coming from stacks or vents) to determine if they exceed emission limits.

EPA now allows new ethanol plants to emit up to 250 tons of regulated pollutants per year in certain areas, not including non-attainment areas.[73] Previously, these plants were permitted to emit only 100 tons of regulated pollutants per year; many think the new limits will mean more pollution and cause breathing problems for residents located near the plants.

The Texas Commission on Environmental Quality (TCEQ) grants permits for air and wastewater quality. It typically takes a year to obtain an air permit for a new ethanol facility in Texas. It can also take about one year to obtain a wastewater permit from TCEQ. These timelines can encounter significant delays, however, depending on public meeting requests or contested case hearings.[74]

Subsidies and Taxes

The largest federal ethanol subsidy is the volumetric Ethanol Excise Tax Credit (VEETC) of 51 cents per gallon of ethanol. The incentive reduces the amount of excise tax the blender has to pay on a dollar-for-dollar basis. If a blender uses the ethanol to make E85, the tax credit amounts to 43.4 cents per gallon of E85 produced (0.85 * $0.51 = $0.434). Congress has extended this incentive through 2010. Often, the blender is the oil company that produces the gasoline.

The largest federal ethanol subsidy is the blender tax credit of 51 cents per gallon of ethanol.

In 1980, Congress placed a 2.5 percent tariff on foreign-produced ethanol. According to the *Wall Street Journal*, this tariff was designed "to protect prices for U.S. corn growers in Farm Belt states."[75] Brazil produces ethanol for much less than the U.S. can because Brazilian ethanol is sugarcane-based. (Again, producing ethanol from sugar removes the starch-to-sugar step of the production, making production costs lower than ethanol produced from corn.)

The import duty on ethanol, currently 54 cents per gallon, has kept the price of Brazilian and other foreign ethanol higher than domestic production. A so-called "Caribbean Loophole" to the law, however, provides an exception for ethanol imported through or from the Caribbean islands, up to a total equivalent to 7 percent of U.S. production. Lawmakers from some farm states want to close this loophole.

Most states offer tax incentives related to ethanol, including exemptions, deductions, credits and loans. Each state's program is different. In South Carolina, producers of corn-based ethanol receive a production tax credit of 20 cents per gallon and producers of ethanol from other feedstocks receive 30 cents per gallon. In Indiana, ethanol producers can claim a credit of 12.5 cents per gallon.[76]

Additionally, some states offer retailer tax credits. For example, Indiana provides E85 retailers a credit against state gross sales tax of 18 cents per gallon of E85 sold. In New York, E85 used to operate motor vehicles is exempt from state sales and use taxes entirely.

Cellulosic Ethanol

In addition to the Energy Policy Act of 2005, the Energy Independence and Security Act of 2007 contains several incentives focused on the research and development of ethanol derived from cellulosic biomass.

In June 2007, DOE announced $375 million in funding grants for three cellulosic ethanol research centers. The centers will be led by Oak Ridge National Lab in Tennessee, the University of Wisconsin in Madison and the Lawrence Berkeley National Laboratory in California.[77]

The Tennessee center will attempt to genetically engineer plant cell walls and new bioenzymes to break down plant cell walls, particularly in switchgrass and poplar trees. The Wisconsin center will work to improve the characteristics of feedstock plants, feedstock processing and the conversion of feedstocks to fuel, focusing on switchgrass and poplar trees as well as corn stover (stalks). It will also educate farmers and society as a whole on current technology related to biofuels. The California center will focus on developing specially designed feedstock crops, increasing the activity of enzymes and studying the microbes used in the ethanol distilling process.[78]

In July 2007, Texas Governor Rick Perry awarded $5 million out of the Texas Emerging Technology Fund for biofuels research, particularly for research into cellulosic ethanol.[79] The grant went to Texas A&M University's Agriculture and Engineering BioEnergy Alliance, a partnership between AgriLIFE Research (formerly the Texas Agricultural Experiment Station) and the Texas Engineering Experiment Station.[80]

More information on subsidies and incentives for ethanol can be found in Chapter 28.

Biobutanol

Many experts in the biofuels industry believe that butanol and other higher molecular weight fuels are the next-generation biofuels with potential to surpass both corn-based and cellulosic ethanol. These fuels can be made from biomass feedstocks and have many advantages over ethanol:

- they are compatible with current fuel infrastructure (pipelines) because of low water affinity;
- they have a higher energy content per gallon than ethanol, almost as high as gasoline; and
- butanol can be used in blends of up to 17 percent without engine modifications, compared to blends of up to only 10 percent with ethanol.[81] Higher molecular weight biofuels may be used as a direct substitute for gasoline and diesel.

Depending on the fuel, new processing systems will be required. These second generation biofuels are still many years away from commercial production, and many technological barriers must be overcome before a large market for this biofuel can emerge.[82]

OTHER STATES AND COUNTRIES

Brazil is the world's largest producer of sugarcane and the largest producer of ethanol. In 2006, Brazil shipped 3.4 billion liters (898 million gallons) of ethanol out of the country. About half of Brazil's ethanol exports went to the U.S.[83]

To support the ethanol industry, the Brazilian government places large sales taxes on gasoline and subsidizes ethanol production. Achim Steiner, the head of the United Nations Environment Program, has expressed concerns that ethanol production in Brazil will further harm the Amazon rainforests, due to an increased need for farmland.[84]

Columbia and China also have significant ethanol programs. In June 2007, the Associated Press reported that China was banning the production of ethanol from corn and other food crops because authorities are worried about food-price inflation. China is considering switching to cassava, a plant native to South America but grown throughout the world, or other types of biomass such as sorghum.[85]

OUTLOOK FOR TEXAS

Availability of E85 remains an issue, especially in Texas. Two ethanol production facilities were recently completed and there are two ethanol production facilities currently under construction. But Texas has only a handful of E85 pumps.

Heavy federal subsidies have resulted in a rapid and large expansion of ethanol production throughout the U.S. As a result, an increasing percentage of the U.S. corn crop is being devoted to ethanol production.

Controversy has arisen regarding the amount of energy needed to produce ethanol compared to gasoline. Numerous studies on this question have yielded varying results. A 2005 study by Dr. David Pimentel of Cornell University and Dr. Tad Patzek of U.C. Berkeley concluded that producing ethanol from corn requires 29 percent more fossil energy than is contained in the resulting product.[86] A 2004 study by Dr. Hosein Shapouri of the USDA, however, concluded that producing ethanol with corn creates a 67 percent net energy gain.[87] The debate over energy conversion efficiency continues, but higher production efficiency processes are emerging.

An increasing percentage of the U.S. corn crop is being devoted to ethanol production.

An article produced by Oxford Analytica, an international consulting firm representing both private businesses and governmental agencies, cautions that the ethanol boom in the U.S. requires careful management because heavy federal subsides and import barriers may distort trade, which could prompt challenges by the World Trade Organization. At present, ethanol depends upon high oil prices and subsidies to be economically feasible.[88]

As noted above, EPA has not studied the overall environmental impact of producing and consuming ethanol, but many experts across the nation are concerned about both.

High corn prices are good for farmers, but bad for livestock producers and consumers, because so many products are made from corn. Texas has a large livestock industry, and high feed prices

Butanol and Ethanol from Glycerin

Another use for waste glycerin is being developed by University of Alabama at Huntsville Professor Katherine Taconi and her colleagues; they are using bacteria from wastewater treatment plants to convert crude glycerin into butanol. Professor Taconi says the butanol "has a higher energy yield per gallon than ethanol, and also blends better with petroleum-based fuels."[89]

At Rice University in Houston, engineers are working on still another use for glycerin waste. Chemical engineer Ramon Gonzalez has developed a fermentation process using common bacteria in an oxygen-free environment that converts glycerin to ethanol. According to Gonzales, producing ethanol from glycerin could be 40 percent cheaper than making it from corn.[90]

The research has lead to a startup company, Glycos Biotechnology, Inc., based in Houston. The company plans to form partnerships with companies in the biodiesel, glycerin and ethanol industries. Glycerin-to-ethanol plants could be built alongside biodiesel production facilities, using glycerin waste generated on site as a feedstock.[91]

This technology provides a way to make a biofuel even more efficient by turning related waste into energy. It would help maximize the energy yield from fuel crops and mitigate the environmental effects of biodiesel production.[92]

affect it. Consumers are likely to feel some impact of high corn prices through increased food costs, even though many other factors may have a greater effect on prices at the grocery store.

Many different choices are needed to meet the growing demand for fuel in Texas. Ethanol can play a role in reducing dependence on foreign oil, but corn-based ethanol clearly is not the only answer to the nation's fuel problems. The nation simply does not grow enough corn to meet its energy needs. Even if the *entire U.S.* corn harvest in 2007, 13.1 billion bushels, were turned into ethanol, it would have produced only 36.6 billion gallons of ethanol, enough to replace about 30.2 percent of U.S. gasoline consumption in 2007.[93]

It is, of course, not feasible to devote the entire U.S. corn harvest to producing ethanol. If it is to make a significant impact on the U.S. fuel supply, ethanol must be imported from other countries or cellulosic ethanol production must be improved and made more cost-efficient. Possible alternative feedstocks include sorghum, energy cane, wood chips and switchgrass, among others.

Scientists have been working to make the cellulosic process economically feasible for commercial production for years, and it is still too expensive to be a viable fuel option. But Texas A&M University recently has shown initiative in this research, forming a four-year partnership with Chevron to study lignocellulosic biofuels. The partnership aims to identify and optimize production of non-food and non-feed energy feedstocks for biofuels; develop harvest, transportation and storage systems for energy feedstocks; and develop technology for biofuels processing.[94]

The ethanol industry in Texas will continue to grow over the next several years. With the promise of federal subsidies and the recently increased federal Renewable Fuel Standard, ethanol production will continue to increase and there will be a noticeable impact to local rural economies.

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[87] Hosein Shapouri, James Duffield and Andrew Mcaloon, "The 2001 Net Energy Balance of Corn-Ethanol."

[88] "Ethanol Boom Requires Careful Management," *Oxford Analytica* (March 9, 2007).

[89] Amy Coombes, "Glycerin Bioprocessing Goes Green," *Nature Biotechnology* (September 2007), p. 953.

[90] "Biodiesel's Waste Glycerin," *Technology News Daily* (June 27, 2007), http://www.technologynewsdaily.com/node/7271. (Last visited January 17, 2008.)

[91] Anduin Kirkbride McElroy, "Research Reveals New Biofuels Link," *Ethanol Producer Magazine* (November 2007), http://www.checkbiotech.org/green_News_Biofuels.aspx?infold=16051. (Last visited April 21, 2008.)

[92] Amy Coombes, "Glycerin Bioprocessing Goes Green."

[93] The National Corn Growers Association reported that 13.1 billion bushels of corn were harvested in the U.S. in 2007. If all of this were converted to ethanol at 2.8 gallons per bushel, 36.6 billion gallons of ethanol could have been produced. Using this ethanol to make E85 could have yielded 43.1 billion gallons of E85, displacing only 30.2 percent of the 142 billion gallons of motor gasoline used in 2007. This hypothetical substitution was made on a gallon-for-gallon basis. Keep in mind that one gallon of E85 has a much lower energy content than one gallon of gasoline.

[94] Texas A&M University System Agriculture Program, "Chevron, Texas A&M Form Alliance To Convert Non-food Crops into Renewable Fuels," College Station, Texas, May 30, 2007, http://www.tamus.edu/systemwide/07/07/research/biofuels.html. (Last visited April 21, 2008.)

CHAPTER 14

Biodiesel

INTRODUCTION

"Biodiesel" — diesel fuel made from animal or vegetable materials — is an alternative fuel that has been used in motor vehicles since the beginnings of the automobile industry. It can be substituted for petroleum-based diesel fuel ("petrodiesel") in diesel engines. Vehicles using biodiesel emit fewer pollutants than petrodiesel, although they also generally get slightly fewer miles per gallon.

The basic process for making fuel from organic matter has not changed since it was invented in the nineteenth century. The process, called transesterification, forces vegetable oil or animal fat to react with a catalyst (usually sodium hydroxide) and methanol or ethanol to produce glycerol and fatty acid esters, the latter being the actual chemical name for biodiesel (**Exhibit 14-1**). Transesterification originally was used to obtain glycerol for soap; what we now call biodiesel was a byproduct of the soap-making process.

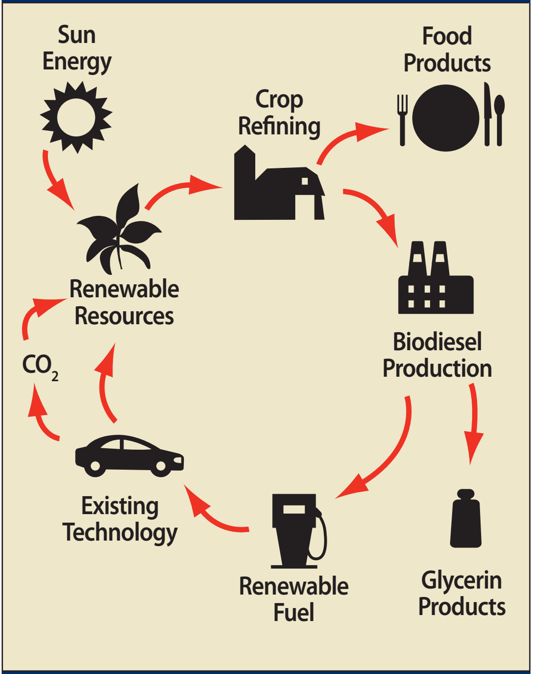
Many products, including peanut oil, hemp oil, corn oil and tallow (beef fat) have been used as feedstocks for the transesterification process.[1] Today, the most common sources for biodiesel are:

- plants: soybeans, peanuts, rapeseed, palm, corn, sorghum, canola, sunflower and cottonseed;
- animal fats: tallow, white grease, poultry fats and fish oils; and
- recycled greases: used cooking oils and restaurant frying oils.[2]

As the nation's largest producer of biodiesel, Texas could benefit from any future expansion in its production or use. The biodiesel industry can affect the economy through investments in construction, spending on related goods and services and jobs.

EXHIBIT 14-1

Biodiesel Production Cycle



Source: PropelBiodiesel.

History

When German engineer Rudolph Diesel first demonstrated his compression ignition engine at the 1898 World Exhibition in Paris, he used peanut oil for fuel. At the time, Diesel thought that biofueled engines were a good alternative to the steam engine. In fact, diesel engines generally ran on vegetable oils until the 1920s, when the engines were first altered to allow them to use petroleum products for fuel.[3]

Diesel was not alone in his faith in biofuels. Henry Ford designed his automobiles, beginning with the 1908 Model T, to use ethanol, a fuel distilled from corn. Ford even built an ethanol plant in the Midwest and formed a partnership with Standard Oil to sell it in the company's fuel stations.

New Sources for Biodiesel

Algae

Making biodiesel from little more than sunlight and water is an attractive proposition that at first may appear to be little more than science fiction. Nonetheless, researchers have been studying this approach since the late 1970s.

Algae are single-celled organisms that, like plants, produce energy through the process of photosynthesis, converting water, sunlight and carbon dioxide into "food" in the form of an oil. This algae oil can be used to produce biodiesel for engines.[4] Extracting the oil leaves behind dried green flakes that can be further reprocessed to create ethanol, another fuel.[5]

Algae intended for biodiesel are grown in water and fed carbon dioxide waste from industrial sources such as power plants, ethanol manufacturers, refineries and cement/kiln operations.[6] The process can be used to reduce carbon dioxide emissions from power plants, and the algae also devour other pollutants.[7]

Algae are highly flexible; they can be grown in most climates, and do not require arable land for production. According to the National Renewable Energy Laboratory (NREL), "[m]icroalgae systems use far less water than traditional oilseed crops."[8] Algae can be grown in brackish water, seawater and even wastewater.

Algae are perhaps the most renewable of energy sources, since unlike most plant stocks, they can be grown throughout the year and harvested continuously.[9]

In early studies, strains of algae selected for their high oil production were grown in large outdoor open-air ponds known as "algae farms." The open nature of the farms was problematic for keeping temperatures consistently warm enough for the algae to grow, however, and for keeping other strains of algae from invading the ponds and overtaking the favored oil algae.

Bioreactors being studied today grow algae in plastic bags or tubes that let sunshine in and keep contaminants out. Production facilities are still called "algae farms," though.

In 1996, NREL ended its algal fuel research program due to a lack of funding. In October 2007, however, NREL announced that it had entered into a collaborative research and development agreement with Chevron Corporation "to study and advance technology to produce liquid transportation fuels using algae."[10] Chevron Technology Ventures is funding the initiative. Other private ventures and university partnerships concerning algal energy production are also under way.

GreenFuel Technologies of Cambridge, Massachusetts has partnered with Arizona Public Service to test algae production at the utility's natural gas-burning power plant just west of Phoenix. Solix Biofuels, an algal energy fuel company based in Fort Collins, Colorado is teaming up with New Belgium Brewery to use the carbon dioxide produced in the brewing process to feed its algae. Solix plans to build a test bioreactor on property owned by New Belgium.[11]

Valcent Products, Inc. has built an algae growing system in the El Paso area dubbed "Vertigro," not only to produce algal oil but also to test and develop the system for eventual sale to other biofuel refineries in the U.S., Europe and South Africa.[12]

South Texas will be home to a proposed research and development program to develop algae derived JP8 jet fuel. The project will be part of PetroSun's initial commercial algae-to-biofuels facility in Rio Hondo, Texas. The algae farm is estimated to produce at least 4.4 million gallons of algal oil and 110 million pounds of biomass annually.[13]

New Sources for Biodiesel (cont.)

The Texas Agricultural Experiment Station and General Atomics have received Department of Defense and Texas Governor's Office Emerging Technology Funds to demonstrate algal biodiesel production at the Texas Agricultural Research and Extension Center at Pecos. At least four different bioreactor designs will be tested with proprietary algae strains under varying conditions.

The algal process is not yet financially competitive with traditional forms of energy. In its 1996 closeout report, NREL projected that the cost for producing biodiesel from algae at that time was "two times higher than current petroleum diesel fuel costs."[14]

In 2007, the retail price of diesel is twice what it was in 1996, but companies have yet to produce algal fuel for less than the cost of other types of energy.

In addition to the sale of algae-based biodiesel, other revenue may come from the sale of "carbon credits" used by various countries in carbon trading markets intended to reduce carbon emissions. The value of such earnings cannot be estimated, but it could make algal oil production commercially viable in some jurisdictions.

Despite the financial support of these leaders of industry, the biofuels industry did not last. Extremely low prices for petroleum products in the 1920s led to their eventual domination of the vehicle industry. Today's sharp increase in oil prices, however, has spurred renewed interest in biofuels.[15]

Uses

Most biodiesel used in the U.S. fuels fleet vehicles. Hundreds of big and small fleets run on biodiesel, including those operated by the U. S. Postal Service (USPS) and the military as well as vehicles belonging to various metropolitan transit systems, agricultural concerns and school districts.[16] USPS states that its fleet of 43,000 alternative-fuel vehicles is the world's largest.[17] San Francisco's city fleet of diesel vehicles, which includes fire trucks, ambulances and buses, also runs on biodiesel.[18]

Biodiesel can be used alone or mixed with petroleum-based diesel fuel. The most common blend in current use, "B20," is 20 percent biodiesel and 80 percent petroleum diesel. B100 is pure biodiesel (**Exhibit 14-2**).

Vehicles using B100 experience a 5 to 10 percent reduction in fuel efficiency.[19] Vehicles that run on B20 have almost the same fuel efficiency as those that run on petrodiesel, experiencing a 1 to 2 percent drop that is difficult to measure.

The U.S. Army, Navy, Air Force and Marines all use B20 at bases and stations throughout the country. Of the four branches, the Marine Corps offers the most B20 locations.[20]

Biodiesel and heating oil mixes also heat homes and businesses, especially in the northeastern U.S.[21] The Warwick School Department in Warwick, Rhode Island, for instance, used various biodiesel-blended heating oils to fuel boilers in several of its schools from 2001 to 2005. When the experiment began, it was the first documented use of "bioheat" in the U.S. All schools reported an improvement in the performance of their boilers as well as a decrease in emissions.

The schools received grants and additional funding from the National Renewable Energy Laboratory to pay for the biofuel, since it cost more than regular heating oil. When NREL funding for the biofuel experiment ended in 2005, the schools reverted to conventional heating oils.[22]

BIODIESEL IN TEXAS

Texas has been the nation's leading biodiesel producer, with 72.9 million gallons produced in 2007. Much of the production is made from soybean oil from plants located in the Midwest. Current high production prices because of climbing soybean prices have slowed sales in the state and led producers to export more biodiesel to Europe.

Texas has been the nation's leading biodiesel producer, with 72.9 million gallons produced in 2007.

Exhibit 14-2

Biodiesel Blends

Name	Blend	Properties
B5	5 percent biodiesel 95 percent petrodiesel	Very similar to petrodiesel; generally accepted by all engine manufacturers. Reduces air pollution from unburned hydrocarbons, carbon monoxide and particulate matter, and emits lower levels of carbon dioxide than petrodiesel. Approved for use in Texas.
B10	10 percent biodiesel 90 percent petrodiesel	Reduces air pollution and emits lower levels of greenhouse gases than petrodiesel.
B20	20 percent biodiesel 80 percent petrodiesel	May cause a slight (1 percent to 2 percent) decrease in engine power and fuel economy. Lowers unburned hydrocarbons by 21 percent, carbon monoxide by 11 percent and particulate matter by 10 percent. Previously thought to cause a less than 2 percent increase in NO_X emissions, although broader, more recent studies indicate no increase on average. Approved to use in Texas with additives.
B100	100 percent biodiesel	May cause a 5 percent to 10 percent decrease in engine power and fuel economy.

Source: U.S. Department of Energy.

The U.S. National Biodiesel Board estimates that the U.S. produced 250 million gallons in 2006 and 450 million gallons in 2007.

Economic Impact

No estimate of the overall economic effect of the Texas biodiesel industry is available, although at this writing the Biodiesel Coalition of Texas is preparing estimates. As the nation's largest producer of biodiesel, Texas could benefit from any future expansion in its use. The biodiesel industry can affect the economy through investments in construction, spending on related goods and services and jobs.

Soybeans are the most common oil source for biodiesel. Biodiesel production consumes 15 percent of the U.S. soybean crop and already has raised soybean prices. Texas farmers, however, raise a relatively small amount of soybeans — 3 million bushels in 2007, compared to national production of 2.59 billion bushels in the same year or a little over one-tenth of one percent of the U.S. total.[23] Texas has no soybean crushing plants because the crop is so small. As a result, soybean oil used in Texas is imported from other states.

The effects of biodiesel production are intertwined with the boom in ethanol production and related corn price increases (see Chapter 12). Record corn prices have prompted corn producers to cut soybean plantings, just as demand for soy products is increasing in Asia. Resulting price increases have affected both human food and animal feeding costs, according to the U.S. Department of Agriculture (USDA).[24]

Consumption

The U.S. consumed more than 43.1 billion gallons of diesel in 2005; biodiesel accounted for only about 91 million gallons or 0.21 percent of that market, according to the U.S. Energy Information Administration (EIA).[25] No Texas biodiesel consumption figures are available from private associations or government agencies at this writing.

In late 2007, the cost of biodiesel production increased dramatically due to the rising costs of feedstocks. State financial incentives and subsidies were eliminated at the same time, although federal subsidies remain in place. At many retail sites, biodiesel now costs more than petrodiesel, and Texas sales have fallen in consequence. Most biodiesel produced in Texas today is exported to other states and countries.[26]

Production

The U.S. National Biodiesel Board estimates that the U.S. produced 250 million gallons in 2006 and 450 million gallons in 2007. Texas has been the largest producer of biodiesel.[27] The state's current production capacity is more than 100 million gallons annually, with another 87 million gallons in annual capacity under construction.[28] This is still a small amount, however, compared to the 7.5 billion gallons of diesel fuel Texas uses annually.[29]

According to the Texas Department of Agriculture (TDA), the state produced 72.9 million gallons of biodiesel in 2007. These data came from producers registered with TDA to receive state incentive payments described below. After funding for the state program ended, TDA stopped collecting registrations and formal reports from producers.[30] Subsequently, high costs have caused some producers to reduce production or cease operations altogether, although no comprehensive statewide data for 2008 Texas production are available.

Biodiesel can be transported by truck, pipeline or train. To keep its cost competitive with that of petrodiesel, biodiesel manufacturers tend to locate their factories near the sources of their feedstocks (farming communities) and consumers (truckers, farmers and companies that maintain vehicle fleets).

In 2006, Colonial Pipeline successfully shipped B5 from Pasadena, Texas to Linden, New Jersey in an existing pipeline previously used for petroleum, with no negative effects to the pipeline; in fact, B5 has been run through pipelines in Europe for many years.[31] This was an important test for the U.S. biodiesel industry, however, because limited capacity in the freight rail system and the cost of building dedicated biodiesel pipelines could affect the industry's growth.

Electricity generated from biodiesel can be used on site or transmitted through the power grid, just as electricity derived from any other source.

The city of Oak Ridge North became the first Texas city to run its electric generators on biodiesel in February 2007. The plant's three diesel generators run entirely on biodiesel made from vegetable oil or animal fat and can generate five megawatts of electricity, enough to service about 3,000 average homes, based on average Texas electric use in 2006.[32]

Availability

The U.S. has more than 1,000 petroleum distributors offering biodiesel and 171 plants producing it. At this writing, 60 more U.S. plants are under construction. Recent disruptions in the biodiesel market due to escalating costs may mean that some of these plans are cancelled or delayed.

EIA estimates that U.S. biodiesel production capacity will reach 1.1 billion gallons by 2008.[33] The National Biodiesel Board estimates that the nation's capacity is more than double that amount.

Texas has 22 commercial biodiesel plants and 12 additional plants under construction or being expanded, as well as about 51 retail biodiesel fueling sites (**Exhibit 14-3**).[34]

Denton's Biodiesel Industries, for instance, produces biodiesel at a plant powered by gas captured from an adjacent landfill. The plant has a production capacity of 3 million gallons a year and a contract with the city of Denton to supply its fleet with biodiesel. The plant produces B100 that the city blends to create B20.

According to Charles Fiedler, vice president of Biodiesel Industries, the plant can produce all the biodiesel it needs to fulfill its contract with the city by operating only one day a week. As sales increase, so will production.[35]

About half of all U.S. biodiesel producers use soybean oil exclusively; the rest also use other fats or oils as well, including recycled cooking grease.[36] According to the National Academy of Science, "Even dedicating all U.S. corn and soybean production to biofuels would meet only 12% of gasoline demand and 6% of diesel demand."[37]

About half of all U.S. biodiesel producers use soybean oil exclusively; the rest also use other fats or oils as well, including recycled cooking grease.

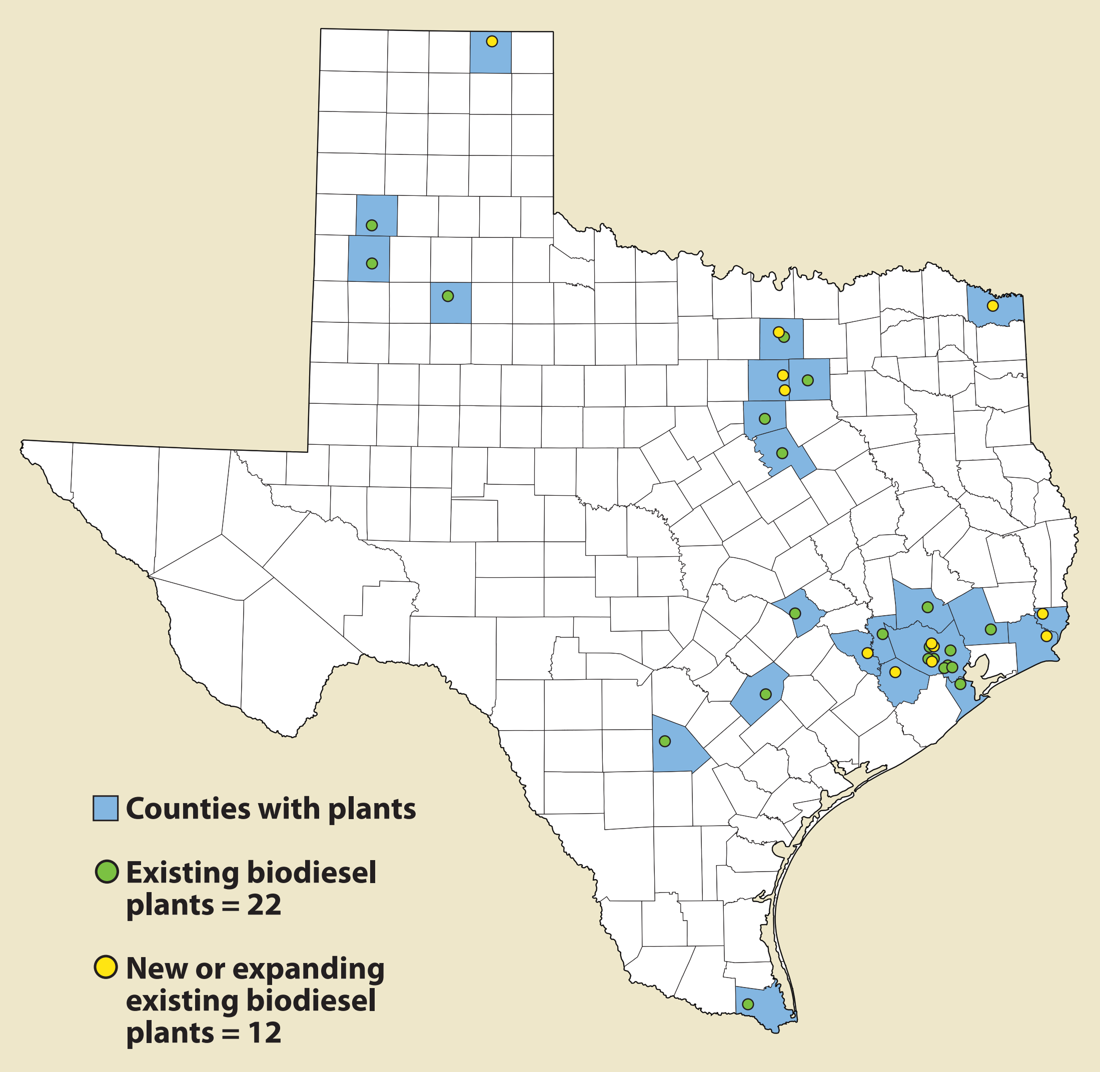
COSTS AND BENEFITS

To be a useful substitute for fossil fuel, biofuels must be price-competitive and available in quantity, and the energy used to produce them should not exceed the energy they provide. The "net energy balance" for soybeans, the most common feedstock for U.S. biodiesel, is quite high; according to the National Academy of Sciences, soybean diesel produces 93 percent more energy than is used in making it.[38] Biodiesel's major disadvantage is its high cost, primarily due to the cost of feedstocks.[39]

Biodiesel production became economically competitive with petrodiesel only with federal

EXHIBIT 14-3

Texas Biodiesel Plants



Source: National Biodiesel Board

incentives and after recent, sharp increases in the cost of petroleum. According to the latest EIA figures from January 2008, the nationwide cost of blended biodiesel (B20) was $3.37 per gallon, while B100 cost $3.69 per gallon. In EIA's Gulf Coast region, which includes Texas, the average cost of B20 was $3.37 per gallon and B100 was $3.19 per gallon, versus $3.30 for gallon for petrodiesel.[40] This includes the $1 per gallon federal tax credit provided to biodiesel.

Recent sharp increases in the price of feedstocks have pushed up production costs. Petrodiesel prices have risen, but not enough to make biodiesel cost-competitive. The cost of the feedstock oil or fat is the most expensive part of biodiesel production. For the 2007-08 season, USDA forecast that soybean prices would be at an all time high of $9.90 to $10.90 per bushel.[41] But as of January 15, 2008, USDA put the price of soybeans at $11.00 per bushel. By comparison, in December 2006, soybeans were selling at $6.14 per bushel.[42]

As a result, the cost of soybean oil, the raw material most often used to produce biodiesel, has more than doubled and has ranged up to 65 cents per pound, above USDA forecasts of prices ranging from 45.9 to 49.5 cents per pound. Each gallon of biodiesel requires 7.35 pounds of soybean oil.[43]

For this reason, today it is difficult to produce and sell biodiesel on a competitive price basis in Texas, even including subsidies. The cost of the soybean oil needed to produce a gallon of biodiesel was over $4.00, excluding costs for production and transportation. So even with a $1.00 per gallon federal tax credit, biodiesel producers face a difficult market.

Again, while Texas is a minor producer of soybeans, they are the preferred feedstock for most Texas biodiesel producers. As the price of soybeans continues to increase, and local access to soybeans in Texas remains limited, Texas biodiesel producers are looking to alternative feedstocks such as other oilseed crops and used cooking oil.[44] Since most soybean supplies are shipped to Texas from the Midwest, Texas biodiesel producers are trying to cut costs by using local feedstocks that do not have to be shipped for long distances.

Environmental Impact

The U.S. Environmental Protection Agency (EPA) and the National Renewable Energy Laboratory (NREL) have studied the effect of biodiesel on vehicle emissions. According to these sources, biodiesel has fewer noxious emissions than petrodiesel. Test results for B20 found that using it in the place of petrodiesel lowered unburned hydrocarbons by 21.1 percent, carbon monoxide by 11 percent and particulate matter (soot) by 10.1 percent. In addition, biodiesel's CO_2 emissions are lower than petrodiesel's.[45]

While Texas is a minor producer of soybeans, they are the preferred feedstock for most Texas biodiesel producers.

Some controversy has arisen, however, over the amount of nitrogen oxide emissions produced by burning biodiesel. In a 2002 EPA study, biodiesel produced 2 percent more nitrogen oxide (NO_X) emissions than petrodiesel.

NO_X is the generic term for a group of highly reactive gases, all of which contain nitrogen and

Biodiesel Byproduct Becomes Energy

Turning biodiesel waste into fuel could be the economic and ecological equivalent of spinning straw into gold. Glycerin, a natural waste byproduct of biodiesel production, is a clear, viscous, nontoxic, sweet-tasting liquid used in cosmetics, soaps, food production and pharmaceuticals. Even with its broad variety of uses, however, the production of glycerin is exceeding demand.

As the amount of biofuel produced increases, so does the amount of glycerin. Every ten pounds of biodiesel produced yields one pound of glycerin.[46] Glycerin has rapidly moved from being a revenue-producing commodity to a waste product with a "disposal cost associated to it."[47] Dow Chemical reportedly closed its synthetic glycerin plant in Freeport, Texas in 2006 due in part to "the flood of glycerin from U.S. biodiesel plants."[48]

But researchers worldwide are searching for ways to turn a profit from the glycerin glut. Studies are under way to turn crude glycerin into bio-based chemicals that can be substituted for petrochemicals in products such as soil treatments, paints, lubricants and antifreeze.

Using a $2 million grant from USDA and the U.S. Department of Energy, Virent Energy Systems, Inc. is working to improve the process for making propylene glycol (PG), a chemical used in a number of industrial processes, from glycerin.[49]

A Vienna, Austria research firm, eTEC Business Development, Ltd. is converting glycerin into electricity by burning it in specially designed engines.

And Organic Waste Systems, a Belgian biogas firm, is developing a methane digester system to produce biogas from crude glycerin; the system would allow a commercial-scale biodiesel facility to generate its own power with waste glycerin.[50]

oxygen in varying amounts. Many nitrogen oxides are colorless and odorless. One common pollutant, however, nitrogen dioxide (NO_2), often is seen as a reddish-brown smog layer over urban areas.

Nitrogen oxides form when fuel is burned at high temperatures. The primary manmade sources of NO_X are motor vehicles, electric utilities and other industrial, commercial and residential sources that burn fuels. NO_X also can be formed naturally in the ozone layer of the atmosphere (the troposphere). It is one of the main ingredients in the formation of ground-level ozone, which can trigger serious respiratory problems in some people.[51]

In November 2005, the Texas Commission on Environmental Quality (TCEQ) adopted emission standards for all diesel, petro- or bio-, sold in 110 counties facing the most severe challenges from air pollution (primarily in the eastern half of Texas, including Austin, San Antonio, Houston and Dallas). The goal of these Texas Low Emission Diesel Fuel Standards (TxLED) is to reduce nitrogen oxide and other pollutants from diesel-powered vehicles and non-road equipment. It did not immediately approve use of biodiesel because of concerns over NO_X, however.[52]

According to NREL, biodiesel has fewer noxious emissions than petrodiesel.

Subsequent tests by NREL and other groups found that biodiesel did not contribute to higher NO_X emissions. A 2006 NREL study stated, "we conclude that B20 has no net impact on NO_X."[53]

In testimony prepared for the Senate Natural Resources Committee of the Texas Legislature, NREL staff outlined their findings. The key difference between the EPA and NREL studies was that the earlier EPA study used one engine model to derive almost half of its data. The NREL study used 43 different engines and found that the change in NO_X varied from plus 4 percent to minus 4 percent but on average was 0 percent. NREL's testimony highlighted similar results from 2005 and 2006 Texas A&M University, the U.S. Navy and other university studies. In light of these developments, Texas biodiesel producers asked TCEQ to study biodiesel again and approve its use in Texas.

As a result, in December 2006, TCEQ announced that it would conduct a year-long study of biodiesel emissions to determine whether B20 meets TxLED and stated that it would delay implementing the standards until December 31, 2007. On December 21, 2007, TCEQ and the EPA announced that B5 meets the TxLED emission standards and can be used in diesel vehicles. At this writing, however, TCEQ has not approved the use of B20 blends unless specific chemical additives are included in the fuel.[54]

Growing crops for biodiesel may require substantial amounts of water: water use for irrigated soy crops averages 45,000 gallons per million Btu of energy produced. Biodiesel processing uses only 4.2 gallons per million Btu.[55]

Even though most biodiesel manufacturing plants use fossil fuels to run their operations, biodiesel is still an energy-efficient fuel. The U.S. Department of Energy has observed:

> You get 3.2 units of fuel energy from biodiesel for every unit of fossil energy used to produce the fuel. That estimate includes the energy used in diesel farm equipment and transportation equipment, fossil fuels used to produce fertilizers and pesticides, fossil fuels used to produce steam and electricity and methanol used in the manufacturing process.[56]

Other Risks

Biodiesel contains residual alcohol from the esterification process that can remove deposits from fuel tanks and lines, causing filter plugging when it is used initially. Fuel systems should be flushed before using biodiesel, and fuel filters may need more frequent replacement when it is first used in older vehicles.

Low temperatures can affect B100 biodiesel during storage and operation, causing it to begin to solidify. At such temperatures, the fuel may need to be stored in a heated building or storage tank, and the engine itself may require heated fuel lines, filters and tanks.

Petrodiesel also may solidify in cold weather, but petroleum companies and distributors manage the fuel inventory and additive treatments based on the history of the fuel's performance in each geographical region throughout each season, so the right blend of diesel fuel is available at the right time of year, allowing consumers to avoid cold flow problems.[57] Biodiesel distributors hope to develop the same system for biodiesel once the market becomes more established across the country.

Biodiesel has a flash point — the temperature at which it will ignite when exposed to a spark or flame — of 150° C. This means that it is safer to store and handle than petrodiesel fuel, which has a flash point of 70° C.[58]

Biodiesel has a tendency to absorb and attract water, so it must be stored in tanks that are free of water and do not absorb it. Above-ground tanks are preferable, since they are not readily contaminated by groundwater. Otherwise, biodiesel stores nearly as well as petrodiesel.[59] Biodiesel may be stored (in the dark and at a cool temperature) for up to eight months before it begins to degrade. Petrodiesel has a longer shelf life; it can be stored for up to one year before it begins to degrade.[60]

Since biodiesel can be stored in tanks currently used to store petrodiesel, little or no additional storage cost is involved in converting from one fuel to the other. The same regulations and monitoring are required for both fuels.

One potential problem is that biodiesel can react chemically with the rubber seals in vehicle fuel systems. This is a slow process, however, and one that usually can be avoided by adhering to normal maintenance schedules. Also, many engine manufacturers now use silicone rather than rubber seals to avoid any problems with biofuels.[61]

Engine Warranties

Engine companies generally recommend a fuel to their customers in their owner's manuals. Since they do not make or sell fuel or fuel components, they do not provide warranties for fuel, including petrodiesel and biodiesel. Engine problems caused by fuel are considered the responsibility of the fuel supplier rather than the engine manufacturer. Most major engine companies, however, have approved the use of diesel blends of up to B20 and will not void their parts and workmanship warranties if the blend is used.

The American Society for Testing and Materials, an internationally recognized standards organization, sets standards for fuels. These standards are the minimum accepted values for fuel properties to provide adequate customer satisfaction and protection. In December 2001, ASTM approved a full standard for biodiesel, D-6751, which covers B100 for blending with petrodiesel in levels of up to 20 percent (B20, in other words). The ASTM standard gave the biodiesel industry the approval it needs to be widely accepted by engine manufacturers and consumers.[62]

Some engine companies state that biodiesel must meet ASTM D-6751 as a condition; others are in the process of adopting D-6751 or have their own guidelines for biodiesel that were developed before the standard's approval. The entire industry is considering incorporating the ASTM biodiesel standard into owner's manuals over time.[63]

The National Biodiesel Board, the trade association for the biodiesel industry, has formed the National Biodiesel Accreditation Commission (NBAC) to audit fuel producers and marketers in order to improve the quality of biodiesel production and handling. NBAC issues a "Certified Biodiesel Marketer" seal of approval for biodiesel marketers that have met all requirements of its fuel accreditation audits.[64]

State and Federal Oversight

Several federal agencies regulate the biodiesel industry:

- USDA – research and development of biofuels;
- DOE – alternative fuel regulations;
- EPA – emission testing and air quality permits;
- U.S. Department of Transportation – alternative fuel regulations;
- U.S. Department of the Treasury – tax credits, incentives and subsidies; and
- U.S. National Institute of Standards and Technology – alternative fuel standards.

In addition, four state regulatory agencies and departments monitor biodiesel in Texas:

- TCEQ – environmental permits;

Since biodiesel can be stored in tanks currently used to store petrodiesel, little or no additional storage cost is involved in converting from one fuel to the other.

- Texas Department of State Health Services – renderer licensing (renderers supply feedstock to biodiesel plants);
- TDA – biodiesel plant registration and monitoring for the state's Fuel Ethanol and Biodiesel Grant program; and
- Texas Comptroller of Public Accounts – supplier and distributor licensing.

Subsidies and Taxes

The federal government provides tax breaks and other incentives for the biofuels industry.[65] EPA, for example, administers the Renewable Fuels Standard (RFS), which requires U.S. fuel blenders to increase their use of renewable fuels from 4 billion gallons in 2006 to 9 billion gallons by 2008 and 36 billion gallons by 2022.[66] Under new legislation, the RFS for biodiesel will increase from 500 million gallons in 2009 to 1 billion gallons by 2012.[67]

The federal government provides tax breaks and other incentives for the biofuels industry.

DOE and USDA also provide loans and research funding to develop and promote the biofuel industry. The most important subsidy is the $1 per gallon federal credit that blenders receive for every gallon on B100 they combine with petrodiesel.[68] For a more complete explanation, see Chapter 28.

The Texas Department of Agriculture has administered the state's Fuel Ethanol and Biodiesel Production Incentive Program since 2006. Texas biofuel producers registered with TDA are eligible for state grants based on the amount of fuel they produce. Qualified producers receive 20 cents per gallon of ethanol or biodiesel produced, limited to the first 18 million gallons produced annually for the first 10 years. Registered biodiesel producers pay 3.2 cents per gallon into the pool of funds while the state provides 16.8 cents per gallon.

Since the program began to pay producers in May 2006, it has distributed $11.5 million in funding, $9.6 million of which is state money. The 2007 Texas Legislature extended the program but did not appropriate any further funding for it. The program made final payments in November 2007 for production during the state fiscal year ending in August 2007.[69]

Texas also provides a diesel fuel tax exemption for biodiesel and ethanol, as well as biodiesel or ethanol blended with taxable diesel, if identified as such at the point of sale.[70] The tax is paid on the percentage of petrodiesel used in the biofuel. If the biodiesel is B20, for instance, tax is paid on 80 percent of each gallon. No tax is levied on B100 purchased in Texas.[71]

The 2007 legislative session approved two bills affecting the biodiesel industry, H.B. 2417 and S.B. 12. H.B. 2417 formally moved the Fuel Ethanol and Biodiesel Production Incentive Program from the Governor's Economic Development and Tourism Office to TDA. Previously, TDA operated the program under contract with the Governor's Office. Again, however, the program received no funding in 2007 and is no longer active.

One 2007 bill relating to programs to improve air quality, S.B. 12, was funded. One of the bill's programs, the Emissions Reduction Incentive Grants Program, provides funds to projects that reduce emission of NO_X from diesel vehicles. Another, the New Technology Research and Development Program, provides grants to research projects that find ways to reduce pollution in Texas.[72] For more information, please refer to Chapter 28.

OTHER STATES AND COUNTRIES

At least seven states have enacted renewable fuels standards to help increase the availability of renewable fuels. Minnesota was one of the first states to encourage the use of biofuels and now requires that 2 percent of all diesel fuel sold in the state must be biodiesel. In March 2007, the state of Washington passed a similar mandate requiring that 2 percent of all diesel fuel sold annually must be biodiesel by November 2008 or whenever the state's Department of Agriculture determines there is enough feed-stock grown in the state.[73]

In 2003, Illinois began its Renewable Fuels Development Program (RFDP), which provides grants for the construction of new biofuel production facilities. The state has 53 million gallons of annual biodiesel production capacity, with 35 million gallons of additional capacity under construction. RFDP awards grants of up to $5.5 million to projects that have a minimum annual production capacity of 30 million gallons. Illinois also has 144 biodiesel dispensing stations.[74]

Polytechnic University in Brooklyn, New York, has created a plastic made from soybeans that can be turned into biodiesel. This invention could be helpful to soldiers in the field who could use the plastic for packaging and then as fuel. It would reduce the waste the military creates as well as the amount of fuel it must transport.[75]

Europe

Biodiesel is the European Union's (EU's) most important biofuel, representing almost 80 percent of its total biofuel consumption. (Ethanol accounts for the remaining 20 percent.) The EU is the world's biggest consumer of biodiesel, in part because almost half of the cars and trucks in the EU have diesel engines.[76]

Biodiesel production in European countries began in earnest in 2003. The EU Common Agricultural Policy includes a set-aside program that pays farmers not to plant food or feed crops on a portion of their arable cropland; they are, however, allowed to plant rapeseed, sunflowers or soybeans for industrial purposes. This encouraged the growth of the European biodiesel industry.[77]

In 2003, the EU set a goal that by the end of 2005, biofuels should account for 2 percent of the energy used by member nations for transportation. At the end of 2005, the actual share attributable to biofuels was 1.4 percent. The European Council, the EU's governing body, has now suggested a new goal of 8 percent by 2015, with the hope of reaching a 25 percent share for biofuel by 2030.[78]

The EU had 20 biodiesel-producing countries in 2005, compared to 11 in 2004. Production has increased sharply, rising by 65 percent between 2004 and 2005 alone. Total EU biodiesel production rose from 2.9 million tons in 2005 to 6.1 million tons in 2007.[79]

"Detaxation" (an EU term for a reduced level of taxation, in this case compared to petroleum-based fuel) offers very strong incentives for biofuel production. EU member states have different detaxation systems affecting the development of biofuels. Germany has been a pioneer in using these incentives to promote the use of biofuels, and their use has grown rapidly in that country. In June 2006, however, the German government reduced the tax benefit for biofuels, and the rate of biodiesel production decreased.

At present, the EU is in a state of overcapacity for biodiesel, particularly in Germany, where the tax incentives were most favorable. Too many biodiesel plants were built and too much biodiesel was produced. Germany increased the taxes on biodiesel in 2007, adding to the fuel's already high cost. At the beginning of 2008, the German biodiesel industry was producing at only 10 percent of its capacity.[80]

In addition, Europeans are complaining about what they call dumping by American biodiesel producers who export their product to Europe while benefiting from the $1 per gallon tax credit.[81]

Asia

In India, a pilot project is running five to ten mobile base stations for wireless communications on biodiesel derived from cottonseed and jatropha.[82] The seeds of jatropha, a plant that originated in South America, can be crushed to produce oil that has been used for centuries in oil lamps.

Some companies and scientists believe that jatropha could become one of the world's key energy crops, since its oil can be refined into biodiesel.[83] Under optimum conditions, jatropha seeds can yield up to 40 percent oil content. Since it is inedible, it does not compete as a food source. Tests have shown that the oil's characteristics are favorable for biodiesel.

Jatropha grows in tropical and subtropical regions. It is hardy and relatively drought-resistant. The trees have a lifespan of 30 to 40 years. Jatropha grows on non-arable, marginal and waste land, and need not compete with food crops for good agricultural land.

One of its downsides, however, is the labor-intensive process needed to harvest the jatropha seed pods. At present, while many countries are experimenting with jatropha plants for biofuel, the only countries currently using them for biodiesel production are developing nations with relatively large and cheap labor forces.[84]

Brazil

Brazil is a global leader in the use of renewable fuels. Ethanol has long been the nation's primary biofuel, accounting for almost 40 percent of car fuel sales. Brazil's biodiesel industry is still young, but is expected to grow quickly since a January 2005 government mandate requires all diesel fuel

Biodiesel is the European Union's (EU's) most important biofuel, representing almost 80 percent of its total biofuel consumption.

to include 2 percent biodiesel beginning in 2008, rising to 5 percent in 2013.

Under current law, Brazil's potential market for biodiesel is estimated at 222 million gallons per year for 2006 and 2007; 264 million gallons per year for 2008 through 2013; and 634 million gallons per year thereafter.[85]

OUTLOOK FOR TEXAS

Texas is the nation's leading producer of biodiesel. It has some local supplies of feedstock (although only a minimal amount of soybean production) and a large consumer base. As of 2006, 528,705 diesel vehicles were registered in Texas, and many farm and industrial vehicles run on diesel as well.[86] Federal policy changes to renewable fuel standards, combined with growing concerns about energy security and environmental change, may improve the outlook for biodiesel because it is domestically produced, renewable and has an excellent environmental profile.

The industry in Texas, however, faces significant obstacles. Rapid increases in the cost of soybean oil, all of which has to be imported into the state, have made the economics of producing biodiesel very difficult, despite the $1 per gallon federal credit. As a result, some plants have cut production or gone out of business. Most Texas biodiesel is exported to Europe and looming taxation and trade fairness issues with European countries could affect that market as well.

The Texas biodiesel production industry also experienced a setback when the Legislature eliminated funding for the Biofuels Incentive Program. The 2009 Legislature may revive the program, but a biofuel plant must remain in business until then to benefit from the incentives.

Furthermore, even though TCEQ has stated that B5 meets the state's emission standards, it has not approved the more common B20 blend without certain chemical additives. This may affect the biodiesel market and the sale of biodiesel in Texas even if feedstock cost issues, the biggest hurdle facing this fuel, are resolved.

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CHAPTER 15

Wood

INTRODUCTION

Wood is an excellent source of energy. It can be used to create biofuels, burned directly, turned into a synthetic gas or pyrolyzed — turned into a liquid to create electricity.

Wood-fired power plants can have a positive impact on the economy of some rural areas. At present, Texas has no operating wood-to-electricity facilities, but two are being developed. Nacogdoches Power is building a large wood-burning facility in Sacul, Texas expected to be operational in late 2009. And Mesquite Fuels & Agriculture in Hamlin, Texas plans to establish a smaller-scale wood-gasification facility expected to be operational in spring or summer 2008.[1] These facilities are projected to add about 500 jobs to all sectors of the economy once completed.[2]

Potential fuel sources for wood-fired power plants include mill residues, sawdust, wood trimmings and construction debris. East Texas, home to much of the state's lumber industry, has a particularly large resource base. In 2005, East Texas wood products companies produced 9.5 million tons of logging and mill residues.[3]

History

Biomass is the oldest human energy source. Mankind has burned wood to create heat for tens of thousands of years. By 1890, commercial, residential and transportation sectors counted on wood as the primary fuel supply. The first power plant to generate electricity from wood was the Joseph McNeil generating station in Burlington, Vermont in 1984.[4]

Uses

Biomass (including organic waste, fuels derived from plants and wood) recently surpassed hydroelectric power to become the largest source of renewable energy in the U.S.

Industrial consumers use the majority of the energy generated from biomass. Most of this energy is generated at mills or paper plants that burn their own wood waste for power and heat (**Exhibit 15-1**).

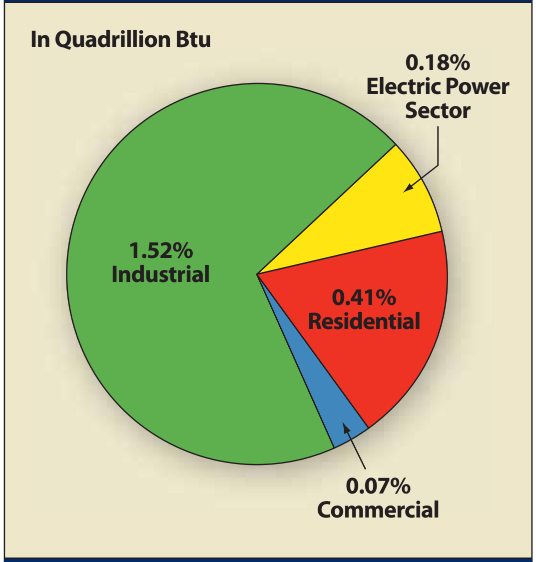
Biomass can be used to create electricity through a variety of methods, including direct firing, gasification and pyrolysis (the liquefaction of biomass to form an oil), among others. Direct firing is the most common of these methods.[5] Although other chapters in this report focus on municipal solid waste and landfill gas; this chapter is devoted to wood biomass only. Electricity generated from wood-fired biomass can be placed on the power grid for residential and commercial use, or used at the source of generation.

WOOD BIOMASS IN TEXAS

Texas produces an estimated 20 million tons per year of biomass that can be used as fuel. This

EXHIBIT 15-1

U.S. Wood Biomass Energy Consumption by Sector, 2006



Source: U.S. Energy Information Administration.

Potential fuel sources for wood-fired power plants include mill residues, sawdust, wood trimmings and construction debris.

includes forest residues, mill residues, urban wood waste, agricultural residues and dedicated energy crops.[6] According to Mark Kapner, a senior strategy engineer at Austin Energy, this is the equivalent of about 4,600 megawatts (MW) of potential capacity, enough to power more than 2.5 million homes in Texas, based on average electric use in 2006.[7] The U.S. had 6,372 MW of installed capacity (on the grid) of wood-fired biomass in 2006. This is up from 5,844 MW in 2002.[8]

Economic Impact

A 1999 study by the National Renewable Energy Laboratory (NREL) stated that 4.9 full-time jobs are created by every megawatt of generating capacity.[9] Applying this figure to the estimated 4,600 MW of total potential capacity in Texas indicates that the wood-fired energy industry could add more than 22,000 jobs to the state.

A 100 MW wood-fired biomass power plant being developed by Nacogdoches Power in Sacul (discussed below) is expected to create about 490 new jobs.[10] The 8 MW wood gasification power plant being developed by Mesquite Fuels & Agriculture in Hamlin will employ eight to nine people, with additional employees needed to harvest wood. Mesquite Fuels & Agriculture anticipates that employees will be paid between $10 and $14 per hour.[11]

In the most common method of electricity generation from biomass, wood waste is burned in a manner similar to coal or gas firing in a power plant.

Consumption

Again, Texas currently has no operational wood-fired biomass power plants, although two Texas plants are planned.

In 2006, energy from wood-fired biomass accounted for 2.1 quadrillion Btu, in the U.S., about 31 percent of all renewable energy consumed.[12]

Production

Most direct-fired biomass plants burn wood waste derived from sources such as mill residues, sawdust, wood trimmings and construction debris. This biomass can be burned alone or co-fired with fossil fuels. In the latter case, biomass generally replaces only a small portion of the fossil fuel (about 20 percent).[13]

In addition to trimmings collected off the forest floor after logs are harvested, forests can be "pre-trimmed" prior to logging. This "pre-commercial" trimming can produce biomass for electricity while decreasing the risk of forest fires and insect and disease attack.[14]

Transportation

Wood-fired biomass power plants usually are located near areas with large amounts of wood waste, to reduce or avoid the cost of transportation. (Transportation costs often account for the majority of the cost of any fuel.) To be economically feasible, wood-fired power plants generally are located within about 50 miles of the wood source.[15]

Power Generation

In the most common method of electricity generation from biomass, wood waste is burned in a manner similar to coal or gas firing in a power plant. The waste is sent through a chipper and then to a boiler where it is burned to heat water,

Producing Electricity from Wood using Gasification and Pyrolysis

Gasification and pyrolysis are similar processes. Both require high temperatures and a oxygen-limited environment.

Gasification

Gasification converts biomass to combustible gases by heating it at high temperatures in an oxygen-limited environment. The resulting "synthesis" gases contain hydrogen and carbon monoxide.[16] Synthesis gases are mixed with oxygen and burned to heat water and produce steam to turn a turbine and create electricity. Synthesis gases can also be used in gas turbines or converted into other fuels.[17] Gasification of biomass removes pollutants such as ash and other particulates.[18]

Pyrolysis

Pyrolysis is used to convert biomass to a liquid. Heating biomass at extremely high temperatures (more than 1,000°F) in an environment with no oxygen produces vapors that can be condensed into a liquid called pyrolysis oil. This oil, a renewable liquid fuel, can be stored and transported easily.[19] It can be burned to create electricity or used to produce chemicals, plastics and other products.[20]

producing steam. The resulting steam spins turbines, which in turn drive generators to produce electricity (**Exhibit 15-2**). In co-firing, fossil fuels and wood waste are burned together to create steam. The wood waste may need to be dried prior to burning to reduce its moisture content.

The wood-fired biomass power plant proposed for Sacul, a small town near Nacogdoches, will employ a fluidized bed combustion boiler (FBC).[21] In an FBC, a layer of sand is heated and agitated using upflowing jets of air. The heated sand is used to distribute air evenly throughout the chamber. Wood waste then is injected into the boiler. The jets of air suspend the wood in midair, allowing it to burn on all sides, yielding a more efficient combustion process.[22]

Selective non-catalytic reduction (SNCR) systems can be used to control wood-fired emissions of NO_X, a known greenhouse gas with adverse health and environmental effects.[23] SNCR involves a chemical reaction that employs NO_X rather than oxygen as its primary reactant. SNCR works by injecting either ammonia (NH_3) or urea into the gas produced during combustion. NO_X then undergoes a reaction in the presence of oxygen; the oxygen is removed from the NO_X and bonds to the hydrogen from ammonia or urea, forming nitrogen gas (the most common gas in the atmosphere) and water vapor. SNCR can reduce NO_X emissions levels by 30 to 75 percent.[24]

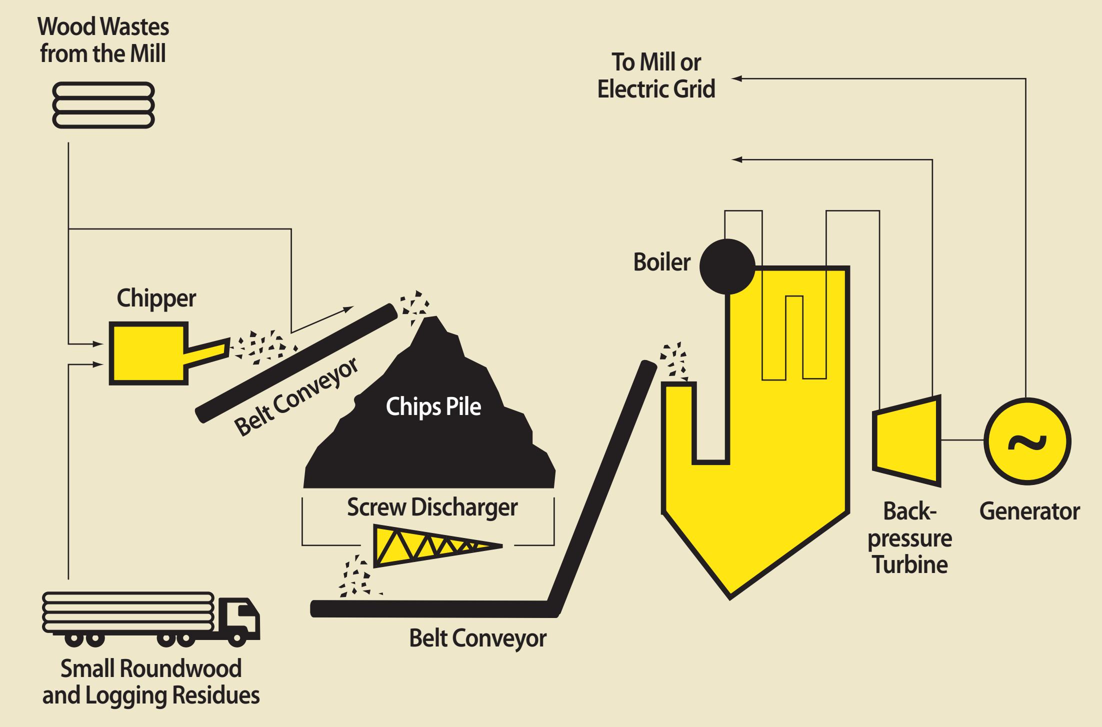
Storage and Disposal

Burning wood biomass for electricity can help to reduce the amount of wood waste sent to landfills. Wood waste can be stored in a variety of ways, depending on the scale of the plant and the fuel's moisture content: in open uncovered wood piles, partially covered wood piles (open sheds), or enclosed wood piles (storage bins, hoppers, or silos).[25] Foreign debris in the wood waste, such as stones, nails and other metal, must be removed prior to use.[26]

Burning wood biomass for electricity can help to reduce the amount of wood waste sent to landfills.

Exhibit 15-2

Electricity Production from Wood Firing



Source: Food and Agriculture Organization of the United Nations.

Availability

Although only a portion could be used for energy generation, Texas has a very large biomass resource base, with more than 12 million acres of forests, mostly of pine, in 43 counties in East Texas alone.

More than 90,000 Texans work in the state's $2.3 billion forest products industry. Texas has more than 1,200 lumber and wood-product mills.[27]

Many sites in the state, such as mills, use wood waste to heat and power their own facilities.

Although only a portion could be used for energy generation, Texas has a very large biomass resource base.

The 100 MW wood-fired biomass power plant being developed in Sacul, located in Nacogdoches County, will use logging residue as its main fuel source, but also could use urban wood waste. Nacogdoches Power estimates that the plant will require 1 million tons of biomass per year.[28] It will be the largest wood-fired power plant in the nation, according to Nacogdoches Power.[29]

In 2005, 3.1 million green tons of logging residues were available for use in East Texas, as well as 6.3 million dry tons of mill residues (**Exhibit 15-3**). Mill residue is already being used; it can be burned to power and heat mills or sold for landscaping materials, sawdust or pulping material. On the other hand, most logging residue is simply left at the logging site and this, too, could be sold for energy production. [30]

The energy content of this material will vary depending on its moisture content. The moisture content of raw wood that has just been cut is typically between 30 and 40 percent.[31]

Exhibit 15-3

Logging and Mill Residue in East Texas, 2005

Type of Wood	Logging Residue (green tons)	Mill Residue (dry tons)	Total (tons)
Hardwood	1,035,334	978,342	2,013,676
Softwood	2,102,947	5,333,589	7,436,536
Total	3,138,281	6,311,932	9,450,213

Note: Numbers may not total due to rounding.

Sources: Texas Comptroller of Public Accounts and Texas Forest Service.

Trees damaged in the wake of Hurricane Rita could have been used in a wood-burning power plant. Hurricane Rita caused more damage to East Texas timber than any disaster in recent history, destroying or damaging about 6 percent or 771,000 acres of East Texas timber (**Exhibit 15-4**).[32]

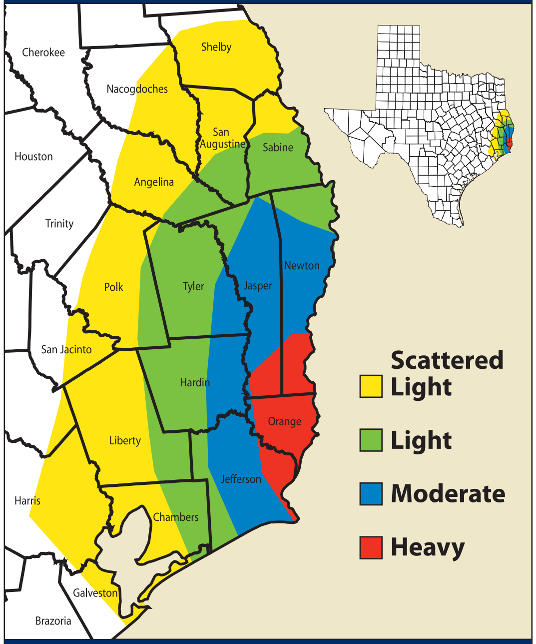
The 2007 Texas Legislature directed the State Energy Conservation Office (SECO) to update a 1995 assessment of Texas renewable energy resources. This report, which will be released before the start of the 2009 Texas legislative session, will include up-to-date data on the availability of various renewable energy resources, including biomass.

COSTS AND BENEFITS

Prices for electricity generated from wood-fired power plants tend to range from 5 cents to 7 cents per kilowatt hour (kWh), with a national average cost of about 6 cents.[33] This price includes incentives that are available for this type of electricity generation, including a 1 cent to 2 cent per kilowatt-hour (kWh) federal renewable energy production credit on corporate income tax.

Exhibit 15-4

Hurricane Rita Timber Damage



Source: Texas Forest Service.

Wood Gasification Plant in Texas

Mesquite Fuels & Agriculture is in the process of constructing a wood gasification facility in Hamlin, Texas, that is expected to open in spring or summer 2008. Hamlin is located about 40 miles northwest of Abilene. The facility will cost $2.5 to 3 million per MW; at 8 MW the facility is expected to cost more than $20 million. This facility will employ 8 to 9 people on a permanent basis, as well as other employees needed to harvest and transport wood.[34] The facility will employ gasification technology to produce electricity from mesquite. Its generation capacity is expected to be 8 MW.[35]

The plant also will be able to generate steam that could be sold to other industrial consumers in the immediate area.[36] In addition to the first plant in Hamlin, Mesquite Fuels & Agriculture is examining other sites in West Texas, and believes there is enough mesquite in these areas for five or six more facilities.[37]

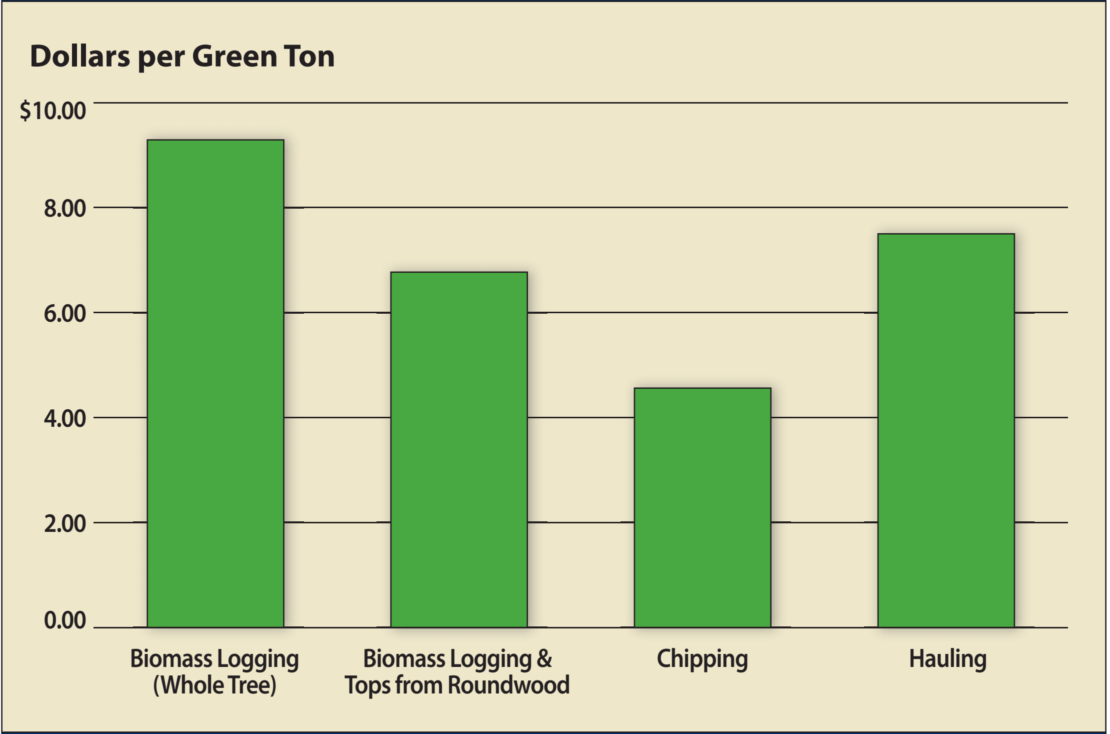
More information on this incentive is found in the Incentives, Subsidies, Taxes and Tariffs section of this chapter.

The Sacul plant will cost about $400 million to build, or about $4,000 per installed kilowatt. In addition to construction costs, the costs of fuel and chipping and transporting it must be considered (**Exhibit 15-5**). For example, a ton of chips produced from whole trees would cost an average of $21.35. This figure includes an average cost of $9.29 per ton for the wood, $4.56 per ton for chipping and $7.50 per ton for transporting the wood. In addition, drying costs may be significant depending on the wood's moisture content.

While Nacogdoches Power officials did not provide their expected costs, in Oregon and other areas of the Pacific Northwest, wood-fired electricity costs from 5.2 cents to 6.7 cents per kWh to produce.[38]

Exhibit 15-5

Cost of Biomass Production in East Texas, 2007



Sources: Texas Forest Service and Texas Comptroller of Public Accounts.

Sugarcane Bagasse to Energy Project

The Rio Grande Valley Sugar Growers, Inc. is turning sugar cane waste into electricity. The facility, located in Santa Rosa, uses waste to produce electricity via steam turbines. Currently, the facility is undergoing a renovation to replace the boilers and turbines with newer, more energy efficient equipment. At an estimated cost of $26.5 million, the project will allow the facility to create enough electricity to run the sugar processing plant (about 9 MW) and to sell the remaining electricity on the grid (about 4.5 MW).[39] In addition, the project will save an estimated 80 percent of natural gas purchases and 90 percent of electricity purchases. This, together with the revenue from selling electricity to the grid, will save an estimated $3.5 to $4 million annually. The use of sugarcane waste to create energy will also save on disposal costs and landfill space.[40]

Co-firing biomass with coal can reduce coal's harmful emissions.

Environmental Impact

Wood-fired biomass power plants produce some air and water pollution. The grinding or chipping of wood creates dust, although wetting the wood before chipping can reduce dust levels. Furthermore, burning wood releases volatile organic compounds, or VOCs, which pose a health risk.[41] The amount of air pollutants, including NO_X and SO_2, emitted by wood burning power plants is significantly lower than those emitted by plants using coal.[42]

The amount of ash produced by burning wood varies depending on the type of wood wastes used. Clean chips containing no bark have a low ash content, typically less than 0.5 percent. Wood chips containing bark have a higher ash content of around 1 percent. Sawdust has a low ash content of around 0.5 percent.[43] Ash resulting from burning wood can be sold as a fertilizer or disposed of in landfills. Typically, softwoods such as pine have higher ash contents than hardwoods.[44]

On the other hand, co-firing biomass with coal can reduce coal's harmful emissions. In particular, co-firing can reduce sulfur oxides (SO_X), which produce acid rain, on a one-to-one basis; in other words, replacing 10 percent of coal with biomass reduces its SO_X emissions by 10 percent.[45]

Depending upon the plant type, electricity generation from wood biomass requires withdrawals of between 9 gallons and 14,655 gallons per million Btu of heat produced.[46] This is the amount of water extracted from a water source; most of the water withdrawn is returned to that source. Water consumption refers to the portion of those withdrawals that is actually used and no longer available. Water consumption ranges from zero to 150 gallons per million Btu produced.[47]

Other Risks

During the Texas Forestry and Bioenergy Conference held in Nacogdoches in May 2007, participants discussed concerns about fertilizer use in the forestry industry. Logging residue provides natural fertilization for remaining trees as well as for new trees that may be planted at the same site. Foresters are concerned that removing these trimmings and other residues will require them to use more fertilizer, adding to their costs.

Finally, wood fuel typically is transported to the power plants by truck, leading to increased traffic in local areas, high transportation fuel costs and increased emissions. Increased truck traffic in areas without a robust transportation infrastructure leads to heavy wear and tear on existing rural roadways.

State and Federal Oversight

The federal Clean Air Act and Clean Water Act both affect wood-burning power plants. Wood-fired power plants are particularly affected by the National Ambient Air Quality Standards, which quantify the amount of particulate matter that a facility may generate, both in a 24-hour period and annually. Wood combustion produces fine particulate matter (2.5 micrometers in diameter or smaller). The standards also regulate course particulate matter (between 2.5 and 10 micrometers in diameter), such as the dust generated by truck traffic.[48]

The Texas Commission on Environmental Quality grants permits for air and wastewater quality. As with other electricity generation facilities, wood biomass plants require other permits including wetland impact permits, a threatened and endangered species permit and an acid rain permit. Permits required vary by geographical location.

Subsidies and Taxes

The federal Renewable Electricity Production Tax Credit, established in 1992 and extended and renewed several times, is a corporate income tax credit that provides an annually adjusted incentive to utilities that produce power from renewable sources. In 2008, the incentive is 2.0 cents per kWh for many renewable sources such as wind, geothermal and closed-loop biomass (see sidebar). A smaller incentive of one cent per kWh was available for energy produced using open-loop biomass, small irrigation hydroelectric power (generated without a dam and with a capacity of between 150 kW and 5 MW), landfill gas and municipal solid waste.[49]

The 2007 Texas Legislature's House Bill 1090 creates incentives of up to $30 million annually to support electricity produced from biomass and made available to the state's electric grid. H.B. 1090 will provide subsidies of $20 per bone-dry ton of wood, up to $6 million per year, for each qualifying entity.[50] This incentive will be given to wood suppliers (loggers, mills and landfills), who could in turn pass along lower fuel costs to electricity generators. Funding for this program will require an appropriation and will not begin until 2009 at the earliest.

Another 2007 bill, H.B. 1214, would have strengthened the current law stating that 500 MW of renewable power in Texas should come from a source other than wind, making it a requirement rather than a suggestion, but the bill did not pass.

More information on subsidies and incentives for wood biomass can be found in Chapter 28.

OTHER STATES AND COUNTRIES

Many states operate wood-fired biomass power plants. California and Michigan have several smaller-scale sites in the range of 10 to 35 MW.[51]

One of the most successful wood biomass operations is the Joseph C. McNeil Generating Station in Burlington, Vermont, a 50 MW electricity plant mostly powered by wood. The facility consumes 180,000 tons of wood per year. Seventy percent of this comes from "low-quality" trees; 25 percent from chip and bark residues; and 5 percent is clean recycled wood. McNeil estimates that the wood it uses costs about $12 to $20 per ton. The facility also has a waste yard where individuals can dispose of wood and yard waste. It sells wood ash to a contractor who mixes it with limestone as a soil conditioner.[52]

OUTLOOK FOR TEXAS

Wood-fired biomass has some potential for Texas, particularly East Texas, which has enough potential capacity to produce the majority of the state's suggested goal of 500 MW of non-wind renewable energy capacity. The main obstacle to wood-fired biomass power plants is economic. Without incentives and subsidies, the cost of the fuel is too high to make such plants profitable.

Furthermore, some oppose the use of wood waste for electricity generation. As already noted, some Texas foresters believe that gathering logging residue off the forest floor may require them to use more fertilizer to grow trees, although further study of this issue is needed.

Some Texas mills and paper plants believe that Texas' incentives and subsidies for biomass-generated electricity are unfair.[53] Again, many mills and paper plants produce electricity for their own use from their own wood waste, yet this electricity is not eligible for state incentives and subsidies because it does not go to the power grid.[54]

Other critics oppose a state mandate requiring non-wind renewable sources such as wood-fired biomass because they believe that it will cost more than electricity generated from other sources.[55] Electricity generated from biomass that is placed on the grid becomes part of the mix of the state's energy portfolio; electricity consumers generally do not get to choose from which source their electricity is generated.

Wood-fired biomass may never comprise more than a small percentage of the state's energy portfolio, but it could create jobs in rural areas and stimulate the local economy in East Texas.

Wood-fired biomass has some potential for Texas, particularly East Texas.

The Energy Policy Act of 2005 defines Closed and Open Loop Biomass:

Closed-loop Biomass: any organic material from a plant that is planted exclusively for use at a qualified facility to produce electricity.

Open-loop Biomass: any agricultural livestock waste nutrients or any solid, nonhazardous, cellulosic waste material or nonhazardous lignin waste material that is segregated from other waste materials and derived from forest-related resources, including mill and harvesting residues, precommercial thinnings, slash and brush or solid wood waste materials. This does not include municipal solid waste, gas derived from the biodegradation of solid waste, paper that is commonly recycled or biomass used in co-firing.

Source: Energy Policy Act of 2005.

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[31] A simple formula can be used to calculate Btu per pound of wood: Energy Content (Btu/pound) = (1-m)*8500, where 'm' is the fractional moisture content of the wood. For example, a wood sample with a moisture content of 30 percent would have an energy content equal to (1-0.3)*8500 = 5,950 Btu/pound.

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Chapter 16

Feedlot Biomass

Introduction

The development of large feedlots for livestock, also known as concentrated animal feeding operations or CAFOs, has created economic opportunity for agribusiness in Texas. Hogs, beef and dairy cattle and poultry at CAFOs are fed in close proximity to maximize efficient production and keep costs low. At the same time, however, CAFOs produce large amounts of animal manure that may emit odors, methane, nitrous oxide, carbon dioxide, antibiotics and ammonia. Manure can also produce water pollution from uncontrolled runoff of phosphorus and nitrates.[1]

Growing environmental concerns coupled with higher energy prices have led to a renewed interest in using animal manure, also known as feedlot biomass, to produce power. This can be accomplished either by burning manure directly for fuel, gasifying it with heat or by turning it into "biogas" through biological decomposition. The best approach to using animal wastes for power depends on the amount of moisture and essentially non-biodegradable solid materials including dirt (generally called ash) mixed with the manure to be used as a feedstock. Each of these methods disposes of large accumulations of manure while mitigating its possible negative environmental effects.

Manure also can be used to reduce emissions from traditional fuels. A recent scientific study by the Texas Engineering Experiment Station and Texas Agricultural Experiment Station found that co-firing coal plants with manure lowers their emissions of nitrous oxide (NO_X). The reburning process involves a second combustion process to reduce these air emissions.[2]

Manure-based power plants can boost rural economic development and provide dairy farmers and feedlot operators with another source of revenue, or at least cut their disposal costs.[3] Although Texas is a leading beef and dairy cattle producer, use of manure for energy is just beginning in Texas. There are promising new plants in Central Texas and the Panhandle both under construction and on the drawing board which have the potential to bring jobs and income to rural Texas, although there are no estimates of the current or potential effects available.

History

Man has burned animal waste for warmth for millennia. It is still used as a cooking and heating fuel in some traditional societies.

The use of biogas derived from waste traces it roots back to early experiments in England and its colonies. The first plant built to process gas from human sewage was constructed in Bombay, India in 1859. Subsequently, gas from a sewage treatment facility was used to fuel streetlights in Exeter, England in 1895. Later, Europe saw extensive use of biogas in the wake of energy shortages following World War II.[4]

Manure-based power plants can boost rural economic development and provide dairy farmers and feedlot operators with another source of revenue, or at least cut their disposal costs.

In the U.S., interest in biogas peaked during the energy crisis of the 1970s. In that era, biogas systems were built at swine, dairy and laying hen production facilities. Some facilities fared better than others. Successful operations were found at farms that had the right kind of system installed and an owner/operator with the technical expertise to make it work.

In many cases, however, these operations failed, for reasons including the indiscriminate use of systems that were inappropriate for a specific farm setting; lower than expected manure production; high maintenance expenses; low returns; dependence on government grants for construction incentives; and the farmer's lack of skills with the system.[5]

Uses

Manure can be used to create gas or electricity. It is not currently used as a transportation fuel. Manure can be used as fuel for a boiler or burned directly for cooking or lighting purposes. It can be converted into combustible gases using thermo-chemical processes or into biogas through biological processes, in a device called an anaerobic digester. It can be used to generate electricity for power needs on the farm or ranch or sold to the local power grid. Dairy farms use a considerable amount of energy for refrigeration, and some use biogas-fired chillers to cool milk.[6]

FEEDLOT BIOMASS IN TEXAS

Texas is the nation's leading cattle state and has significant potential resources for the use of manure to create energy. In 2006, there were 14.1 million beef cattle in the state as well as 334,000 dairy cows.[7] Thus far, however, using manure to create energy is relatively rare in the state.

Economic Impact

Because this practice is new and not yet commercialized, there is no estimate of the economic impact of using manure for energy purposes in Texas. One plant that uses manure from dairy cattle to create gas at Huckabay Ridge, near Stephenville, has created seven full-time jobs. Construction of the $18 million plant also employed an average of 12 to 14 workers for nine months.[8]

A Panda Ethanol plant already under construction near Hereford that will use 1,400 tons per day of manure as a fuel will create 61 permanent jobs and 500 to 600 construction jobs. The $120 million facility is expected to produce 105 million gallons of ethanol per year.[9] Panda has also announced two other Panhandle projects. (See below for more on these facilities.)

Consumption

Thus far, manure is not a major source of electricity generation in Texas or the U.S. According to AgSTAR, an EPA program that promotes such uses as a means of managing livestock waste and generating new sources of farm income, 111 anaerobic digesters operating across the U.S. at the end of 2007 produced electricity, gas to fuel boilers, and in some cases just flared the gas.[10] Texas' Huckabay Ridge digester produces biogas that is treated and sent via pipeline to the Lower Colorado River Authority (LCRA) to run electric generators.

Production

The increase of confined animal feeding operations has created the need for management systems to collect, store and dispose of the manure for sanitary and environmental reasons.

Manure occurs in forms ranging from solid to slurry to liquid. Dairy cattle and hogs confined

Texas is the nation's leading cattle state and has significant potential resources for the use of manure to create energy.

in enclosed areas produce wet manure that can be collected for processing into biogas. Dry manure, such as that often produced in beef cattle feedlots, can be accumulated and transported for burning, gasification or conversion into biogas.

The collection method for liquid manure typically involves flushing the livestock pens with water. Slurry manure is collected using a mechanical scraper system. Solid manure can be handled using a wheel loader or mechanical scraper.[11]

The Texas Agriculture Experiment Station and Texas Cooperative Extension have conducted field research on the energy potential of manure. They estimate the heating value of dry, ash free manure at 8,500 British thermal units (Btu) per pound and from 2,500 to 6,000 Btu on an as received basis depending on ash and moisture content. This is below that of Powder River Basin coal from Wyoming widely used in Texas for power generation. By contrast, Texas lignite ranges from 3,500 to 4,000 Btu per pound.

Biogas produced by digesters typically is 60 percent to 65 percent methane after moisture and other materials have been removed. Biogas's heating value is about 600 Btu per cubic foot. (A thousand cubic feet of methane is equivalent to 600 cubic feet of natural gas, 6.6 gallons of propane or 4.7 gallons of gasoline.)[12]

Researchers at agriculture colleges such as Purdue University and the University of Missouri have examined the potential for livestock methane production. For example, a 1,000-pound dairy cow can produce about 28.4 cubic feet of biogas per day, as can three hogs weighing 240 pounds each.[13]

Selecting an appropriate technology for energy production from animal manure depends on its moisture content and other qualities. These factors in turn depend on the type of animal being fed and the way it is fed. Cost is an additional factor that, combined with physical characteristics of manure, dictates the best collection method for the manure. There are some variations in the characteristics of beef and dairy cattle manure. For example, dairy manure contains more volatile solids. But the key factor in how it is used for energy is the manure collection and management system.

Animal waste in a slurry or liquid form can be converted to methane gas using an anaerobic

Texas' Huckabay Ridge digester produces biogas that is treated and sent via pipeline to the Lower Colorado River Authority to run electric generators.

digester, a piece of equipment that ferments the manure and promotes its decomposition in the absence of oxygen. This process often is used for animal waste with relatively high moisture content, such as that from dairy operations. Microbes in the digester break down the organic matter to produce methane, the major component of natural gas. Operations employing this technique include four common elements: a digester, a gas handling system, a gas-use device such as an engine or a flare and storage tank for treated effluent.

One type of digester is the *covered lagoon*. Liquid manure flushed from dairy or swine operations is held in earthen lagoons, typically 12 feet deep or greater and covered with reinforced plastic fabric. The biogas is collected using manifolds or covers. Covered lagoons can recover biogas in warm climates any time of the year. In colder climates, however, where biological reactions slow down in cold weather, they may work only on a seasonal basis.

According to a Texas A&M University study, the Texas Panhandle region, including parts of neighboring Oklahoma and New Mexico, produces more than 7 million fed beef cattle per year, or 32 percent of the U.S. total.

Complete mix digesters are steel or concrete tanks in which slurry manure is heated to speed biological processes. The contents are mixed occasionally with a pump.

Plug flow digesters are a form of heated tank used for dairy waste. These are typically long, narrow and built below ground level.

Fixed film digesters are made using a tank filled with plastic that holds anaerobic bacteria called biofilm. As the waste passes through the biofilm, biogas is produced.[14]

Different types of digesters work better under different climatic conditions and with different types of manure. Covered lagoons are not heated and are more suitable for warmer areas; they are best used with manure having a lower level of solids. Fixed film digesters also are better for warmer climates and are best used with slurry manure. Plug flow and complete mix digesters are heated; these are typically used in cooler climates and can process manure with a higher solid content and at much higher rates. As the temperature of the reaction increases, the size of the digester can decrease.

Drier manure, such as that from beef cattle feedlots, can be turned into gas via high-temperature thermochemical processes. These heat-based methods are differentiated by the oxygen environment applied in each one. *Combustion*, for example, depends on a plentiful supply of air; *gasification* depends on adequate amount of air (described in technical terms as *stochiometric*). The resulting product, called syngas, can be used like natural gas but has a lower Btu content, in the range of 250-300 Btu per cubic foot.

In a related process called *pyrolysis*, manure is heated with very little oxygen to produce gas, oil and charcoal. Manure also can be burned directly, but this can be impractical due to its high and variable ash content, which can cause the manure to burn unevenly unless it is ground or pulverized. It can be burned more successfully when mixed with other fuels, such as coal, in a method called *co-firing*.

Another process called *reburning* may have significant implications for manure management and the use of coal for electric generation. Reburning refers to the addition of a secondary combustion process to a coal-fired plant. This is intended to eliminate nitrous oxide (NO_X), a source of air pollution. This is typically accomplished using natural gas as a reburn fuel. In small-scale experiments conducted by engineers at Texas A&M University, the use of feedlot biomass as a reburn fuel resulted in lower NO_X levels.[15]

Transporting manure long distances to be used as fuel is impractical, since doing so can use more energy than the manure can generate.[16] As a result, manure generally is used close to its source to generate gas for use on site or for localized distribution, or to make electricity. Once converted, biogas can be transported via pipeline or used to generate electricity that can be sold to the local power grid. Long-term storage of manure can result in loss of methane, carbon dioxide and ammonia into the air, resulting in more greenhouse gas emissions as well as lowering the fuel value of the manure and contributing to lingering odor problems.

Availability

As a result of Texas' large livestock industry, manure is available in significant quantities at some locations in the state. It is useful as a fuel only where it is found in large concentrations, such as the Panhandle (beef and dairy cattle) or Bosque River Basin (dairy cattle). According to a Texas A&M

University study, the Texas Panhandle region, including parts of neighboring Oklahoma and New Mexico, produces more than 7 million fed beef cattle per year, or 32 percent of the U.S. total.[17]

The manure produced in Texas could produce a theoretical amount of energy equal to 12 billion to 25 billion cubic feet of natural gas.[18] Practically speaking, however, it can be used for energy production only in those areas where it is found in high volumes in close proximity, such as the Texas High Plains (**Exhibit 16-1**).

Using the abundant manure resources of the Bosque River Basin, Environmental Power Corporation, through its Microgy Inc. subsidiary, has built what it claims is the largest renewable natural gas plant in the U.S., and perhaps the world. The company's Huckabay Ridge plant near Stephenville puts it in reach of dairy producers in Erath County, Texas' leading dairy county.

Microgy combines manure from local dairy farms with "substrate" — fats, greases and oils from restaurants and other sources — to produce gas. The gas is treated and compressed and then delivered by to the Lower Colorado River Authority (LCRA), which uses it to generate electricity.

Comptroller staff visited the Huckabay Ridge facility in summer 2007 to observe its operations (**Exhibit 16-2**). The facility has eight digester tanks that hold 916,000 gallons each, six of which were operating at the time of the site visit. The tanks are heated to speed up bacterial reactions. The contents are mixed to aid processing, and fats and oils are added to the manure to enhance the amount of energy produced. The process used is technically described as an above-ground, thermophilic, complete mix, co-digestion system. Microgy attributes the project's success to its patented Danish technology and innovations from previous projects.

When fully operational, the plant is expected to use the manure from 10,000 cows to produce a billion cubic feet of biogas per year, or 650,000 million Btu of energy. LCRA's contract calls for it to take as much as 2 million cubic feet per day from the plant for its power plants in Llano and Bastrop counties.[19] Microgy officials say the result is enough energy for 10,000 homes. The addition of substrate dramatically boosts the amount of energy in the gas and its volume.[20]

Microgy plans to build three more of these plants, one close to the existing plant, near Dublin, and the others near Hereford in Deaf Smith County at the Mission and Cnossen dairies.[21]

Broumley dairy farm in nearby Hico is the site of a demonstration project intended to reduce pollutants from dairy waste by using the waste to generate electricity. The project has been under way for several years and is expected to begin full operation in 2008.

The Hico project started in 2003 and at the time was envisioned strictly as a water quality project. It has since been modified to include electricity generation.[22] The project began in response to controversy over dairy waste washing into the Bosque River and concerns on the part of citizens of Waco who rely on the river for drinking water.

Numerous government agencies have partnered with Keith Broumley, owner of the dairy farm, to create a phosphorus removal project involving an anaerobic digester. The goal is to remove 80 percent of the phosphorus from the farm's waste

EXHIBIT 16-1

Texas High Plains Manure Resources

Type of Livestock	Number of Head of Livestock	Harvested Manure Millions of Dry Tons per Year	Higher Heating Value, Trillion BTU per year
Beef Cattle	2,750,000	4.7 million	30-50
Dairy	133,000	1.5 million	6-15
Swine	565,000	0.034 million	Not included in estimates

Source: Texas Agricultural Experiment Station.

Exhibit 16-2

Microgy's Huckabay Ridge Processing Plant

Source: Microgy.

Broumley dairy farm in Hico is the site of a demonstration project intended to reduce pollutants from dairy waste by using the waste to generate electricity.

stream while producing methane gas to generate electricity for sale to the grid.

The digester consists of a lined lagoon to hold the dairy waste. Biogas captured from the lagoon is used to generate electricity; the wastewater is then circulated to accumulate the phosphorus for land application. Leftover solids are used for compost.[23]

Renewable energy from manure is helping to support the development of another renewable fuel in Texas. Panda Ethanol is building an ethanol plant near Hereford that will gasify 1,400 tons of feedlot manure from beef cattle and cotton gin waste each day as fuel. The $120 million plant is expected to start production in 2008 and will convert corn and grain sorghum into 105 million gallons of ethanol annually. Panda expects that its construction will require more than 500 workers. After it opens, it will employ about 61 people.[24]

According to Panda, this plant will be the largest biomass-fueled ethanol plant in the U.S. By using more than a billion pounds of manure per year instead of natural gas, Panda estimates it will save the equivalent of 1,000 barrels of oil per day. Panda Ethanol also has announced plans to build similar ethanol plants near Stratford and Muleshoe.

The 2007 Texas Legislature directed the State Energy Conservation Office (SECO) to update a 1995 assessment of Texas renewable energy resources. This report, which will be released before the start of the 2009 Texas legislative session, will include up-to-date data on the availability of various renewable energy resources including feedlot biomass.

Costs and Benefits

Gasifying or burning manure is a way to avoid the monetary and environmental costs of its disposal. Producers usually are not paid for manure used as fuel in Texas; for example, cattle producers are planning to supply the manure to the Hereford ethanol plant for free to avoid disposal costs. Similarly, Microgy's Huckabay Ridge plant receives its manure free of charge from area dairy producers. Microgy has not publicly disclosed the price it receives for the gas it produces.[25] However, as more efficient methods of manure collection are crafted and produce higher quality manure for conversion, there may be more opportunities for agricultural producers.

Environmental Impact

Concentrated animal feeding operations produce residual solids and flush water. For these reasons, both the Texas Commission on Environmental Quality (TCEQ) and the U.S. Environmental Protection Agency (EPA) regulate their operations. Biomass digesters can greatly reduce the effects of CAFOs. Residual products from digesters contain high levels of nitrogen and phosphorus, both common components of fertilizer. Biogas production can produce very localized unpleasant odors, however, and lagoon-based projects carry the potential for wastewater releases during flooding if they are not engineered properly.

Recent studies at Texas A&M University have shown that combining the fuel with pulverized manure, in a process called reburning, can reduce NO_X emissions from coal burning.[26]

In addition, electricity generation from waste can require some water. Estimates of water use place many biomass waste products – wood biomass, feedlot waste, municipal solid waste – in a single category. Depending on the plant type, electricity generation from waste requires withdrawals of between zero and 14,658 gallons per million Btu of heat energy produced. This is the amount of water extracted from a water source; most of the water withdrawn is returned to that source.

Water consumption refers to the portion of those withdrawals that is actually used and no longer available. Electric generation using waste consumes between zero and 150 gallons of water for each million Btu of heat energy produced.

Other Risks

A 2005 study commissioned by the SECO concluded that biogas is a viable technology but a precarious investment, and may be driven more by the need to deal with waste problems than the prospect of making a profit. Digesters can mitigate criticism for odor, surface water and contamination problems. In addition, any cost recovery at least helps pay for the biogas equipment.[27]

One Texas A&M University study examined a Johnson County biogas plant and found that it did not make a profit in the 1990s, although it did help to solve the environmental problems created by animal waste.[28]

State and Federal Oversight

The most significant federal law affecting manure management is the federal Clean Water Act, which includes a National Pollutant Discharge Elimination System that specifically covers animal feeding operations. In 2003, EPA introduced revised Clean Water Act regulations to protect surface water from nutrients released by CAFOs.[29] In 2006, TCEQ issued a general permit under the Clean Water Act setting out regulations and monitoring requirements for waste discharges from CAFOs.[30]

Microgy officials report that they were required to have three different kinds of permits for their plant: an air permit for the boiler; a water discharge permit for land application of wastewater (a permit dairies must obtain as well); and a permit to handle grease trap waste obtained from restaurants.[31]

The Hereford Panda ethanol plant was required to obtain an air quality permit. TCEQ grants permits for air and wastewater quality. It typically takes a year to obtain an air permit for a new ethanol facility in Texas. It can also take about one year to obtain a wastewater permit from TCEQ. These timelines can encounter significant delays, however, depending on public meeting requests or contested case hearings.[32]

Subsidies and Taxes

The 2002 federal Farm Security and Rural Investment Act (the "Farm Bill") contained a specific section encouraging the use of digester systems to produce biogas. Section 9006 of the bill provides partial funding for the installation of livestock waste digestion technology. EPA reports that $25 million was awarded under this program from 2003 to 2005.[33]

According to the U.S. Department of Agriculture, no federal money was committed to Texas digester

The number of digesters operating in the U.S. has more than doubled in the last two years.

projects until 2007, when a dairy south of Sulphur Springs received a $300,000 grant.[34]

In 2007, the Texas Legislature passed a bill to provide state subsidies for the use of biomass, apparently including manure, for electricity production beginning in 2009. No money was appropriated for this program, however.[35] Eligibility for these funds, if any are ever appropriated, would be determined by rules published by the Texas Department of Agriculture.

OTHER STATES AND COUNTRIES

AgStar, a joint program sponsored by the EPA, USDA and the U.S. Department of Energy, encourages biogas production at animal feeding operations, particularly those that manage manures such as liquids and slurries. AgStar reports that the use of anaerobic digesters to produce biogas or methane has accelerated across the country in recent years, due to more reliable digester technology, concern over environmental issues, government incentives and state energy policies that allow producers to sell to the grid.[36]

Using manure for fuel is seen as a way to mitigate potential environmental problems associated with feedlots and dairy operations.

The number of digesters operating in the U.S. has more than doubled in the last two years.[37] Leading states include California, Iowa, Wisconsin, New York and Pennsylvania. These digesters typically produce electricity, although in colder climates they also produce heat for the dairy. Most of these systems are farm-owned and are most common at dairies, although some are used at swine- and duck-feeding operations.[38] EPA is currently preparing a new report on digester activity around the country. As of September 2007, preliminary data being developed for the report indicated that 103 digesters are operating around the country with an energy capacity equivalent to about 22 megawatts.[39]

Some states have incentives for using digesters to produce electricity. EPA reports that New York and Pennsylvania have net metering laws related to feedlot biomass that allow producers to sell energy they generate back to the grid, and California and Maryland are developing similar laws.[40] The Texas Public Utility Commission is currently conducting a rulemaking process that could significantly expand the use of net metering in Texas, as is described in Chapter 9.

California passed a law to extend net metering until the end of 2009. Under this program, electricity produced by biogas is credited against electricity consumed by the dairy farm. In addition, the California Dairy Power Production Program (DPPP) has approved grant funding of nearly $58 million for 14 projects with a generating capacity of about 3.5 megawatts.

Hilarides Dairy in Lindsay, California is one of these projects. The DPPP paid for half of the $1 million cost of its digester. Manure from 6,000 dairy cattle produces 90 percent of the dairy's power. In addition, odor is reduced, methane is captured before it escapes into the atmosphere and the plant reduces demand on the power grid.[41]

The Public Service Commission of Wisconsin has approved a plan by Wisconsin Energy to expand its renewable energy program. Farmers will be paid 8 cents per kilowatt-hour (kWh) for peak energy and 4.9 cents/kWh for off-peak energy. Animal feeders, food processors and wastewater treatment facilities also will be eligible.

Central Vermont Public Service (CVPS) offers a voluntary program for customers to support renewable energy. Ratepayers pay a premium on their bill to receive energy from renewable sources. In turn, CVPS pays farm-based generators the market price of their energy, plus four cents per kWh.[42]

Denmark has pioneered digester technology in Europe. The nation has large-scale plants that combine manure, municipal waste and organic industrial wastes to create electricity and hot water for use in heating systems. In addition, Germany has recently been expanding its number of digesters, a technology it experimented with in the wake of energy shortages following WWII.[43]

OUTLOOK FOR TEXAS

No significant public controversy has arisen over the use of manure as fuel in Texas—or anywhere else, for that matter. Instead, using manure for fuel is seen as a way to mitigate potential environmental problems associated with feedlots and dairy operations. Texas has two digesters, one commercial and one experimental, operating in Central Texas. In addition, Panhandle ethanol plants planned or under construction will use manure as a fuel. Other plants are planned, but the industry is still in its early stages in Texas.

While the use of manure for fuel alone will not solve Texas' or the nation's energy problems, agricultural wastes including manure do have significant potential for power use. Livestock manure and other forms of agricultural waste including poultry litter, rice straw, peanut shells, cotton gin trash and corn stover have the potential to produce 418.9 megawatts of electricity (enough to power over 250,000 homes in Texas, based on average electric use in 2006) according to a recent report from the Houston Advanced Research Center.[44]

The Environmental Protection Agency cites a number of factors that are different today that can contribute to the success of using feedlot biomass for fuel.[45] These include more reliable technology; examples of successful operations to emulate; increasing subsidies; greater concern about environmental issues; state efforts to support the production of renewable energy; and more precise estimates of harvestable manure quantity and quality as a feedstock.[46]

Using manure as a fuel can help agricultural producers cut their disposal costs and earn extra income. It can help solve potential environmental problems associated with CAFOs. By providing another source of energy, it could yield positive economic development effects in rural Texas.

Finally, research indicates that co-firing manure with coal could mitigate the environmental effects of using relatively inexpensive but comparatively dirty coal. It is unclear whether these findings will ultimately result in a widely applicable commercial way to use coal for electricity in a more environmentally friendly way, but it is a very promising avenue for further research.

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CHAPTER 17
Landfill Gas

INTRODUCTION

The natural decomposition of materials deposited in landfills creates more man-made methane than any other source in the U.S.[1] About half of the gas emitted by landfills is methane; these gases have about half the energy potential of natural gas. Landfills must monitor their methane production or collect and burn it to prevent air pollution. Therefore, using landfill methane to generate electricity, fire boilers or substitute for other energy sources can turn a potential liability into a benefit.[2]

Preparing a 1 million-ton landfill for energy production can entail initial capital costs of $600,000 to $750,000 or more and operating costs of $40,000 to $50,000 a year. Other costs include legal fees, permitting, environmental impact studies and other costs associated with maintaining the landfill.[3] Their long-term economic and environmental impacts, however, are difficult to calculate because landfills can pollute the air, ground and water if they are not managed well.

History

From colonial times, residents of American cities tossed trash and garbage onto their streets. As cities grew, so did the volumes of garbage. Modern solid waste management started in 1895, when New York City Street Cleaning Commissioner Colonel George E. Waring Jr. arranged to send the city's wastes to dumps and incinerators, or to be deposited in waterways. The New York Board of Health quickly noticed that this new policy lowered the city's death rate from disease, one indication of the problems caused by waste. Yet most cities at that time still had no organized system of disposal, continuing to pile rubbish in open pits that could accidentally catch on fire or be set on fire intentionally.[4]

In the 1920s, the British began the practice of "sanitary" landfilling — covering the trash each day with earth. This practice was adopted in the U.S. in New York City and Fresno, California in the 1930s. The U.S. Army Corps of Engineers also experimented with the practice during World War II. The practice spread rapidly in the postwar era, as civilian waste volume increased dramatically and open dumps spewed forth odors, smoke, rats, flies and paper trash.[5]

But engineers underestimated the amount of methane generated by landfills, and its ability to cause fires or explosions in nearby structures as the gas migrated. When landfills sited in quarries or pits are covered with earth each day, conditions are ideal for the formation of methane, which is produced by the anaerobic (meaning "without oxygen") decomposition of trash. More importantly, this methane can travel through porous ground or layers of trash, appearing up to one kilometer away.[6]

Methane is explosive even at low concentrations in air.[7] In previous decades, the U.S. Environmental Protection Agency (EPA) documented at least 40 explosions or fires caused by migrating landfill gas, including 10 accidents causing injuries or deaths.[8] More recent accidents are less common. On December 20, 2007, the Operations Manager of the Mountainview Landfill near Cumberland, Maryland received second- and third- degree burns from a methane gas explosion. A spark from an electrical device being used by the manager ignited the flash fire.[9]

The U.S. Solid Waste Disposal Act of 1965 established a federal solid waste research and development program and directed funds to states and cities for new disposal programs. In 1976, with the passage of the Resource Conservation and Recovery Act, the federal government assumed more responsibility for solid waste management. EPA guidelines issued in 1979 ended legal open dumping in the U.S. Clean Air Act amendments in 1990 required stricter regulations on landfills and the EPA issued these in 1991.[10]

Federally funded research and other changes in policy also spurred the development of a market

Using landfill methane to generate electricity, fire boilers or substitute for other energy sources can turn a potential liability into a benefit.

for landfill gas. The Energy Research and Development Administration (ERDA), created by the federal Energy Reorganization Act of 1974, concentrated on developing technologies to enhance domestic energy resources. Also in 1974, the Non-Nuclear Energy Research and Development Act required federal research on the use of solid waste. A key ERDA study on municipal solid waste found that methane recovery from wastewater treatment could supply 10 to 15 times the amount of energy cities use in providing municipal services. The study spurred ERDA to study solid wastes. As a direct result of these studies, the first commercial landfill gas-to-energy project at Rolling Hills Estates in California opened in 1975.

Several more national energy policy changes were needed to make landfill methane economically feasible. The 1978 Public Utility Regulatory Policies Act required the Federal Energy Regulatory Commission (FERC) to guarantee a market for electricity produced by small power plants. FERC required electric utilities to buy electricity produced by facilities producing less than 80 megawatts (MW) of electricity, which generally includes landfill gas production sites.

The Department of Energy Act of 1977 created the U.S. Department of Energy, which was authorized to fund and regulate waste-to-energy research projects and energy research. Federal tax credits enacted in 1980 encouraged the development of private enterprises to participate in the landfill gas market. Finally, federal air pollution regulations enacted in 1991 and 1996 required some landfills to meet higher standards for controlling their gas emissions, another factor encouraging the adoption of landfill gas technology.[11]

Uses

Landfill gas can be burned directly to generate electricity or it can be processed into a higher-energy gas for power generation. It can also be burned as a heat source for various industrial processes.

Texas has 24 landfill gas energy projects and at least 57 more sites suitable for such projects.

The McCommas Bluff Landfill, Operated by the City of Dallas

Source: Texas Comptroller of Public Accounts.

LANDFILL GAS IN TEXAS

According to an EPA landfill database, Texas has 24 landfill gas energy projects and at least 57 more sites suitable for such projects. All but two of these projects are generating electricity, with a total collective capacity of at least 79 MW. No economic data on these projects are available.

Texas' first landfill gas project, Harris County's McCarty Road Landfill, opened in 1986. Most projects in Texas, however, began after 2000. Compared to other states, Texas is a relative newcomer to the use of landfill gas as an energy source.

Waste Management, Inc. owns ten operating landfill gas energy sites; Allied Waste Services owns five operating sites. Texas cities and counties own the remaining sites.[12]

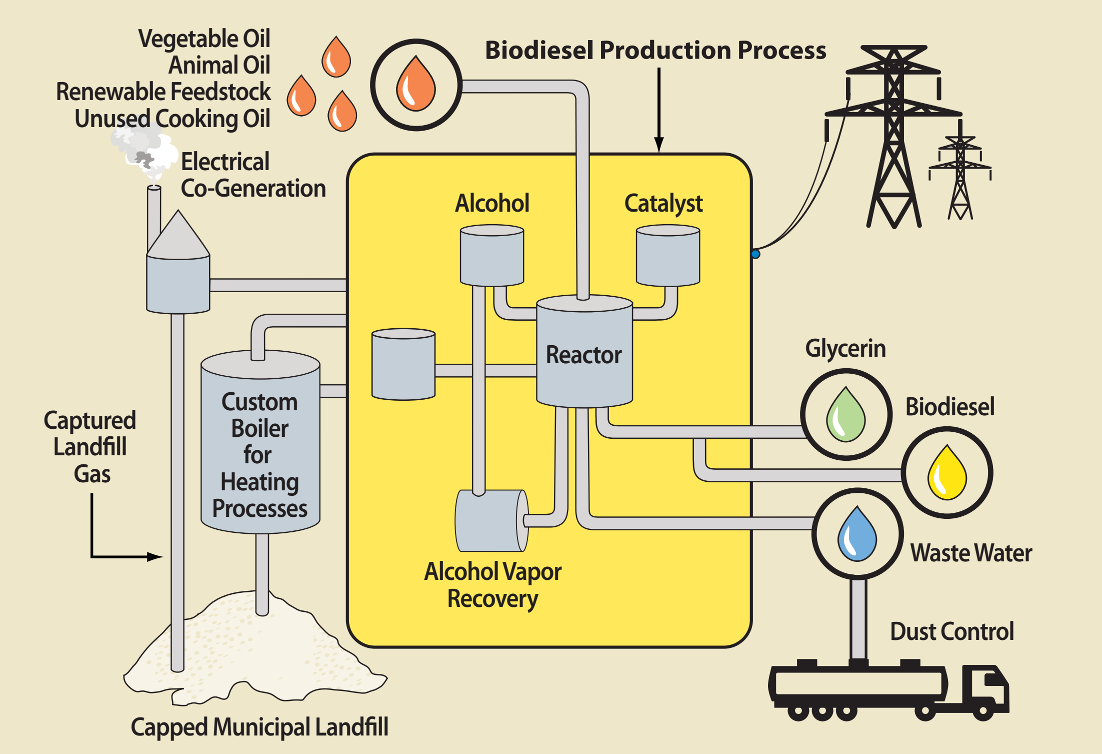
Two projects, Dallas' McCommas Bluff landfill and Houston's McCarty Road landfill, process landfill gas into a fuel with the same energy value as natural gas. The city of Dallas has contracted with a private company to develop the methane in its landfill; the company will own the rights to the gas produced for 30 years. The company sells the fuel directly to Atmos Energy Company, a natural gas supplier.[13]

Six other Texas projects generate energy for direct use. For example, in Denton, landfill gas is used to produce biodiesel fuel. Gas wells from Denton's landfill supply gas for heating water, as part of a chemical process that converts vegetable oils and animal fats to biodiesel fuel (**Exhibit 17-1**). The biodiesel production facility, owned and operated by BioDiesel Industries of Greater Dallas Fort Worth, sells the fuel it produces to other companies for blending with diesel; the blended fuel is used in garbage trucks and other utility trucks.[14]

Some landfills use gas to power generators that provide electricity to a utility or industrial customer.

EXHIBIT 17-1

Denton Biodiesel Plant



Source: Biodiesel Industries of Greater Dallas Fort Worth, LLC.

Consumption

Federal statistics combine landfill gas with the burning of municipal solid waste (See Chapter 18) for energy production in calculating state comparisons. Texas landfill and municipal waste projects produced just 230 million kilowatt-hours (kWh) in 2006. California, Florida, Massachusetts, New York and Pennsylvania each produced in excess of 1 billion kWh of electric power from both sources, led by Florida, with 1.9 billion kWh in 2006.[15]

Production

Most new landfills, if they fall under federal regulations, are required to collect methane to prevent air pollution, but most existing Texas landfills simply burn it off, a process called "flaring," without producing any useful energy.[16]

Landfills with collection systems can drill small wells and install compressors and pipes to remove the gas. The gas collects in the pipes and is channeled to a central collection point, where it may be treated to remove contaminants and moisture. It then can be transported by pipeline or used on site to generate heat or electricity, or transformed into cleaner gas and sent to a natural gas pipeline.[17]

The State Energy Conservation Office estimates that if the 70 largest landfills in Texas were fully developed for energy production, about 40 billion cubic feet of methane could be put to use generating nearly 200 MW of electricity.

Methane is generated as soon as solid waste is put in a landfill. Peak production starts about a year after deposit, but gas can be generated for 20 or more years, depending on the individual landfill characteristics. Moisture, the composition of materials in the landfill, soil types, air temperatures and other factors make each landfill unique in how much gas it produces, what the gas's components are and when it begins producing the gas.[18]

Generation

There are many ways to generate energy from landfill gas. The gas from the landfill can generate electricity; heat water into steam; be converted to fuel for vehicles; or purified to be used in natural gas pipelines.

The simplest and cheapest way to use landfill gas is to pipe the gas directly to the customer, who uses the gas to fuel boilers or combustion equipment. It can be used commercially for industrial kilns, thermal dryers (used in waste management operations), and cement and asphalt plants.[19] A greenhouse in Burlington, N.J. uses landfill gas to fuel a boiler for heating and to power four microturbines to convert landfill gas into electricity.[20]

Some landfills use gas to power generators that provide electricity to a utility or industrial customer. There are several types of electric generators: combustion turbines; steam/boiler turbines; and internal combustion engines.

About two-thirds of the landfill sites collecting methane in the U.S. generate electricity for on-site use or for sale. Most of these projects use internal combustion (IC) engines because they are efficient, cost effective and are usually a good match with the gas output of the average size landfill. IC engines are generally used at landfills where gas flows are capable of producing one to three MW.[21]

Larger landfills, with gas flows of more than two million cubic feet per day (cfd), can more efficiently use a combustion turbine to generate electricity, generating at least three or four MW.[22] Boiler/steam turbines are used mainly at very large landfills that have gas flows of at least five million cfd, generating at least eight to nine MW. The boiler/steam turbine systems are expensive to operate and only the largest landfills can afford to use them.[23]

Transmission

Most landfill gas energy projects collect, process and either use or distribute methane near the landfill site. However, landfill gas can be moved across longer distances via pipeline. In Hopewell, Virginia, Honeywell has a 23-mile long, 18-inch polyethylene pipeline carrying gas from a landfill in Sussex County, Virginia, and a 15-year contract with the landfill owner, Atlantic Waste Disposal. This is believed to be the longest landfill gas pipeline currently in use in the United States.[24]

In 2001, EPA reported that projects of this type were economically feasible only with pipeline lengths of less than five miles, however the Honeywell pipeline, which came on line in 2004, demonstrates the changing market potential for landfill gas and the fact that a longer pipeline can be successful.[25]

Storage and Disposal

The methane gas produced by landfills is not stored. It is used to produce energy either for sale or use on site or to generate energy as heat or steam for other purposes.

Landfill Gas Wells and Collection Systems

Source: Texas Comptroller of Public Accounts.

Availability

Every year, U.S. residents and companies discard mountains of waste — an estimated 251 million tons of it in 2006.[26]

Texans threw away 30.5 million tons of garbage in 2006. Even after removing construction waste and water treatment plant sludge from the total, this means that an average of 5.8 pounds of solid waste for every man, woman and child in the state was thrown away each day. This waste was deposited in one of 187 landfills actively accepting waste.[27]

According to the Texas Commission on Environmental Quality (TCEQ), landfills suitable for transformation into power-generating sites are those that have more than 1 million tons of refuse, are at least 40 feet deep and are in areas receiving more than 25 inches of rainfall annually. TCEQ estimated that 59 Texas landfills meet these criteria.[28] This is similar to EPA's landfill gas energy database estimate that Texas has 57 landfills that are candidates to generate power.[29]

By any estimate, Texas has potential for using this untapped energy source. The State Energy Conservation Office estimates that if the 70 largest landfills in Texas were fully developed for energy production, about 40 billion cubic feet of methane could be put to use generating nearly 200 MW of electricity, powering more than 100,000 homes in Texas.[30]

COSTS AND BENEFITS

According to EPA, preparing a 1 million-ton landfill for energy production can entail initial capital costs of $600,000 to $750,000 and operating costs of $40,000 to $50,000 a year. Administrative costs associated with legal issues and permitting, environmental impact studies and other costs also may be incurred.[31] Capital costs vary according to the type of plant used to process the methane. California's capital costs varied from $606 per kW to $6,811 per kW in 2001.[32]

Production costs and gas prices vary according to the size of the project, the technology used and the uses to which landfill gas is put. Prices of most renewables are not collected, according to the Energy Information Administration. Most newer renewable projects are developed and operated by independent power producers, and sold to utilities on a contractual basis (known as a power purchase agreement, or PPA). The price in the PPA represents wholesale cost and is typically held confidential by the parties involved.[33]

Landfill gas is less expensive than natural gas. For March 2008, the average natural gas price on the New York Mercantile Exchange was $9.590 per million Btus (MMBtu).[34]

Environmental Impact

Using landfill gas as another source of energy reduces the release of methane into the atmosphere and thus the accumulation of greenhouse gases. Landfills operators are required to meet air quality standards, so recovering energy from methane can help them offset the cost of meeting federal requirements.[35]

According to EPA, a three MW landfill gas project producing electricity generates the environmental equivalent of removing 25,000 cars from the road; planting 35,000 acres of trees; or preventing the use of 304,000 barrels of oil.[36]

Sometimes, pipelines carrying landfill gas traverse sensitive environmental areas. Methane gas is

Using landfill gas as another source of energy reduces the release of methane into the atmosphere.

transported from the Arlington, Texas, landfill via a four-mile pipeline to the Fort Worth Village Creek Wastewater Treatment Plant. This pipeline passes under River Legacy Park, a 1,300-acre Trinity River greenbelt, forest and floodplain area.[37]

Other Risks

Methane forms naturally as organic materials decompose. If not properly vented or collected and flared, it can potentially cause fires or explosions. The gas can migrate into nearby structures or buildings built on top of old landfills. EPA regulations requiring landfills to have non-porous liners and to vent, collect or flare gas have greatly enhanced safety.

State and Federal Oversight

House Bill 3415, enacted by the 2001 Texas Legislature, encouraged the use of landfill gas for state energy purposes. The bill required TCEQ and the Public Utility Commission to promote the economic development and use of landfill gas. Specifically, the agencies were to publicize agency information on landfills with a potential for landfill gas development; assist various industry sectors to form partnerships for developing landfill gas; and establish an information clearinghouse on landfill gas development and use.[38]

In November 2002, TCEQ released a status report on the development of Texas' landfill gas resources. The report concluded that there were few obstacles to the development of landfill gas projects, but that some actions could speed their development. TCEQ recommended outreach and informational efforts such as developing a primer and Web page on landfill gas development and sponsoring a workshop for interested parties.[39]

Also in 2002, the Texas Senate Interim Committee on Natural Resources made legislative recommendations on alternative fuel sources. The committee recommended surveying existing landfills and connecting potential gas recovery projects with the U.S. EPA's Landfill Methane Outreach program (LMOP).[40] LMOP provides information and resources to communities, companies and other parties interested in recovering and using landfill gas.

State laws and regulations require landfills to acquire appropriate air, wastewater and solid waste permits. These rules outline actions a landfill must take to protect the environment and public health and safety.[41]

As noted above, federal involvement with landfill regulation began with the Resource Conservation and Recovery Act of 1976 and was intensified by 1979 EPA guidelines and 1990 Clean Air Act amendments.[42] In the 1990s, federal air pollution regulations further tightened emissions standards at existing landfills.[43]

Subsidies and Taxes

A federal production tax credit of one cent per kWh is available for energy produced from landfill gas. Chapter 28 contains more information on biomass subsidies.

OTHER STATES AND COUNTRIES

Pennsylvania serves as a model state in the development of landfill gas. The state has 24 landfill gas-to-energy projects, representing a relatively high percentage of all Pennsylvania landfills.[44] In 2006, EPA named Pennsylvania as the State Partner of the Year for its work in promoting the use of landfill gas as a renewable energy source. Pennsylvania developed a landfill methane database and wrote a landfill gas development primer.[45] Landfill gas is included as part of the state's alternative energy portfolio standards, and the state has provided an estimated $3.8 million from several different programs to benefit landfill gas projects.[46]

Massachusetts has 15 landfills producing about 51 MW of power across the state. In Massachusetts, one megawatt powers about 1,200 homes. Many of these projects began in the 1990s when the Massachusetts Department of Environmental Protection began promoting landfill gas as a renewable fuel source. The state was looking for ways to diversify and expand its energy portfolio so that it did not rely on a few sources for energy. Landfill gas to energy projects benefited the state in two ways: they decreased the methane emissions from landfills (which improved air quality), and provided the state with a renewable fuel for generating power. More landfill gas to energy projects are in development and are expected to generate an additional 9 MW of power for Massachusetts residents when completed.[47]

OUTLOOK FOR TEXAS

Given the rising costs of oil and natural gas, landfill gas presents an attractive and relatively untapped energy source. Yet it has not been a major focus for research and development in the state.

Some new technologies in this area are being studied, however, such as "landfill bioreactors," in which water is added to the landfill to speed up the process of decomposition. Other companies are exploring ways to thoroughly clean the gas that landfills produce. Cleaning the gas separates the methane, which is the main component of natural gas, and CO2, which can be sold separately for commercial purposes.

Richard DiGia, vice president of operations and construction for DTE Biomass Energy, has said that landfill gas is very attractive for electric generation compared with other renewable sources of energy because of the capacity. "As long as we keep landfilling there'll be landfill gas," he stated.[48]

With 186 landfills actively accepting waste and an estimated 50-plus candidate sites that could develop landfill gas, Texas has an opportunity to turn much more of its waste into cash.

Developing landfill gas facilities makes sense only if private or public entities can use, buy or sell it. Gary Bartels, general manager of the city of Arlington's landfill for Republic Waste Services, pointed out the advantages of having private companies as partners: as private entities, they can qualify for federal landfill gas production tax credits, lowering the break-even threshold for the operation.[49]

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CHAPTER 18

Municipal Waste Combustion

INTRODUCTION

Some cities, primarily in the northeastern and mid-Atlantic U.S., burn part of their municipal solid wastes. Hemmed in by major population centers, landfill space there is at a premium, so burning wastes to reduce their volume and weight makes sense. Combustion reduces the volume of material by about 90 percent and its weight by 75 percent.[1] The heat generated by burning wastes has other uses, as well, as it can be used directly for heating, to produce steam or to generate electricity.

In Texas, municipal waste combustion facilities have had little to no economic impact on the state as a whole. Texas had two permitted waste incinerators in 2006, and one waste-to-energy facility in Carthage.[2] The Carthage plant is now owned by a private company that uses the facility to incinerate medical waste.

History

In 1885, the U.S. Army built the nation's first garbage incinerator on Governor's Island in New York City harbor. Also in 1885, Allegheny, Pennsylvania built the first municipal incinerator. As their populations increased, many cities turned to incinerators as a convenient way to dispose of wastes.

These incineration facilities usually were located within city limits because transporting garbage to distant locations was impractical. By the end of the 1930s, an estimated 700 incinerators were in use across the nation.[3] This number declined to about 265 by 1966, due to air emissions problems and other limitations of the technology. In addition, the popularity of landfills increased.[4]

In the early 20th century, some U.S. cities began generating electricity or steam from burning wastes. In the 1920s, Atlanta sold steam from its incinerators to the Atlanta Gas Light Company and Georgia Power Company.

Europe, however, developed waste-to-energy technologies more thoroughly, in part because these countries had less land available for landfills. After World War II, European cities further developed such facilities as they rebuilt areas ravaged by war. U.S. cities interested in converting waste to energy tended to acquire European technologies when they built or improved their incinerators.

In the 1970s, the Arab oil embargo and increasing energy prices encouraged the development of waste combustion. The U.S. Navy, for instance, built waste-to-energy plants at two Virginia naval stations, one of which is still in use.

Federal laws and policies aided the development of the waste-to-energy industry. The 1970 Clean Air Act authorized the end of open burning at U.S. landfills. City incinerators also were required to install pollution controls or cease operation, and a number of the worst polluters were closed down. Losing incinerators forced cities to consider waste-to-energy plants and look again to Europe for technology. In 1975, the first privately built waste-to-energy plant opened in Massachusetts; it experienced a number of operational problems at first as engineers sought to adapt it to the contents of American waste and made other operational changes.

In the late 1970s, the federal government started to fund feasibility studies for local governments interested in setting up new waste-to-energy plants.

The 1978 Public Utility Regulatory Policies Act (PURPA), which required the Federal Energy Regulatory Commission to guarantee a market for electricity produced by small power plants, allowed new waste-to-energy projects to find financing. PURPA made waste-to-energy projects financially viable, since projects could find buyers for the electricity they generated.[5]

The 1980 Energy Security Act appropriated funds to support biomass energy projects and required

Combustion reduces the volume of solid waste material by about 90 percent and its weight by 75 percent.

federal agencies to prepare a plan for maximizing its production and use. The act provided insured loans, loan and price guarantees and purchase agreements for biomass projects, including waste-to-energy projects using municipal solid waste. It also directed the U.S. Department of Energy to prepare a municipal waste energy development plan and support it with construction loans, and loan guarantees, price support loans and price guarantees. The act also authorized research and development for promoting the commercial viability of energy recovery from municipal waste.[6]

While the majority of this funding was rescinded in the 1980's, some federal money flowed to businesses and local governments, and about 46 new waste-to-energy facilities were built.[7]

The 1986 federal Tax Reform Act simultaneously benefited and harmed the development of waste-to-energy facilities. The act extended federal tax credits available for waste-to-energy facilities for ten years, but also repealed the tax-free status of waste-to-energy plants financed with industrial development bonds.[8]

The use of municipal waste combustion for energy is not common; the nation had only 87 such facilities in 2007.

In the 1990s, after the tax credits extended in 1986 finally ended, fewer waste-to-energy plants were built.

Uses

The heat generated by burning waste can be used directly for heating; to produce steam; or to produce electricity.

MUNICIPAL WASTE COMBUSTION IN TEXAS

Space for landfills has been plentiful in the past, but is becoming harder to find in large urban areas. Recycling programs have reduced the amount of matter going into landfills, but combustion may become more viable in some urban areas if landfill sites become scarce or if energy prices make combustion more economically viable.

Economic Impact

Municipal waste combustion facilities in Texas have had little economic impact on the state as a whole. Texas sole permitted waste-to-energy facility does not produce electricity. At this time, the Sharps Environmental Service Solid Waste Incineration Facility has the capability of producing steam for sale, but it is currently operating the facility only as an incinerator.[9] A 50 MW waste-to-energy plant in Polk County, Florida, has an estimated $6 million annual regional economic impact, according to its operator, Wheelabrator Ridge Energy, Inc.[10] A similarly-sized plant in Texas would have comparable economic impact.

Consumption

The use of municipal waste combustion for energy is not common; the nation had only 87 such facilities in 2007.[11] Even so, about 31.4 million tons of solid waste were channeled to these plants in 2006, representing 12.5 percent of all municipal solid waste disposal.[12]

Texas' sole permitted waste-to-energy facility processed 387 tons of waste in 2006.[13]

In addition, a 2006 agreement between two energy contractors will lead to the development of another waste-to-energy power plant supplying Dyess Air Force Base in Abilene.[14] About a third of Abilene's solid waste — some 35,000 tons a year — will be fired, along with garbage from the base and the nearby city of Tye. Dyess will buy discounted energy from the contractor operating the waste-to-energy plant, saving nearly half of its current energy costs.[15] The Air Force contract totals over $39 million and includes the waste-to-energy plant plus diesel back-up generators.[16]

Production

Waste-to-energy facilities tend to be built near the landfills of large urban centers. A few facilities are modular units, smaller plants built off-site and transported to wherever they are needed.

Waste-to-energy plants generate electricity by burning municipal wastes in large furnaces to produce steam, which in turn drives a steam turbine to generate electricity. On average, one ton of waste produces 525 kilowatt-hours (kWh) of electricity. This is equivalent to the energy produced by a quarter-ton of coal or one barrel of oil.[17]

One type of waste-to-energy plant is called a *mass burn facility* (**Exhibit18-1**). These facilities use solid waste directly off garbage trucks, without shredding or processing the materials. The solid waste is then fired in large furnaces to produce steam, which turns a steam turbine to generate electricity.[18]

Less than a fifth of the U.S. municipal solid waste incinerators recover glass, metals and other recyclable materials and then shred the combustible materials before firing. This type of plant is called a *refuse-derived fuel* (RDF) plant.[19] Sometimes, refuse-derived fuel is prepared at one facility and then transported to another for burning.[20] The shredded waste also may be added as a fuel to boilers that burn fossil fuels.

Mass burn and RDF plants are the most common facilities in use today. A new technology called *thermal gasification*, however, changes waste into synthesis gas, a mixture of hydrogen and carbon monoxide. Contaminants are removed from this gas, which can then be burned as fuel.[21] The Dyess Air Force Base project will be a thermal gasification project.[22]

Storage

The energy or hot gas produced by waste-to-energy plants is not stored. It is used to produce energy, either to sell to an electric company or business or to produce steam for other purposes.

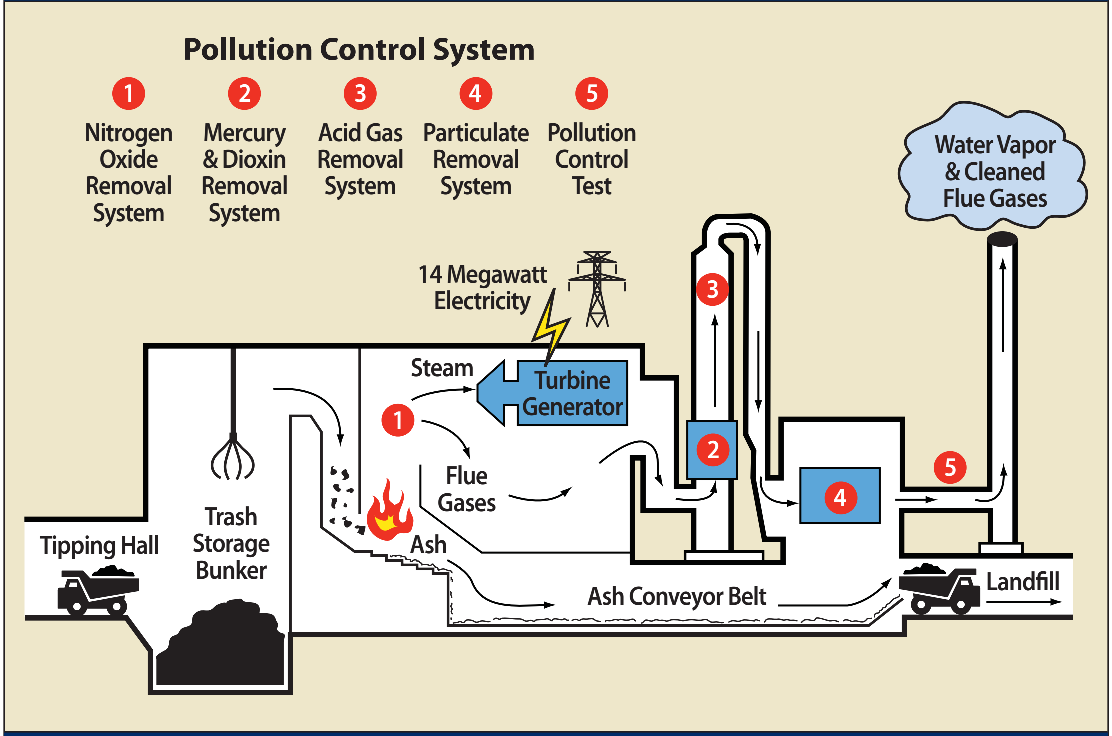
Availability

The nation's 87 waste-to-energy facilities are mostly located in the Northeast, but 25 states have at least one. Their generating capacity is a total of 2,720 megawatts of power, enough electricity to power all the homes in Maine, New Hampshire, Vermont, Rhode Island and most of Massachusetts. They can process 28.7 million tons of waste each year.[23] Most sites burn all types of solid waste, but some burn material separated from the main waste stream, such as tires, wood or paper.

According to a Columbia University survey published in *BioCycle* magazine, the U.S. generated about 388 million tons of municipal solid waste

EXHIBIT 18-1

Waste to Energy Plant Diagram



Source: ecomaine.

A typical waste-to-energy plant generates about 500 to 600 kWh per ton of waste.

in 2004. Of this amount, about 28.5 percent was recycled and composted; about 7.4 percent was burned in waste-to-energy plants; and the majority, 64.1 percent, was put in landfills (**Exhibit 18-2**).[24]

The U.S. Environmental Protection Agency (EPA), using a different methodology, estimates that the U.S. generated 251.3 million tons of garbage in 2006. Of this amount, 81.8 million tons (32.5 percent) were recycled and composted; and 31.4 million tons (12.5 percent) were burned for energy production. The remaining 138.2 million tons (55 percent) were placed in landfills (**Exhibit 18-2**).

The waste-to-energy industry has been outpaced by the growth of recycling and composting. In 1990, recycling and composting accounted for 33.2 million tons of waste; that rose to 81.8 million tons in 2006, an increase of 146 percent. The amount of waste burned for energy recovery in 2006 (31.4 million tons) is only slightly larger than that in 1990, 29.7 million tons — a 0.3 percent average growth rate.[25]

COSTS AND BENEFITS

In 2005, an official of one of the leading U.S. companies operating municipal waste combustion facilities, American Ref-Fuel Company, testified before Congress that a new facility that can generate 60 megawatts of electricity from about 2,250 tons of trash daily would cost about $350 million. Its operating costs would be about $28 million a year.[26] This would be a very large plant; only fourteen locations in the U.S. have the capacity to combust more than 2,250 tons of trash per day.[27]

EXHIBIT 18-2

U.S. Waste Disposal

	EPA Estimate, 2006	BioCycle Estimate, 2004
Amount of Waste Generated	251.3 million tons	388 million tons

Mode of Disposal	Percent	Percent
Combusted	12.5	7.4
In Landfills	55	64.1
Recycled or composted	32.5	28.5

Sources: U.S. Environmental Protection Agency and BioCycle Magazine.

A typical waste-to-energy plant generates about 550 kWh per ton of waste. At an average price of four cents per kWh, revenues per ton of solid waste would be $20 to $30.

Even so, waste-to-energy plants are undeniably expensive. According to the Waste-to-Energy Research and Technology Council (WTERT), capital costs to build a facility range from $110,000 to $140,000 per daily ton of capacity. Thus a plant that processes 1,000 tons of municipal solid waste per day might cost from $110 million to $140 million. It would also require a staff of about 60, and materials, supplies and the cost of ash disposal also would add to operating costs.[28]

Due in part to the high cost of their construction, no new U.S. waste-to-energy facilities have been built in the last ten years. But rising energy costs and tax and other incentives enacted in the Energy Policy Act of 2005 have prompted some existing waste-to-energy facilities to expand their capacity, and the industry is encouraging governments to build new ones. In Florida, the Lee County Solid Waste Resource Recovery Facility in Fort Meyers has begun an expansion of its facility that will expand its operations by 50 percent.[29]

The economic benefits generated by such plants include the value of the energy generated; the trash disposal fees paid by communities contracting with the waste-to-energy company; and the value of scrap collected.[30] Both the fees paid to the plant for trash disposal and fees paid for generating electricity are key to the facilities' economic success, but these are not sufficient to cover the total costs of building new facilities. Federal tax credits help to make up the difference.[31]

Environmental Impact

Burning solid waste produces nitrogen oxides and sulfur dioxide as well as trace amounts of toxic pollutants such as mercury compounds and dioxins.

The nature of the waste burned affects the composition of its emissions. If batteries or other materials containing heavy metals are burned, particularly toxic materials can be released into the air.[32] Some of these materials, such as dioxins, furans and metals, do not degrade quickly when released, and may be deposited on plants and in water. Animals and fish may absorb them, and humans may be exposed if they eat the contaminated animals or fish. Particulate matter, hydrogen chloride, carbon monoxide and nitrogen oxides also can be released into the air and absorbed into the environment.[33]

Waste-to-energy power plants use water in boilers and in cooling. When this water is discharged, its higher temperature and pollutants it contains can harm aquatic life and reduce water quality.

Scrubbers — devices that use a liquid spray to neutralize acid gases — and filters to remove particles are used to treat the emissions created when solid waste is burned. Ashes representing about 25 percent of the weight of the original combustible material are generated when waste is burned. Metals must be removed from this ash, and the ash must be tested to ensure that it meets environmental standards before it is recycled for use in roadway construction or placed in a landfill. Ash may be used as daily cover at landfills, but its disposal still represents a considerable operational cost for most waste-burning facilities.[34]

In 1995, EPA ordered waste-to-energy facilities to meet maximum pollution control standards by 2000. This required the facilities to significantly reduce their emissions of dioxin, mercury, lead, cadmium, hydrochloric acid and particulates. Between that time and the present, EPA estimates that these requirements reduced emissions of dioxins and furans from waste-to-energy plants by more than 99 percent; metals by more than 93 percent; and acid gases by more than 91 percent. In 2006, EPA further tightened standards for large municipal waste burners. [35]

A Renewable Resource?

Should waste-to-energy be regarded a renewable source of energy? Fifteen states have categorized waste-to-energy as a renewable resource in their renewable portfolio standards and some federal laws have categorized it as a renewable resource.[36] On the other hand, some federal and state tax advantages given to other renewable resources are not available to waste-to-energy facilities. In Texas, some consumer groups have opposed including waste-to-energy in Texas's renewable energy goals.[37]

Noise also may be an issue with waste-to-energy plants. Trucks that bring solid waste to the facility, plant operations and fans can be sources of noise pollution.

In addition, electricity generation from waste can require some water. Estimates of water use place many biomass waste products – wood biomass, feedlot waste, municipal solid waste – in a single category. Depending on the plant type, electricity generation from waste requires withdrawals of between zero and 14,658 gallons per million Btu of heat energy produced. This is the amount of water extracted from a water source; most of the water withdrawn is returned to that source.

Water consumption refers to the portion of those withdrawals that is actually used and no longer available. Electric generation using waste consumes between zero and 150 gallons of water for each million Btu of heat energy produced.

Scrubbers — devices that use a liquid spray to neutralize acid gases — and filters to remove particles are used to treat the emissions created when solid waste is burned.

Other Risks

The expense of waste-to-energy plants poses a considerable financial risk. Assessments of their viability should include accurate projections of the amount of waste that is available to burn; the potential price for the energy produced; and potential customers for this energy.[38]

Subsidies and Taxes

A federal production tax credit of one cent per kWh is available for energy produced from municipal solid waste. Chapter 28 contains more information on biomass subsidies.

STATE AND FEDERAL OVERSIGHT

Federal and state pollution laws regulate waste-to-energy power plants. As mentioned previously, EPA ordered waste-to-energy facilities to reduce their emissions of dioxin, mercury, lead, cadmium, hydrochloric acid and particulates significantly.[39]

These facilities are also regulated under Texas' environmental pollution laws in the Health and Safety Code, which establishes air quality and environmental standards to protect public health and the environment.[40]

OTHER STATES AND COUNTRIES

Again, most municipal solid waste combustion facilities are in the Northeastern or mid-Atlantic states.

Federal statistics for power generation from waste-to-energy plants are combined with those for power generation from landfill gas. In combination, Florida generates more energy from waste-to-energy facilities and landfill gas than any other state – an estimated 3.0 billion kWh in 2005. New York, with 2.2 billion kWh and Pennsylvania, with 2.1 billion kWh were second and third in 2005. Texas generated only 207 million kWh and most of this was from landfill gas.[41]

In 2005, there were over 430 waste-to-energy plants in Europe burning about 50 million metric tons of waste.[42] This is more than one-and-a-half times the 33.4 million tons of materials the U.S. burned in 2005.[43]

Japan incinerated 69 percent and Denmark incinerated as much as 54 percent of its solid waste for energy in 2003 (latest figure available); France and Belgium burned 32 percent each, in 2005 and 2003, respectively.[44]

The primary advantage of waste-to-energy plants is that they consume wastes from highly populated urban areas, relieving the burden on landfills.

OUTLOOK FOR TEXAS

The primary advantage of waste-to-energy plants is that they consume wastes from highly populated urban areas, relieving the burden on landfills. The electricity the plants generate, however, is more costly than energy produced by coal, nuclear or hydropower plants.[45] In addition, the costs of waste-to-energy facilities are much greater than the cost of landfills — if the latter are available.[46]

The potential pollution problems of waste-to-energy facilities involve perceptions as well as realities. The public is likely to perceive these facilities as more polluting than other types of energy. Any new waste-to-energy plant would require zoning, air and water permits, and many communities might reject such a proposal on the basis of air pollution, noise or odors.[47]

Many urban areas in Texas already have air pollution problems, and a new waste-to-energy facility could add to them. Yet, new waste-to-energy plants must be located near large cities, because they require large amounts of waste, and the cost of transporting waste from remote locations would be prohibitive. Also, increases in recycling could affect the financial viability of waste-to-energy facilities, which depend upon dumping fees from users.

In all, the outlook for waste-to energy plants in Texas is challenging. The expense of building plants, the availability and lower costs of landfill space, air pollution problems and other issues pose considerable obstacles.

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Chapter 19
Hydropower

Introduction

Hydropower is the most common source of renewable electricity in the United States. In 2005, even with the recent expansion of the renewable energy sector from sources such as wind, solar and biomass, hydropower still comprised 73 percent of the nation's renewably generated electricity.

Large-scale hydroelectric power generation is, however, concentrated in certain geographic regions in the U.S., most notably the Pacific Northwest.[1] Texas hydroelectric power has played an important role in the past, particularly in bringing electricity and jobs to rural areas of the state in the mid-1900s. Currently, however, it is a tiny portion of the state's electricity supply with little economic impact and limited prospects for expansion.

History

Human beings have harnessed the power of moving water for millennia, originally for purposes such as grinding grain and sawing wood. They have been employing its power to generate electricity since the 19th century, near the very beginning of the electric age. For example, Niagara Falls, New York began powering its street lights with hydroelectricity in 1881. In the following year, the world's first hydroelectric power plant opened in Appleton, Wisconsin.[2]

Until the development of effective transmission technology in 1893, however, hydroelectricity was limited to uses near its water source.[3]

Uses

Most American hydroelectric power is generated through the force of falling water, by damming a stream or river to raise its water level and then allowing the water to fall against a turbine connected to a generator. Thus, the potential energy of the elevated water is transformed into kinetic energy of the falling water, which becomes mechanical energy in the turbine, and transformed again into electric energy in the generator (**Exhibit 19-1**).

Another type of what is called "conventional" hydroelectric power comes from "run-of-river" facilities that rely on the strength of the river's flow to drive turbines, without raising the water level with a dam. To provide significant amounts of electricity in this way requires a fast-flowing river, usually found in steep terrain or where a large stream is confined in a narrow bed.

Still another form of hydroelectric power is created through what is called "pumped storage," in which water is moved from a lower-elevation storage facility (either a reservoir or a purpose-built container) to a higher elevation for release during peak demand. Although pumping the water uphill consumes more electricity than is generated by the water flowing back down, the financial return for the peak power is higher than the cost of pumping water during off-peak times.[4] Furthermore, this procedure can be used to store the energy from intermittent or variable sources such as wind and solar power, a technical challenge receiving a lot of attention; this use for pumped storage is currently being tested in Europe.[5] Consequently, hydroelectric power in this pumped-hydro configuration becomes an enabler for bringing online greater capacity from non-hydroelectric renewable sources.

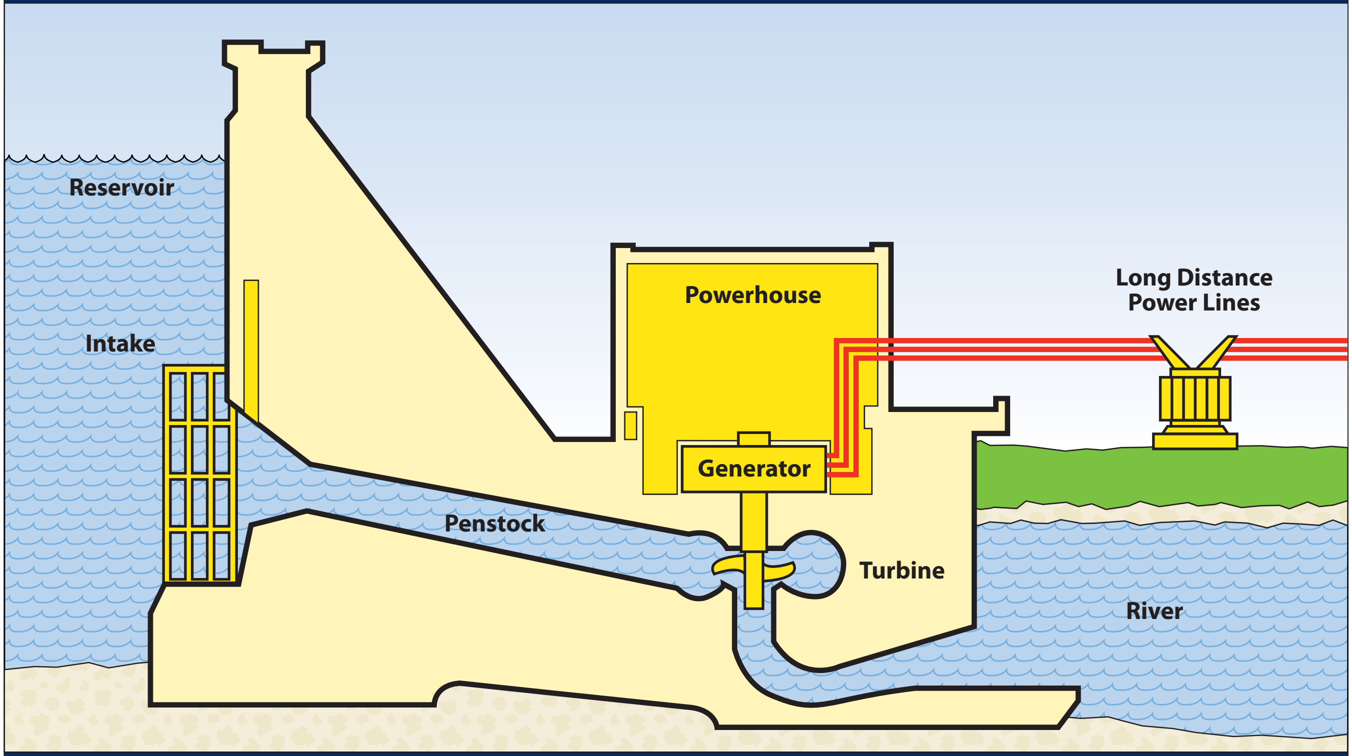
Hydropower is the most common source of renewable electricity in the United States.

For most common types of hydroelectric power, the amount of electricity generated is in direct proportion to the volume of water in motion and the distance it falls; in other words, doubling the amount of water or the height of the water's fall will double the amount of electricity that can be produced.[6] Because of the site requirements for power production, most dams in the U.S. do not generate any electricity, but instead were built for flood control and irrigation (**Exhibit 19-2**).

Hydropower requires no transportation or fuel combustion. As with other methods of generating electricity, transmission capacity is needed to deliver hydropower to the electric grid. Most hydroelectric plants have been around for so long, however, that their transmission infrastructure

EXHIBIT 19-1

Schematic of a Hydroelectric Dam



Source: Tennessee Valley Authority.

is well established. If an existing plant were to require new transmission capability, issues of access, rights of way and property ownership might arise. In the case of new dams and reservoirs, however, developing transmission lines is a minor obstacle compared to site selection, land acquisition and potential displacement of people, property and wildlife.

Hydroelectricity made its largest impact on Texas in the mid-1930s, as part of the rural electrification efforts of the New Deal.

HYDROPOWER IN TEXAS

Hydroelectricity made its largest impact on Texas in the mid-1930s, as part of the rural electrification efforts of the New Deal.[7] With the fresh example of the federally funded Tennessee River Authority's hydroelectric dams, and aided by the considerable political clout held by Texans in Washington, the Lower Colorado River Authority (LCRA) was able to build four of an eventual six dams on the Colorado River between 1935 and 1941.[8]

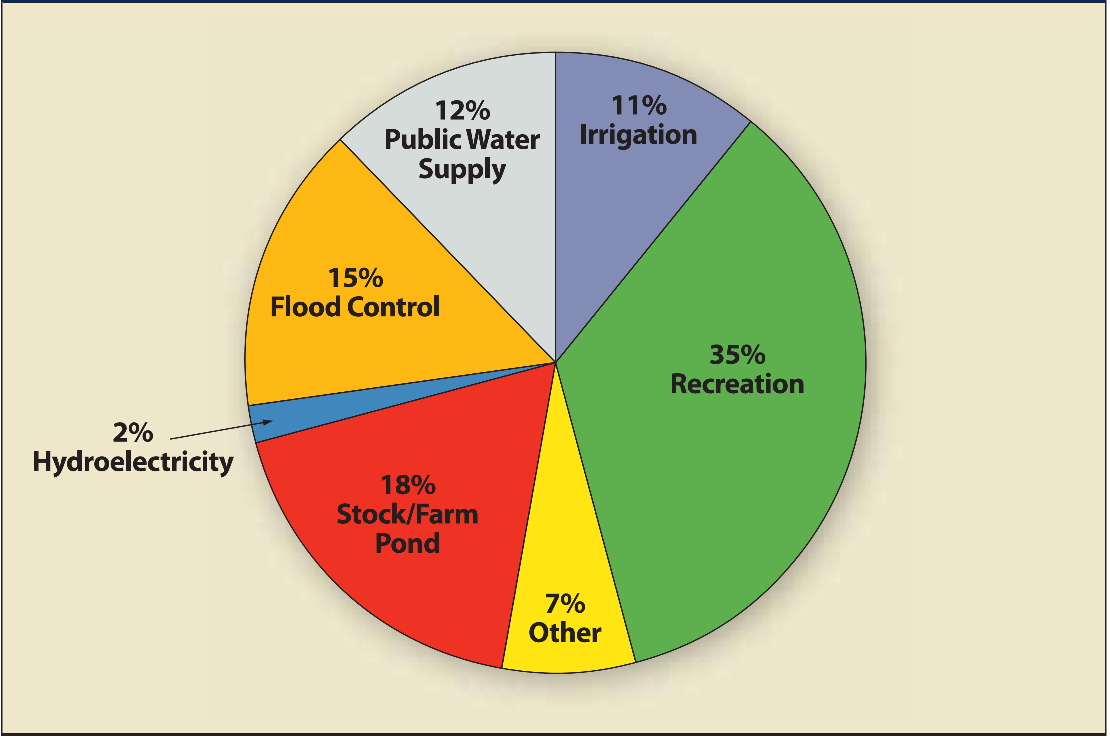
Economic Impact

Hydroelectricity brought jobs as well as electricity to the Hill Country and other areas of the state. Nevertheless, other sources of power soon dwarfed the contribution of dams. At the end of 1946, 15 percent of Texas' electricity came from hydropower; its share fell to less than half of that within about seven years.[9]

Because reservoirs in Texas are used primarily for water storage, dam operators can choose to release water through the power plant at the times when the resulting electricity is more valuable. Consequently, hydropower often is used to supplement the electrical grid during times of peak demand; the power plants can start generating within seconds. Hydropower's availability for use during peak demand enhances its economic value, but in largely semi-arid Texas, water usually is not released from reservoirs solely to generate electricity, so its economic potential is not always realized.

Exhibit 19-2

Primary Purpose or Benefit of U.S. Dams



Source: U.S. Army Corps of Engineers, National Inventory of Dams.

In the long run, the role of Texas dams in controlling flooding and preventing property damage has proven more economically important to the state than hydroelectric power.

Production

In current usage, "hydropower" refers solely to electricity generated by water, most often through a dam. As of 2006, Texas has only 23 dams with hydroelectric power plants out of hundreds of medium to large dams around the state. These 23 dams have a total generating capacity of 673 megawatts (MW), although the amount of electricity they actually produce annually is well below the maximum potential of generating 100 percent of the time. In 2004, Texas hydropower plants operated at an average 22 percent capacity factor, and in 2006 the capacity factor averaged only 11 percent. Hydropower production is limited by droughts or other factors that affect surface water flows.[10]

Availability

Most of Texas' terrain does not lend itself to large-scale hydroelectric projects. In 2004, hydro accounted for 0.62 percent of the state's electrical capacity and only 0.34 percent of electricity actually produced.[11] In the absence of additional hydroelectric plants, these percentages will continue to shrink as the state's overall generating capacity grows.

While Texas has some identified potential for additional hydroelectric capacity, the likelihood of its development is not high. Reservoirs can face opposition from the public and policy-makers, and all the new reservoirs being proposed by water planners are intended for storing water supplies. (It should be noted, however, that some of the state's water supply — about 1.5 percent of all Texas water consumed in 2004 — is consumed by traditional power plants in the process of generating electricity.) Even if all of the state's potential hydroelectric sites were dammed and supplied with generators, the total capacity would still be less than 1.5 percent of the current state total. Texas simply does not have many big-river/big-drop settings that would justify overcoming the hurdles of land acquisition, construction cost and ecosystem destruction inherent in dam building and reservoir creation.

More than 12 percent of Texas' hydropower capacity belongs to the Sabine River Authority, which lies in the Southeastern Electric Reliability Council region rather than that of the state's main power grid, the Electric Reliability Council of Texas (ERCOT). Another 10.4 percent of the state's generation capacity flows into the part of the Southwest Power Pool grid, which covers most of the Panhandle and parts of Northeast Texas. LCRA owns six of the 22 hydroelectric plants that feed energy into the ERCOT grid; these comprise more than 65 percent of ERCOT's hydro-generating capacity. Plants owned by the U.S. Corps of Engineers and various river authorities provide the remainder.[12]

The cost of generating hydroelectric power lies almost entirely in the construction of the dam and power plant.

Costs and Benefits

The cost of generating hydroelectric power lies almost entirely in the construction of the dam and power plant.[13] Once in place, its costs are largely limited to equipment maintenance, with no further costs for fuel and its transportation, so operating expenses for hydroelectric plants are significantly lower than those for other conventional power plants.

As long as there is sufficient water to run the turbines, electricity can be produced very cheaply. Compared even to mature nuclear plants, hydropower costs less than half as much to produce, at under 0.9 cents per kilowatt-hour (kWh).[14] It then joins the stream of power transmitted and sold in the wholesale and retail markets at the same prices as electricity generated by other means, complete with premiums for peak demand production.

But dams and reservoirs are expensive to build. The cost of the proposed Marvin Nichols reservoir in northeast Texas, for example, has been estimated at $2.2 billion, with no power plant included.[15] And water dammed for use in city water systems is unlikely to be released for other purposes, even to generate low-cost electricity.

Environmental Impact

The environmental impact of hydropower is mixed. Although a hydroelectric plant uses the motion of water as a renewable fuel, *gathering* that water can have a large impact on the environment. The most obvious impact is the destruction of a river ecosystem and its replacement with a reservoir. This displaces flora and fauna as well as human inhabitants, and disrupts any activity dependent on aspects of the prior ecosystem, such as bottomland timber. In addition, below the dam the instream flow (the amount of water left flowing in the river) is affected, as are downstream water users and bays and estuaries at the coast. And, because reservoirs created behind dams vastly expand the surface area of the water body, evaporative water loss increases significantly.

Reservoirs also collect sediment, concentrating nutrients as well as pollutants; eventually (as can be seen in older Texas reservoirs) these sediments build up, making the reservoirs shallower.[16] And recent research has found that reservoirs and hydroelectric dams, previously thought of as zero-emissions power sources, actually do emit greenhouse gasses, particularly methane from the decomposition of organic materials (**Exhibit 19-3**).[17] Although scientists are debating how much gas is released and under what conditions, there is little disagreement about the fact that it occurs. This phenomenon is particularly relevant in tropical locations with large reservoirs that contain significant amounts of buried biomass.[18]

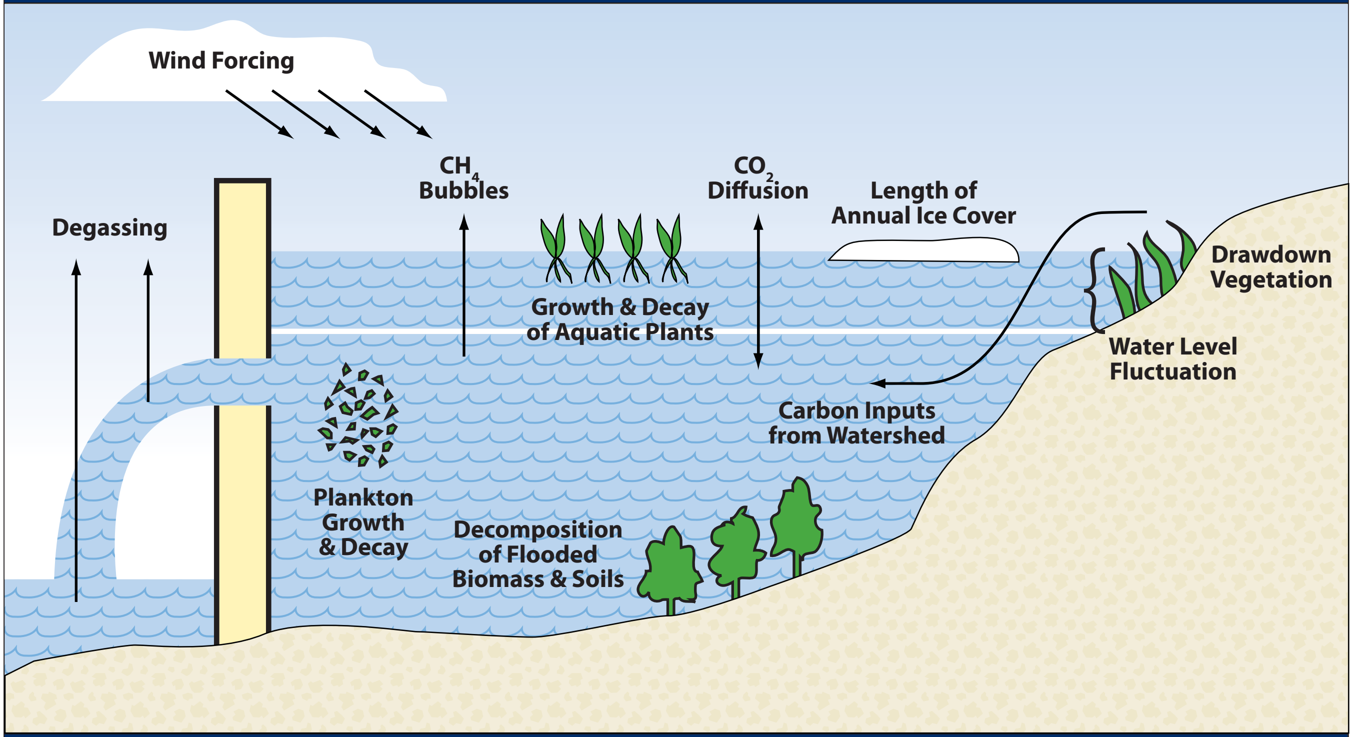
More study is required to accurately compare the environmental impacts of hydroelectricity with other power sources.[19] Some have even proposed ways to tap the methane in reservoirs for use in power production.[20] Overall, hydroelectric dams remain a low-emission method of generating electricity compared to fossil fuel power plants and, as noted at the beginning of this chapter, the largest source of renewable electricity in the United States.

Other Risks

If a dam breaks due to extreme rainfall or inadequate maintenance, it can cause great damage downstream. The safety of aging dams has been the subject of a considerable amount of discussion both domestically and worldwide. The fact that a fairly large portion (25 percent or more) of dams included in the National Inventory of Dams are

Exhibit 19-3

Some Key Factors Influencing Reservoir Emissions



Source: International Rivers Network.

at least 50 years old is a concern, particularly in light of subsequent improvements in design and construction standards.[21]

State and Federal Oversight

If any new hydroelectric plants were built, most of the laws affecting them would concern the dam and reservoir rather than the generating plant. In Texas, the water in rivers belongs to the state, and state regulation covers dams and reservoirs unless they are built on federal land. Federal environmental regulations concerning wetlands and wildlife protection also could come into play, depending on the site.

Subsidies and Taxes

Hydropower is such a mature technology that it often is not even included in discussions and incentive programs for renewable energy. Nevertheless, renewable energy tax credits are available for hydroelectric power production, and federal ownership of a number of dams allows the U.S. government to set subsidized prices for the electricity they produce. More information on this topic can be found in Chapter 28.

OTHER STATES AND COUNTRIES

Texas has no plans for new hydroelectric facilities, and, according to the Energy Information Administration, through 2010 only four states will add new hydroelectric capacity, for a total additional 16 MW of capacity.[22]

Hydroelectric capacity is still expanding in other parts of the world, with the largest growth occurring in Asia, particularly China and India, and in Central and South America and Canada.

China has several large projects under way, including Three Gorges, which will provide 18,200 MW of hydroelectricity capacity by 2009, and India is adding over 13,000 MW in the next few years. In countries that already rely heavily on hydropower, such as Brazil, greater emphasis and investment is expected on the diversification of electricity sources.[23] Even so, the current administration in Brazil is pushing for large new hydroelectric projects in the Amazon region, stirring much controversy.[24]

OUTLOOK FOR TEXAS

Hydroelectricity supplies a very small percentage of Texas' power supply, and that percentage is shrinking as total generating capacity grows. Although the state has some limited potential for additional hydropower, there are no current plans to develop it. The new reservoirs being planned for the state do not include electric generation plants; those plans are about water, not power.

Hydroelectricity supplies a very small percentage of Texas' power supply, and that percentage is shrinking as total generating capacity grows.

While existing facilities may be able to increase their generating capacity due to efficiency improvements from new turbines or other factors, these gains are likely to be modest. The amount of hydroelectricity Texas generates this year and into the future is more likely to depend on the weather — floods or droughts — than on state demand for electricity. In all likelihood, hydropower has reached its peak in Texas.

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Chapter 20

Ocean Power

Introduction

Ocean power includes technologies that tap the sea's energy, not only that of crashing waves but also the motion of tides and even the heat stored in the oceans, which are the world's largest solar collectors. Ocean power, then, includes three types: wave power, tidal power and thermal energy conversion.

A variety of new ocean power technologies are poised on the threshold of commercial development. In various places around the world, pilot projects are under way or have been completed, and several energy plants are being planned or are under development. Progress in this area has been slow, however, due mainly to the fact that these systems, based on emerging technologies with high research and development and startup costs, have significant engineering hurdles to overcome and are not competitive with current prices of fossil fuels.

With the push toward clean, renewable sources of power and growing concern about climate change, fresh attention is being focused on the enormous power potential of the world's oceans. The potential for ocean power to have an impact in Texas, however, given the state's type of coast, is negligible. The Gulf of Mexico is too shallow and enclosed, for the most part, for its waters to contain sufficient energy to convert to onshore power.

History

Efforts to tap the force of the seas have a long history; tidal mills were used to grind grain in Northern Europe in the Middle Ages, and a Frenchman and his son filed the first patent for a method of using wave power in 1799.[1] More recently, the industry has been engaged in the trials and errors of developing new technologies for using ocean energy, with the errors sometimes bringing setbacks and negative publicity. In 1995, as interest in wave power was building, there was the failure of the Osprey, a large wave device that was destroyed by the very power it was intended to tap, even before its installation on the Scottish coast could be completed. And in 2007, a $2 million wave power buoy sank near the Oregon coast and tidal turbine blades broke in the East River of New York City.[2] Nevertheless, the search for the proper tools continues.

Uses

All forms of ocean power generate electricity by converting water's kinetic or thermal energy into mechanical energy, to drive a turbine or pump. One form of ocean power, ocean thermal energy conversion (OTEC), can be put to secondary uses such as air conditioning, chilled-soil agriculture (which allows plants from temperate zones to grow in the tropics) and aquaculture. And fresh (desalinated) water is a byproduct of some ocean power devices.[3]

Ocean Power in Texas

While Texas has a lengthy coastline, offshore conditions make it unlikely that the state will benefit significantly from ocean power technologies. None of the types of ocean power currently on the drawing boards are suited for the Gulf of Mexico, due to that body of water's shallow and semi-enclosed nature. Almost 40 percent of the Gulf is less than 20 meters deep, and the prevailing current of water entering it runs around the tip of the Yucatan Peninsula, far away from the Texas coast.[4] Given present technology, Texas' coasts have none of the characteristics necessary for the cost-effective use of ocean energy.

None of the types of ocean power currently on the drawing boards are suited for the Gulf of Mexico.

Economic Impact

At present, the U.S. has no ocean energy project delivering significant amounts of usable power. States with potential for ocean power include Alaska, Washington, Oregon, California, Hawaii, Maine and Massachusetts.[5]

Production

Wave Energy

The most obvious form of ocean energy is the power of waves. For energy conversion, wave power can be captured on or near shore as well as offshore. Offshore systems use the motion of the waves either to create an electrical charge with a pump and a floating bobber or buoy, or to operate hydraulic pumps within the joints of a floating device resembling a string of sausages. The pressurized fluid from the pumps powers a turbine.[6]

Onshore techniques include the pendulor, the tapchan and the oscillating water column. The *pendulor* uses a flap swung back and forth by waves to power a pump and generator. The *tapchan* is a tapered channel that forces waves higher and thus feeds water into a reservoir above sea level; this water then is used to turn a turbine, as with conventional hydroelectric generation. A related wave device pressurizes seawater to send it to an elevated onshore storage tank for release through a turbine; this device was tested in the Gulf of Mexico before "seeking actual ocean environments" for in-situ testing.[7] And the partially submerged *oscillating water column* channels waves into an opening to compress the air column above the water, forcing it through a turbine; as the wave retreats, the falling water pulls the air through the turbine once again.

To convert tidal power into electricity, a power plant site requires a large volume of fast-moving water.

Tidal Energy

To convert tidal power into electricity, a power plant site requires a large volume of fast-moving water. This can be found either in locations with a wide swing in tidal heights or with tidal flows that pass through a narrow channel. The former is often called "traditional" tidal power, while the latter is called "tidal stream" power.[8]

Forty years ago, tidal power plant design took its cue from the established hydroelectric industry. The world's four "traditional" tidal power plants, in France, Russia, Canada and China, use a "barrage" or dam that functions much like an onshore dam but requires a tidal inlet or estuary. The tide comes in and builds up a difference in water height, and then water is released through gates into turbines.[9]

Tidal stream power is featured in two different designs: the tidal fence (underwater turnstiles spanning a channel or narrow strait) and the tidal turbine.

Of the three types of tidal power systems — "traditional," tidal fence and tidal turbine — the tidal turbine is simplest, and the one generating the most research at present. These are essentially underwater wind turbines turned by the tidal currents. Even though ocean currents are slower than wind speeds (currents of 4 to 5.5 mph are optimal for tidal turbines), the density of water is almost 1,000 times that of air, which translates to a higher energy yield. The turbines also have little impact on the environment; the other types can have problems with silt buildup and can interfere with sea life migration because they obstruct a channel.[10]

Ocean Thermal Energy Conversion

Finally, ocean thermal energy conversion (OTEC) is the least accessible form of ocean power, and perhaps the least useful for the U.S. To work, OTEC needs an optimal temperature difference between warm water on the surface and colder water below of about 36°F—a range found only in tropical coastal areas near the equator. In the U.S., OTEC research and testing is taking place in Hawaii. The cold water is brought to the surface by a deeply submerged intake pipe.

Researchers have developed two different types of OTEC and a third that is a hybrid of the other two; all use the thermal energy stored in seawater to power a steam turbine. *Closed-cycle OTEC* uses warm seawater to vaporize a low-boiling point liquid that then drives a turbine to generate electricity. (This approach is similar to the binary cycle method of geothermal generation.) The vaporized liquid then is cooled and condensed back to liquid with cold seawater, and the cycle repeats. *Open-cycle OTEC* gets warm seawater to boil through lowered pressure and uses the resulting steam to drive the turbine. Once again, cold water from the deep converts the steam back to (now desalinated) water.

The *hybrid method* uses the steam from boiled seawater to vaporize a low-boiling point liquid, which then drives the turbine.[11] In concept, these systems are quite simple, but in practice the depths and scale that are required to effectively harness OTEC have been prohibitive.

Transportation and Transmission

Ocean energy does not involve or require fuel transportation or storage. As with other alternative methods of generating electricity, however, ocean energy processes need transmission capacity to make them a viable power source. Electricity generated offshore by OTEC and deep-water wave systems typically would send the power through an underwater cable to the electrical grid onshore. And all transmission lines can involve issues of access, rights of way and property ownership.

Availability

Wave power varies depending on location; more powerful waves are a result of stronger winds blowing over the water's surface. Globally, this occurs primarily in the areas between 30° and 60° latitude, both north and south (**Exhibit 20-1**).[12]

According to the U.S. Department of Energy, traditional (barrage) tidal power requires a difference between high tide and low tide of at least 16 feet. In the U.S., such conditions are limited to the Northeast and Northwest coasts; there are only about 40 such sites worldwide (**Exhibit 20-2**).[13] Tidal stream, on the other hand, simply needs a strong current and, in the case of a tidal fence, a narrow inlet to span.

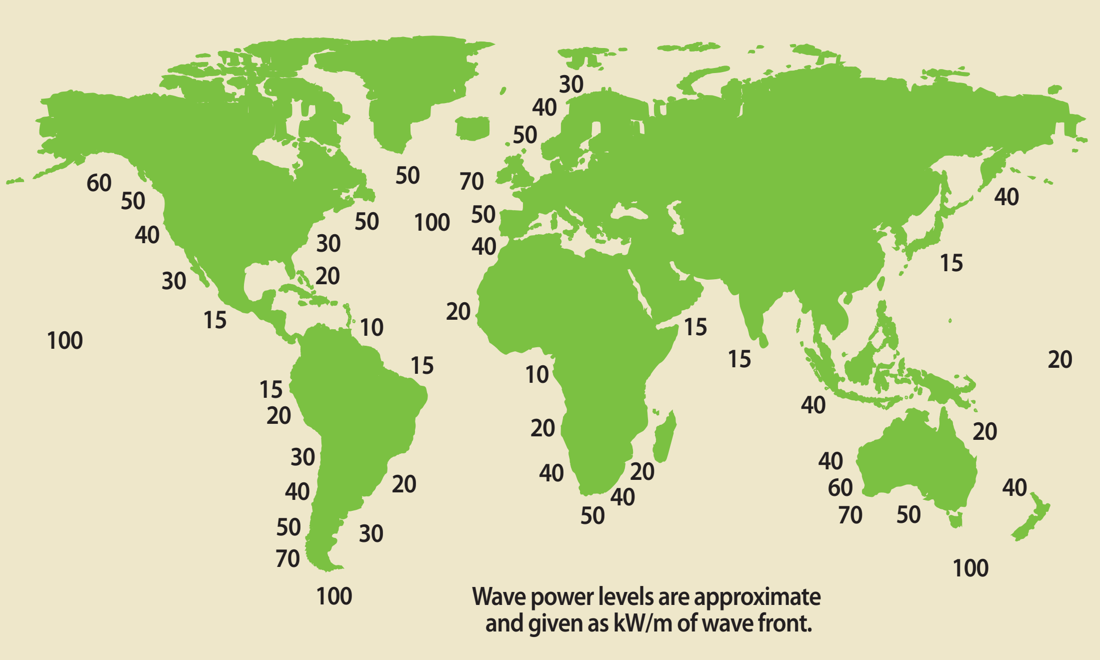
In summary, OTEC requires consistent, substantial temperature differences; tidal power requires large tidal swings or strong tide streams; and even wave power is economically feasible only in certain coastal areas of the world, such as the Northwestern and Northeastern coasts of the U.S.[14]

Other than a few existing tidal dam plants, only small amounts of electricity are being produced by ocean power in pilot projects and startups worldwide. Estimates of the potential amounts of generating capacity are enormous, however, ranging from 140 to 750 terawatt-hours (TWh) per year for wave power alone. (A terawatt is a trillion watts.)[15] That much power could have supplied 4.9 percent of the world's total electricity consumption in 2004.[16]

Estimates for tidal and OTEC energy potential are similarly impressive; the question is whether these resources can be tapped in a cost-competitive manner, and where.

Exhibit 20-1

Approximate Global Distribution of Wave Power Levels



Wave power levels are approximate and given as kW/m of wave front.

Source: T.W. Thorpe, "An Overview of Wave Energy Technologies: Status, Performance and Costs."

Exhibit 20-2

Areas Appropriate for Traditional Tidal Power

Source: Statkraft Development AS, "Tidal Power: Versatile. Reliable. Renewable."

Costs and Benefits

The cost of generating electricity from ocean energy mostly involves the research and development of prototypes and, later, the construction or purchase of equipment and facilities. Operations and maintenance carry significant costs as well, due to the often harsh environment of the oceans. Some in the industry hope that the long experience of the offshore oil and gas extraction industry could help them produce durable equipment to survive the harsh conditions in the sea.

The predicted costs of wave power, in particular, have been falling against that of fossil fuels. The World Energy Council estimates that electricity from "arrays of mature devices located in promising wave energy sites" could cost from 5 cents to 10 cents per kilowatt-hour (kWh).[17] In fact, the Limpet, an on-shore oscillating water column device, began commercially generating electricity in Scotland in late 2000. At the time, the expected cost of Limpet's electricity was 7 cents to 8 cents per kWh, already nearly competitive with the non-renewable price of about 5 cents.[18] And according to the Electric Power Research Institute (EPRI), the cost of ocean electricity production will drop significantly as the volume of production increases, as usually happens in the development and commercialization of any new technology. [19]

Environmental Impact

The long-term environmental impacts of commercialized ocean power are as yet unknown. As mentioned earlier, some concerns for potential impacts include interference with sea life migrations, silt buildup and sediment deposits. OTEC also has a potential to affect the temperature of the water near a power plant and, when desalinated water is a byproduct, to require disposal of the removed salts.

Careful site selection along with rigorous monitoring will be necessary to prove boosters' claims of extreme environmental friendliness. Certainly, in the area of air quality, ocean power has less impact than most other forms of electricity generation. Once the devices are in place, they produce electricity without emissions.

Other Risks

Wave power projects can face public resistance to installing large equipment along coastlines. Equipment on the ocean floor can also interfere with sediment flow. Thus far, even wave energy is not yet economically competitive.[20] That situation is likely to change over time, however, as research and testing moves the technology forward.

The early risks of ocean technology are likely to be financial in nature, with venture capital, corporate investment and government subsidies riding on finding the "right" product to access the oceans' energy.

State and Federal Oversight

Ocean power generation falls under the Federal Energy Regulatory Commission's (FERC) jurisdiction. Because the technology is so new, however, applications for pilot projects have been anything but routine, with companies asking for waivers of some licensing requirements. In particular, the applications require some data that cannot be gathered without installing and operating the devices.

In 2005, FERC granted limited licensing exceptions for pilot projects, particularly one in New York, and preliminary permits for the study of potential sites off the Florida coast. The commission also began to streamline its process for permitting ocean power projects.[21] State regulations for such facilities are similarly immature and are likely to be drawn from existing laws governing conventional power plants and electricity transmission.

Subsidies and Taxes

To date, ocean energy projects have received little assistance in the form of incentives or subsidies from the state or federal governments. EPRI considers the lack of government support to be the foremost obstacle to the development of this energy resource. According to EPRI, the "U.S. government…has supported the development and demonstration of all electricity technologies except ocean wave energy."[22]

There is one recent, minor exception to that statement: the U.S. Navy is funding a wave power plant built by Ocean Power Technologies at a base in Hawaii. This installation eventually will have a capacity greater than 1 MW; its first wave power device was installed in 2004.[23] Nevertheless, this emerging technology has received little promotion in the U.S. The current federal renewable energy tax credits do not cover ocean energy, although Florida has included it in a state tax incentive for commercial electricity production.[24]

The U.S. Congress, however, appears to be giving ocean energy some new attention. In June 2007, the House Committee on Science and Technology approved the "Marine Renewable Energy Research and Development Act" that would provide $50 million a year for the next four years to promote ocean energy research and projects.[25]

While many states are supporting research in renewable energy, only Maine, which is considered to have a high potential for tidal energy, includes any support for research into ocean (tidal) power in its eligible renewable technologies.[26] Hawaii includes both wave energy and ocean thermal conversion in its generous 100 percent tax credit for investment in "high tech business."[27] The state of Texas offers no subsidies or incentives for ocean power.

The current federal renewable energy tax credits do not cover ocean energy.

There are no state or federal taxes or fees specific to ocean power, although ocean power companies would have to receive permits from FERC for power plants tied into multi-state electrical grids.

More information on subsidies for ocean energy can be found in Chapter 28.

OTHER STATES AND COUNTRIES

In the U.S., Hawaii was an early location for experiments with ocean power, particularly ocean thermal conversion, and now interest is growing in the Northwest and the Northeast. Tidal pilot projects are being considered in San Francisco Bay and New York City. Wave energy is being investigated in states such as Oregon, Washington, Maine, Rhode Island and Florida. FERC has given approval for wave energy projects in Washington and Oregon to proceed, granting a preliminary permit for a demonstration of a device at Reedsport, Oregon and accepting a commercial license application for a project in Makah Bay, Washington.[28]

Other nations, however, have led the way on ocean energy, particularly wave power, primarily because they are situated near valuable ocean energy assets (e.g., good tide differentials or wave intensity). Various ocean power technologies are planned, in place or being tested in the United Kingdom, Portugal, Spain, Australia and Japan, and new sites and designs are being pursued in these nations and others. In Portugal, a wave power project already has begun delivering electricity to homes, due in large part to government assistance.[29]

A glance at wave power levels across the world (**Exhibit 20-1**) makes it clear why the United Kingdom, in particular, has been the site for the most aggressive development of electricity generated by the sea. In 2004, Scotland opened the European Marine Energy Centre in the Orkney Islands to act as a proving ground for wave energy devices; the facility is expanding to include tidal devices. The partners in the research center, including the Scottish government and the Carbon Trust, have invested nearly $30 million in the endeavor.[30]

OUTLOOK FOR TEXAS

There has been some speculation recently about the possibility of tapping the "Loop Current," the stream of ocean water running from the Caribbean into the Gulf of Mexico through the Yucatan Strait, but this would be very difficult to accomplish.[31] The Loop Current is highly variable, making its U-turn back towards the tip of Florida at different points on its northward path within the Gulf. No matter how far north it travels before turning, however, the loop never goes very far westward; the only parts of the Loop Current that approach the Texas coast are eddies that are "pinched" off of the loop and spin into the western half of the Gulf.[32]

Therefore, while the Loop Current may someday be used for power generation, it would probably be tapped at the locations where it is most energetic — in the Yucatan Strait (the entrance) or the Florida Strait (the exit). As with the other forms of ocean power conversion, this is unlikely to have a place in Texas' renewable energy portfolio.

In all, ocean power is an unlikely choice for Texas. Despite our hundreds of miles of coastline, and the energy industry's many years of experience in Gulf waters, the state lacks the conditions needed to bring inventors and investors to our shores.

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CHAPTER 21
Geothermal

INTRODUCTION

Geothermal (meaning "earth heat") energy involves using the high temperatures produced beneath the earth to generate electricity from heated water, as well as for various direct uses (such as hot springs spas, lumber drying or aquaculture). The term geothermal is also applied to the temperatures of the Earth near the surface which are used as a source of consistent temperatures for heating and cooling of buildings. Geothermal applications that involve water heated within the earth are also called hydrothermal processes.

Geothermal energy is the focus of considerable interest and activity in Texas, due to the emergence of new technologies and the state's long experience with subsurface oil and gas extraction. Indeed, 2007 brought the first leases of state lands for possible geothermal energy development. Although Texas' geothermal electricity production has been experimental thus far, the energy produced by the heat of the earth's core is essentially inexhaustible, and research into ways to tap that energy is ongoing and accelerating. The potential impact of geothermal energy on Texas' economy is considerable, although when and how much of that potential will be realized is as yet unclear.

History

Man has taken advantage of geothermal energy for purposes such as cooking and bathing for many centuries; the Romans used waters heated by the earth in bathhouses, for instance.[1] An early example of commercial geothermal energy use took place in Idaho in 1890, where the Boise Water Works Company drilled wells to create a geothermal radiant heating system for the city. Hot water from the geothermal wells was piped into more than 200 homes and businesses; this system, as well as three newer versions, is still in use today.[2]

Geothermal energy was first used to generate electricity in Larderello, Italy in 1904. The site had hot springs and steam outlets that had been used for Roman baths. In 1904, a turbine there lit five light bulbs, and by 1913 the first geothermal power plant was built in an area that continues to provide about 10 percent of all the world's geothermal electricity.[3]

Uses

Geothermal energy is used to generate electricity and for direct applications such as drying crops. Geothermal heat pumps also use the earth's heat for heating and air conditioning systems. These heat pumps work with heat exchangers to transfer heat between warm and cool spaces.

GEOTHERMAL IN TEXAS

While geothermal energy is not being used to generate electricity in Texas at present, some of these emerging technologies hold considerable promise for the state.

Economic Impact

Geothermal energy recently provided a very small amount of revenue to Texas state government, in the form of $55,645 in fees paid in February 2007 for energy leases on 11,000 coastal acres of state lands. Ten percent of any income from energy produced on this land will go to the state's Permanent School Fund.[4]

Today, geothermal energy has practically no impact on the Texas economy, although that could change with further technical developments in the field. Geothermal energy currently provides slightly more than a third of one percent of the U.S. energy supply, with the potential for that amount to nearly double if all the projects currently in development come to fruition.

An MIT study released in 2006 evaluated the potential of engineered or enhanced geothermal systems (EGS) to be "a major energy source for the United States." The report found that new methods to access geothermal energy could, "with

While geothermal energy is not being used to generate electricity in Texas at present, some of these emerging technologies hold considerable promise for the state.

a reasonable investment in R&D, …provide 100 GW [gigawatts, or 100,000 megawatts] or more of cost-competitive generating capacity in the next 50 years." This includes using hot water co-produced from existing oil and gas wells to generate 11,000 megawatts (MW) of electricity with existing technology.[5]

Since Texas has many wells producing quantities of heated water along with fossil fuels, geothermal energy could have a significant impact on the state's economy, not just by providing power but also by building a new industry on the base of an existing one.

Production

According to the Texas State Energy Conservation Office (SECO), the geothermal zones that run through Central Texas and along the Rio Grande in the Trans-Pecos region have temperatures of 90°F to 160°F. There has been some limited direct use of this heated water in spa baths and heating systems and, where the water is potable, as a municipal water source.[6] These lower-temperature geothermal resources could be applied to other uses, such as greenhouse cultivation, aquaculture, crop drying and milk pasteurization.

Many Texas homes and other buildings use geothermal heat pumps for heating and cooling.

In traditional geothermal electricity production, using near-surface high temperature water or steam, three methods are used to convert thermal energy into the mechanical energy of a spinning turbine.

The first and most direct is the "dry steam" method, suitable when extremely hot water is already in the form of steam and thus ready to drive a steam turbine. The water (minus some that escapes as steam) is returned to the thermal reservoir through an injection well to sustain the resource. The second method, called "flash steam," vaporizes water above 360° F by releasing it from the pressurized reservoir into a lower-pressure tank. Flash steam is the most common form of geothermal electric generation. The third method, called "binary cycle," uses less superheated water (200° to 360°F); this water is run through a heat exchanger to vaporize another liquid with a lower boiling point (such as isobutane), which then drives the turbine.[7]

Geothermal heat pumps (GHPs, also called ground-source heat pumps) require a buried system of pipes. Fluid (mostly water) circulating in the pipes carries heat into a building in the winter and pulls heat out of the building in the summer, exchanging the heat with the cooler surroundings at either end of the loop. GHPs are very energy-efficient, using 25 percent to 50 percent less energy than conventional heating and cooling systems.[8] According to the U.S. Environmental Protection Agency (EPA), GHPs have the lowest carbon dioxide emissions and smallest environmental impact of all residential "space conditioning" systems available.[9]

Many Texas homes and other buildings use geothermal heat pumps for heating and cooling; by the late 1990s, Texas had more than 100 schools with GHP systems, more than any other state at the time.[10] This form of geothermal energy has great potential in a state that devotes so much electricity to cooling buildings, even with upfront costs that can take two to ten years to recoup from energy savings. In the U.S. as a whole, home heating and cooling accounts for more than half (56 percent) of all residential energy use, and wider use of GHPs could reduce that percentage.[11]

Among the traditional hydrothermal energy methods, the binary cycle process is proving to have the largest potential for expanded electricity generation, since it allows producers to take advantage of lower-temperature fluids. In addition, the potential of geothermal energy is inspiring the adaptation of existing heat-handling equipment, such as air conditioners and waste heat generators, to new purposes.

For example, the binary cycle geothermal unit pictured in **Exhibit 21-1** uses modified air conditioning technology with water as low as 165°F, and generates 225 kilowatts (kW) of electricity.[12] This unit, however, has an advantage, in that it is located in Alaska. To generate electricity in Texas would require hotter water in order to have a large enough temperature differential for the binary cycle to continue; this has to do with "heat rejection," a concept of great importance in geothermal applications.

In geothermal heat pumps, the question of heat rejection is fairly straightforward: for the heat exchange system to work, there has to be enough exchange, that is, enough heat moving into the liquid carried into a house to warm it in the winter. In summer, obviously, the heat carried out of the house must be removed, or rejected, from the fluid

Exhibit 21-1

A Binary Cycle Geothermal Power Generator

Source: UTC Power.

so it will cool the house on its return. This means the system must be designed with sufficient lengths of piping passing through enough cool ground for the temperature of the liquid to change.

For geothermal electricity generation, however, heat rejection is critical for somewhat different reasons. In all three types of systems (dry steam, flash and binary), vaporized fluid must be condensed back into fluid form so that it can either be injected back into the reservoir or (in a binary cycle unit) used to start the cycle over again. This means its heat must be eliminated either through air or water cooling. For the system in Alaska, this is easy; nearby water at 40°F to 45°F can easily condense the working fluid.[13] Heat rejection at other locations around the country can be more difficult to accomplish, especially in the arid west, where geothermal energy is accessible, but water may not be.

Transportation and Transmission

The "fuel" for geothermal power — water — is delivered through pipelines and wells. Geothermal power, like other methods of generating electricity, requires transmission capacity. If new plants require new transmission lines to access the grid, issues of access and property ownership may arise. Many of the high-potential areas for geothermal use of oil and gas wells, however, are actually located near population centers or transmission facilities, so that delivering the electricity should not pose much difficulty. The plants themselves require no fuel storage or combustion space and take up relatively little space, particularly in the case of small, modular generation units.

As of 2007, five states produced all the geothermal electricity generated in the U.S.: California, Hawaii, Utah, Nevada and Alaska. All of those states except Hawaii have new capacity under construction. Geothermal power plants generated more than 14.8 million megawatt-hours (MWh) in the U.S. in 2006, or 0.37 percent of the nation's total electricity. In all, geothermal energy constitutes about 4 percent of the nation's renewable energy generation.[14] The U.S. Energy Information Administration also estimates that the residential and commercial sectors used 32 trillion Btu of non-electric geothermal energy in 2006, through heat pumps and direct use.[15]

Availability

Geothermal heat pumps do not require temperatures any warmer than the normal, constant subsurface temperatures of 45° to 75°F, so this energy resource can be used everywhere.

For electricity generation by traditional, hydrothermal methods, the required near-surface, high-temperature resources are found in only a few locations in the U.S., in California, Hawaii, Nevada and Utah. Some new power generation capacity is being developed in these areas.

With the emergence of new technologies, however, seven additional states — Arizona, Idaho, New Mexico, Oregon, Texas, Washington and Wyoming — are considering or developing geothermal projects. Idaho already has one of its projects under construction.

The U.S. has more geothermal electric generation capacity than any other nation. According to the Geothermal Energy Association (GEA), U.S. geothermal capacity stands at 2,850.9 MW.[16] Its estimate of worldwide generating capacity is around 9,000 MW, with considerable new development under way leading to a prediction that, by 2010, worldwide capacity could be up to 13,500 MW.[17]

Emerging technologies called "unconventional geothermal" or "Enhanced/Engineered Geothermal Systems" (EGS) are contributing to the renewed interest in geothermal power. EGS means

The U.S. has more geothermal electric generation capacity than any other nation.

"all geothermal resources that are currently not in commercial production and require stimulation or enhancement," according to the U.S. Department of Energy (DOE).[18] The technologies include "engineered reservoirs" (made by creating cracks in heated rock for water to circulate in); geopressured-geothermal (using high-pressured brine trapped in sedimentary layers, especially under the Gulf Coast); "co-produced fluids" (water mixed with fossil fuels in oil and gas fields); and low-quality, or low-temperature, conventional hydrothermal methods (as yet non-productive resources).

Particularly significant for Texas is research into the use of existing, deep oil and gas wells to access areas that are hot enough to have geothermal potential. Indeed, hot fluids co-produced from oil and gas wells have created a disposal chore for producers for decades. Texas' hydrocarbon exploration and production industries have enough data on the characteristics of miles-deep environments to allow for some estimates of the energy that could be "harvested" from them. The Geothermal Laboratory at Southern Methodist University (SMU), for instance, estimates that in five to ten years, Texas could have 2,000 to 10,000 MW in generating capacity from geothermal resources accessed through oil and gas wells.[19] (In Texas, one MW of electricity is enough to power about 630 homes, based on average use in 2006.)

The Geothermal Laboratory at Southern Methodist University estimates that in five to ten years, Texas could have 2,000 to 10,000 MW in generating capacity from geothermal resources accessed through oil and gas wells.

Texas has several zones where previous deep oil and gas exploration may provide access to the higher temperatures needed for generating electricity. According to SECO, the areas highlighted in **Exhibit 21-2** may be suitable for producing geothermal electricity, based on data gathered from existing wells.

Retrieving geothermal resources to generate electricity is a significantly different process from that of oil and gas drilling, however. The most valuable aspect of a crossover of the two industries is the existence of large amounts of data on existing wells. SECO has been working with SMU and the University of Texas at Permian Basin to assess well data and determine how it can be used to guide a new generation of energy exploration in mature oil and gas fields.[20]

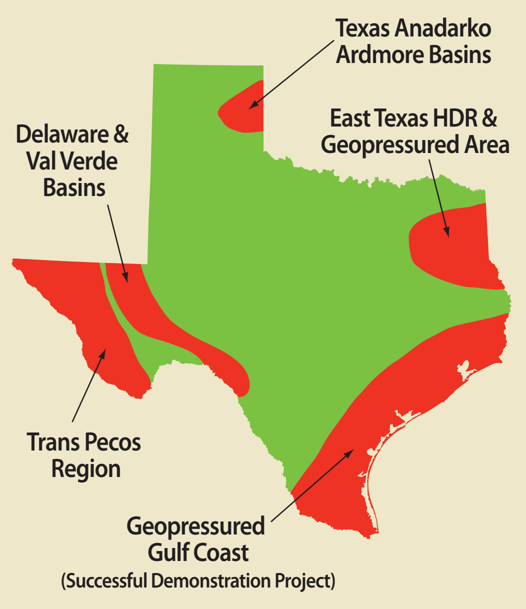
Exploration and drilling are expensive and risky operations, so this wealth of information about conditions and resources around and at the bottom of existing oil wells offers a large advantage. And while an oil or gas well cannot simply become a geothermal well once the hydrocarbons are tapped out, it can be redesigned and redrilled at a lower cost than that of drilling a new well. In addition, heat can be extracted from fluids already being co-produced by oil and gas wells.

A geopressured-geothermal power plant already has generated electricity in Texas. In 1989, DOE conducted a six-month test run of a 1 MW binary power plant on the Gulf Coast not far from Houston at Pleasant Bayou, producing nearly 3,500 MWh of electricity. Geopressured-geothermal areas contain three different forms of energy, namely thermal, chemical (from methane dissolved in the brine) and mechanical (from the high pressure and flow rate of the brine) energies. Although the test plant did not capture the mechanical energy of the water, it made use of exhaust heat from burning the gas present in the water to increase its output.[21]

At the time of the test, this type of geothermal production was not cost-competitive with other methods of generating electricity, but geothermal researchers believe that has changed in the

Exhibit 21-2

Potential Geothermal Energy Production Regions



Source: University of Texas at Permian Basin Center for Energy and Economic Diversification.

intervening years. As one study said, "Though the Pleasant Bayou test project was cut in 1990 due to extremely low oil and gas prices, today's energy market suggests that electricity generated by geothermal power plants is cost competitive with prices between $0.05 to $0.08 per kWh."[22] In February 2007, the Texas General Land Office awarded leases for lands on the coast to a Nevada company that plans to use existing wells for geopressured-geothermal energy recovery.

The "engineered reservoir" technique mentioned above also could have some potential for Texas. This form of EGS uses the heat trapped in layers of subsurface rock. Using water injected under high pressure, the rock can be fractured, creating space for an artificial reservoir. Water injected into this reservoir then can be captured by a production well for use in hydrothermal processes.

This technique, while still new, is quite similar to the "fracking" process used to extract natural gas from the Barnett Shale in North-Central Texas. It does, however, require large amounts of water to break the rock layers and create the reservoir.[23]

In summary, the availability of geothermal energy is increasing and the economics of the resource have changed, sparking interest in new technologies that can be used to access it.

COSTS AND BENEFITS

Geothermal heat pumps have a higher initial installation cost than conventional heating and air conditioning systems, but can recover those costs in two to 10 years through energy savings. The actual cost of a GHP system will depend on not only the size requirements for the building but also the location, size and configuration of its lot, and even the proximity of contractors familiar with GHPs. The systems overall cost roughly $2,500 to $5,000 per ton of capacity.[24]

Conventional geothermal-generated electricity generally is sold for five cents to eight cents per kWh.[25] Establishing a steam geothermal power plant costs $1,400 to $1,500 per kW, including exploration and drilling. For a binary plant, the total cost is about $2,100 per kW.[26]

In the case of systems that use existing oil and gas wells, however, exploration and drilling costs could be greatly reduced. Since geothermal electric production can have a 90 percent to 95 percent capacity factor (the ratio of actual electricity production to the total capacity of the energy source), compared to, for example, a factor of 20 percent to 30 percent for wind farms, this source has the potential to be very profitable.

Environmental Impact

Geothermal energy produces no air emissions other than steam, and the water used in the conventional hydrothermal process often is injected back into the source reservoir. Because available water can be depleted, as can the heat, if too much cooler water is injected, there has been some discussion as to whether geothermal is truly "renewable." The heat in the Earth, however, is for all practical purposes inexhaustible, if people can figure out how to access it sustainably. And geothermal electricity has a very high capacity factor in that it can be generated practically continuously, 24 hours a day.

Heat rejection (cooling and condensing the geothermal resource), if accomplished through water cooling towers, can require considerable amounts of water. Engineered reservoirs, as noted above, also require large amounts of water.

Other Risks

Other risks are those typically associated with geologic drilling, including potential seismic activity from EGS-engineered reservoirs; these types of risks are well understood in Texas due to the long experience with accessing oil and gas resources.

State and Federal Oversight

Geothermal production would require permits for drilling; as with oil and gas fields, the Railroad Commission of Texas would issue these permits and enforce applicable state and federal environmental laws. The commission also has jurisdiction to regulate wastes from oil and gas fields for pollution control. The Public Utility Commission of Texas regulates electricity transmission and sale.

Subsidies and Taxes

The federal Energy Policy Act of 2005 (EPAct) created incentives including a corporate tax credit for geothermal equipment (excluding geothermal heat pumps), and a personal income tax credit and the Renewable Energy Security rebate for homeowners who do include GHPs.[27]

The availability of geothermal energy is increasing and the economics of the resource have changed, sparking interest in new technologies that can be used to access it.

DOE also has operated various geothermal energy programs, but appropriations for these were cut drastically in 2006. Previous appropriations were around $20 million to $25 million annually. The latest DOE budget set the appropriation at $5 million for fiscal 2007 but provided no funding for fiscal 2008.

In summer 2007 S. 1543, the "National Geothermal Initiative Act of 2007" was introduced in the U.S. Senate. This legislation would authorize new funds for research into geothermal energy and would set a goal that geothermal should constitute at least 20 percent of the nation's total electrical energy production by 2030. This goal would be backed by $75 million in federal funding in 2008 and $100 million in each of the next four years.[28]

Many states have included geothermal systems in their tax incentives or credits for renewable energy and energy efficiency, although several, including Texas, mention "geothermal electric" in referencing them. This may exclude geothermal heat pumps. Texas also includes geothermal electric systems in its property tax exemptions.

Although Texas does not yet have any geothermal energy projects underway, there is a significant amount of interest and activity surrounding this form of energy.

The only taxes associated with geothermal energy concern the resulting electricity transmission and sale. There are no applicable fuel taxes. Fees to lease land for drilling sites, if on state property, go to the Permanent School Fund, as do fees for oil and gas leases.

More information on subsidies for geothermal energy can be found in Chapter 28.

OTHER STATES AND COUNTRIES

Eleven states other than Texas have geothermal projects under consideration; five of those states already have power plants under construction, with a total added capacity of up to 250.6 MW. If all of the projects under consideration are developed fully, GEA reports that they could yield "up to 2,915.9 MW of new geothermal power plant capacity" in the U.S.[29] This would more than double the current geothermal production capacity.

Geothermal development is ongoing in a number of countries around the world, from Canada to Indonesia. Iceland, a country with large geothermal resources, uses this energy to provide about 90 percent of its home heating and 20 percent of its electricity generation.[30]

In 2005, 24 countries were producing geothermal electric power; 22 additional countries are exploring the possibility. Many of these efforts are being aided by those countries' government policies and initiatives.[31]

OUTLOOK FOR TEXAS

Although Texas does not yet have any geothermal energy projects underway, there is a significant amount of interest and activity surrounding this form of energy. SECO and SMU are working to build databases of well information, and energy companies are assessing the state's potential for this new energy industry. The estimates of the potential are large, as is their range.

Exploration of exhausted fossil fuel fields for new energy could bring new jobs and new lease income for landowners. And geothermal electricity could help restrain energy prices, particularly if utilities can avoid the expense of large new power plants with ongoing fuel costs.

In all, the outlook for a Texas geothermal industry is promising, but it will require considerable investment to achieve its potential.

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CHAPTER 22
Hydrogen

INTRODUCTION

Hydrogen is colorless, odorless, tasteless and nontoxic. It is a gas at temperatures above -423° F and is highly diffuse, having a density approximately 14 times less than that of air. Because it is buoyant and diffusive, hydrogen dissipates quickly in open areas and can move through small spaces, which makes it difficult to store. Hydrogen is flammable over a broad range of gas concentration (from 4 to 74 percent), although its lower flammability limit — that is, the lowest temperature and pressure at which it will combust — is higher than those for some common fuels such as gasoline, propane or diesel.[1]

On Earth, hydrogen is found in combination with other elements such as carbon (hydrocarbons), oxygen (water) and nitrogen (ammonia). Although hydrogen may sometimes be used as a fuel, it is most often used as an energy *carrier*, such as electricity, and not an energy *source*. To make hydrogen a usable, stand-alone fuel, it must be separated from these other elements by chemical, thermal or electrochemical processes. Hydrogen can be separated from water using the heat of the sun, for example, and then used as a power source. After it is combined with oxygen to produce power, the only emission is water (**Exhibit 22-1**).

Even so, hydrogen has been described as "the fuel of the future." Because it is abundant and benign in terms of emissions, proponents say it holds tremendous promise. Due to technical barriers and resulting high costs, however, even its ardent supporters do not see hydrogen power as a short-term solution for America's energy needs. Nonetheless, growing interest in the issue of carbon emissions has spurred hydrogen activity around the world, particularly in Europe, Japan and California. Use of hydrogen for energy purposes is in a developmental stage, so the economic effects in Texas are largely limited to grant funds for research and pilot projects.

History

British scientist Henry Cavendish identified hydrogen as a distinct element in 1766. Subsequent experiments by British and French scientists resulted in the first flight of a hydrogen balloon and the discovery that applying electricity to water can produce hydrogen and oxygen. Further nineteenth-century discoveries included the identification of the fuel cell effect, in which the combination of hydrogen and oxygen results in water and electricity. By the 1920s, German engineers were using early hydrogen and hydrogen-mixed fuel cells to power submarines as well as trucks.[2]

The 1937 explosion of the German dirigible *Hindenburg* in Lakewood, New Jersey led to widespread public concerns about the safety of hydrogen. German and U.S. investigators blamed the accident on static electricity that ignited a hydrogen leak, concluding that static electricity ignited the exterior canvas coating. Further research found that the coatings covering the canvas were materials that would later be used in solid rocket fuel.

Hydrogen has been described as "the fuel of the future."

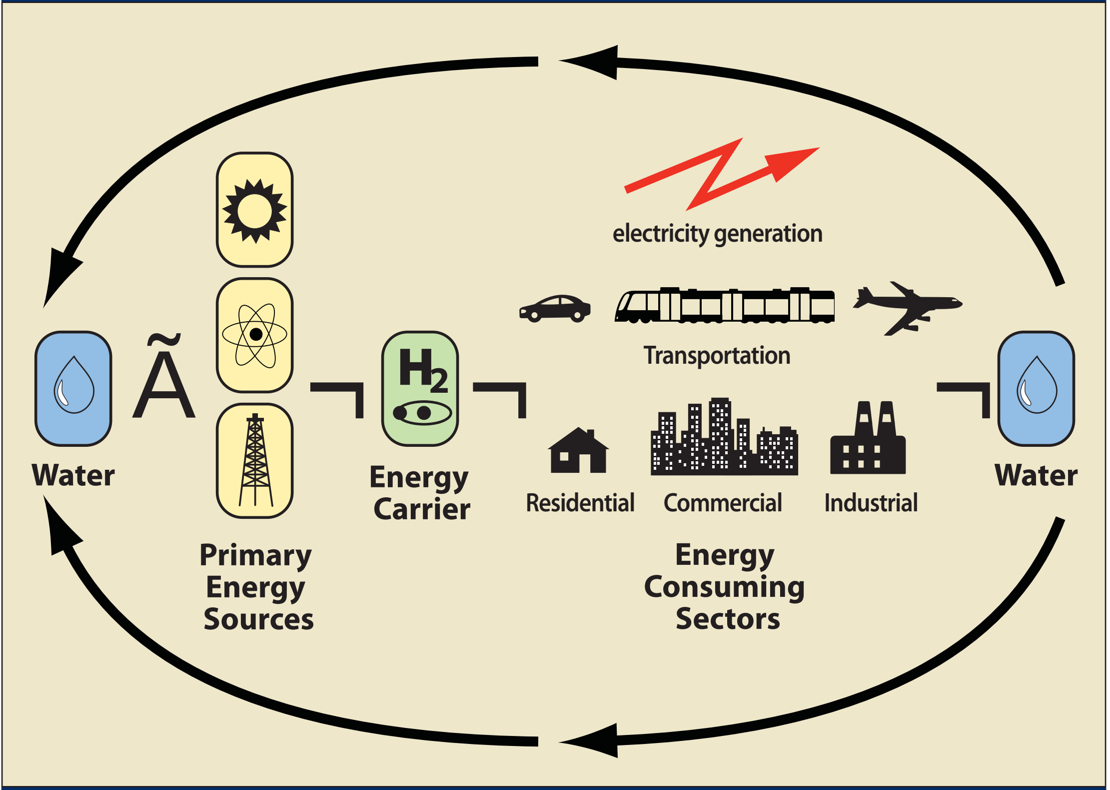
The postwar era saw more development of hydrogen technology. In the 1960s, NASA space capsules used hydrogen fuel cells for onboard electric power, heat and water. The term "hydrogen economy" was coined in 1970 by Australian electrochemist John Bockris during a discussion at the General Motors Technical Center in Warren, Michigan.[3] The first major international hydrogen conference was held in 1974 in Miami Beach, Florida. The theme of the conference was that hydrogen was the answer to depletion of fossil fuels and environmental problems.

The 1990s saw demonstration projects applying previous hydrogen-related research, particularly in Europe. Germany built a solar-powered hydrogen production plant. Daimler Benz demonstrated its NECAR or "New Electric Car," powered by a hydrogen fuel cell. Hydrogen fueling stations opened

The most common modern uses for hydrogen do not involve power production.

Exhibit 22-1

Hydrogen Energy System



Source: United Nations Industrial Development Organization.

in Hamburg and Munich.[4] Commercial-scale power generators based on fuel cells were successfully demonstrated in Japan and the U.S.

In 2002, major U.S. car manufacturers and then U.S. Secretary of Energy Spencer Abraham announced a research program called FreedomCAR to develop hydrogen technology for the production of cars and light trucks and to study how the U.S. transportation system might make the transition to a hydrogen economy.

And in 2003, President Bush announced the Hydrogen Fuel Initiative, a $1.2 billion program to fund hydrogen technology development. Funding for the initiative totaled $269 million in 2007; the Bush Administration has requested more than $309 million in further funding for 2008, the program's final year.[5]

Although biofuels such as ethanol and biodiesel have attracted more public attention in recent years, various states also have begun significant hydrogen initiatives, including California, Florida, New York, Ohio and South Carolina. Most federal hydrogen program funding has gone to states that have created specific hydrogen initiatives.

Uses

The most common modern uses for hydrogen do not involve power production. Hydrogen is widely used in the refining and fertilizer industries, both of which are important Texas businesses. These uses include the manufacture of ammonia-based nitrogen fertilizer and the removal of sulfur in petroleum refining processes that produce gasoline.

But hydrogen can also be used in fuel cells for transportation or power generation. According to the U.S. Department of Energy, hydrogen fuel cells have a wide variety of potential applications in several major areas.

Portable applications include consumer electronics or auxiliary power units. In *transportation*, hydrogen fuel cells can be used for basic propulsion. In addition, hydrogen can be burned directly as a fuel in an appropriately adapted internal combustion engine; this is considered a transition strategy toward widespread use of hydrogen for transportation. Finally, hydrogen fuel cells can be used for power at remote locations, in backup power units for conventional power plants or as stand-alone, stationary power plants.[6] Stationary power systems, commonly referred to as Distributed Power Generation, can operate independently or in parallel with an existing power grid.

Today, NASA is a leading user of hydrogen outside of the petrochemical industry. NASA uses it to generate spaceship power, heat and water. Space shuttles use fuel cells to power such things as computers, life-support systems and lighting. In addition, the cells perform double duty by also providing heat and synthesizing pure water for astronauts to drink and use.

Hydrogen fuel cells are being used for stationary and transportation power in various places around the world, mostly notably in Japan, Europe and California. Some emerging commercial products use fuel cell technology as well, such as portable power generation systems and fuel cell modules that can be used to replace battery packs in forklifts. Most economic activity in the fuel cell industry, however, is still focused on research and product development.

Expectations for the evolution of this energy carrier are evident in the official goals of the federally funded Hydrogen Fuel Initiative, which is intended to improve the state of related technology so that various industries including transportation can make a decision on its commercial viability by 2015. The next step would be to have these technologies, including commercially available hydrogen-powered cars, start to penetrate consumer markets by 2020. DOE does not expect hydrogen power to begin displacing petroleum in a significant way before 2030.[7]

Others, however, expect shorter timelines. Energy companies and carmakers continue to tout their progress toward hydrogen-powered transportation.

At this writing, Chevrolet's Project Driveway program is taking applications to place 100 hydrogen vehicles with individuals in California, New York and Washington D.C. as a demonstration project in 2008.[8] Honda says it will begin leasing its new four-door hydrogen-powered sedan, the FCX Clarity, for demonstration purposes to a few California customers in 2008, for about $600 per month.[9]

HYDROGEN IN TEXAS

Texas is a major producer and user of hydrogen, but again, most of it is used for fertilizer manufacture and in petrochemical processes. Its use for power purposes is limited mostly to research and demonstration projects, as is the case around the world.

Economic Impact

The new "hydrogen economy," as advocated by its supporters, is based on the idea that the U.S. will shift to new forms of energy that are sustainable, pollution-free and domestically produced. The desired result is a better environment, new economic growth and improved national energy security.

Texas is a major producer and user of hydrogen.

The energy industry (and specifically the vehicle fuels industry) has been steadily moving toward fuels with fewer emissions. Since the 1970s, when lead was phased out of gasoline, there have been continual changes in fuel content, leading to today's ultra-low sulfur diesels and biofuels. Many industry observers expect these changes to continue, leading to fuels with lower carbon "footprints" such as hydrogen. The transition toward hydrogen as a broadly available vehicle fuel source may occur over the next few decades as technical hurdles to its widespread commercial use are overcome.[10]

According to the National Academy of Sciences, two public goals — environmental quality and energy security — are the foundations of the U.S. Department of Energy's hydrogen program. The environmental goals include both the reduction of pollutants that directly affect human health and the reduction of greenhouse gases such as carbon dioxide.[11]

No estimate is available of the economic impact of using hydrogen for energy purposes in Texas because of the developmental nature of these efforts.

Consumption

Today, Texas has only a few stationary hydrogen power facilities, and there is one hydrogen fueling station under construction in Austin, where a fuel cell bus is being operated by University of Texas researchers. There have been several one- and two-day fuel cell demonstrations in the state over the past five years. According to the National Hydrogen Association, the entire nation has 66 hydrogen fueling stations.[12] The U.S. Department of Energy (DOE) does not maintain comprehensive statistics in this area, but the various demonstration projects suggest that there are some hundreds of hydrogen fuel cell vehicles on the road in the U.S.

Texas has only a few stationary hydrogen power facilities, and there is one hydrogen fueling station under construction in Austin, where a fuel cell bus is being operated by University of Texas researchers.

The National Renewable Energy Laboratory reports that about 250 fuel cells are being used for power in hotels, hospitals and office buildings in 19 countries.[13] A 2002 Texas State Energy Conservation Office (SECO) study illustrated the embryonic stage of hydrogen development: in that year, an estimated 300 fuel cells being used in the private and public sectors around the world produced 50 megawatts of electricity, or about enough to power just 20,000 homes.[14]

Production

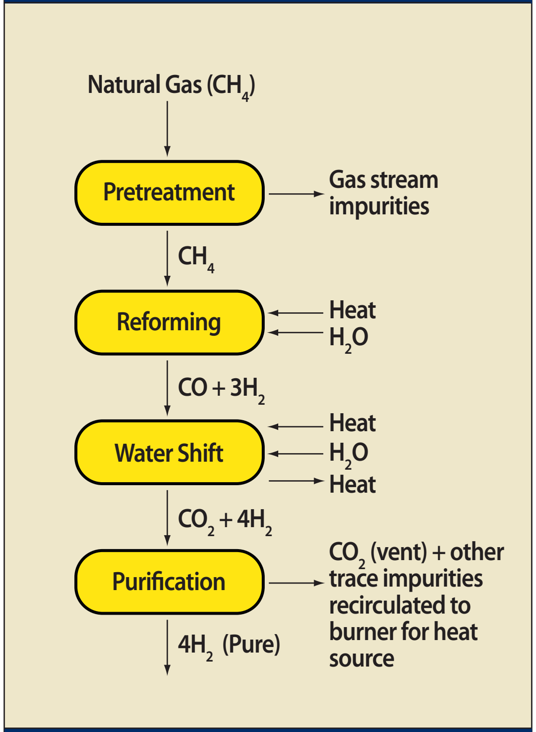
Hydrogen can be produced from a wide range of sources, including fossil fuels such as coal and natural gas as well as nuclear, wind, solar and hydroelectric power.

Current ways to produce hydrogen include:

- *steam methane reforming*. High-temperature steam is combined with methane in the presence of a catalyst to produce hydrogen (**Exhibit 22-2**). This is the most common and least-expensive method of production in use today.
- *electrolysis*. An electric current is used to "split" water into hydrogen and oxygen.
- *gasification*. Heat is applied to coal or biomass in a controlled oxygen environment to produce a gas that is further separated using steam to produce hydrogen.

Exhibit 22-2

Steam Methane Reforming Block Flow Process



Source: Gas Technology Institute.

The following methods for producing hydrogen are in the research and development stage:

- *renewable liquid reforming*. Ethanol or biodiesel derived from biomass reacts with steam to produce hydrogen.
- *nuclear high-temperature electrolysis*. Heat from a nuclear reactor is used to improve the efficiency of electrolysis, again splitting water to make hydrogen.
- *high-temperature thermochemical water-splitting*. Solar concentrators are used to split water.
- *photobiological* microbes. Certain microbes produce hydrogen as part of their metabolic processes. Artificial systems can encourage these organisms to produce hydrogen through the use of semiconductors and sunlight, improving their natural metabolic processes.

- *photoelectrochemical* systems. These use semiconductors and sunlight directly to make hydrogen from water. [15]

Again, natural gas reforming in large central facilities is by far the most common method of creating hydrogen; it is also the most economical, although it is not yet competitive with energy from fossil fuels, primarily because the hydrogen still must be transported and stored for use, which can cost as much as 10 times the actual production cost. Other methods are more expensive and have other drawbacks. Gasification of coal, for instance, results in carbon dioxide releases that some observers say blunt hydrogen's claim to environmental superiority.

Authoritative studies from sources including DOE, however, say that fuel cell-powered vehicles, running on hydrogen derived from natural gas, produce fewer carbon emissions than internal combustion or gasoline-electric hybrid engines.[16]

Hydrogen Fuel Cells

Fuel cells are electrochemical devices that combine hydrogen with oxygen from the air to generate electricity. Fuel cells work by converting the chemical energy in hydrogen into electricity, producing heat and water as byproducts. They can be added together in stacks to generate significant amounts of power. In a fuel cell vehicle, hydrogen flows from a storage tank into the fuel cell, which generates electricity that is used to power an electric motor, often supplemented by batteries or capacitors.

A single fuel cell consists of an electrolyte, which is an electric conductive medium layered between two electrodes, an anode and a cathode. Hydrogen is fed into the anode and oxygen into the cathode. A catalyst causes the hydrogen atom to split into a proton and an electron. The protons pass through the electrolyte while the electrons travel around an external circuit, creating a current that can be used for power before they reunite with the hydrogen ion and oxygen to form water.

All the various fuel cell technologies have the same basic structure, an electrolyte and two electrodes. The type of electrolyte used, however, affects the chemical reaction that takes place and the amount of heat generated.[17] Common fuel cell types include:

- *alkaline*. Used by NASA, these are highly efficient and operate at a relatively low temperature. Alkaline cells are susceptible to carbon contamination in fuel and require pure hydrogen and oxygen to operate.

- *phosphoric acid*. These cells are commercially available today and are used in hospitals, office buildings and wastewater plants; they can also produce steam for heating purposes, using their otherwise wasted heat. They are less efficient than alkaline cells but more tolerant of fuel impurities.

- *polymer electrolyte membrane (PEM) cells*, also called proton exchange membrane exchange cells. These operate at relatively low temperatures and can respond quickly to changes in power demand. They are most adaptable to transportation uses.

- *molten carbonate*. These cells operate at high temperatures and can be used by electric utilities to generate grid power.

- *solid oxide*. These cells operate at very high temperatures and are most suitable for stationary power applications.[18]

PEM fuel cells operate at lower temperatures and have a high "power density" (i.e., they generate a relatively large amount of power with a small device). This makes them the most popular choice for vehicle and portable power applications. Those that operate at a higher heat are more efficient, however, and can be used in large electric generation plants where the waste heat can also be captured to generate power in a process known as cogeneration.

Fuel cells are typically more efficient than gasoline engines. Internal combustion engines are typically 18 to 20 percent efficient, meaning that most of the energy they use is lost in the process. Some hydrogen fuel cells used in vehicles, by contrast, are up to 60 percent efficient.[19] This is because electrochemical reactions are much more efficient than combustion in converting energy to power needed to operate the vehicle.

Natural gas reforming in large central facilities is by far the most common method of creating hydrogen.

Fuel cells contain no moving parts and thus sustain less friction loss. They are, however, dramatically more expensive to manufacture than gas or diesel engines, which have the advantages of more than a century of technological improvement and mass production expertise. Production costs for fuel cells are expected to decline substantially if and when they are produced in large volumes, such as would be needed for vehicle manufacturing. Other efficiency improvements expected in the future would mean that smaller, lighter fuel cells can be used, along with smaller quantities of onboard hydrogen.

Hybrid gas-electric vehicles, for example, have benefited from earlier improvements that reduced vehicle weight, improved aerodynamics and changed various design features. The emergence of inexpensive microprocessors, electronic controls and special software also paved the way for practical hybrids. Fuel cell vehicles are expected to benefit from similar improvements.

While hydrogen-fueled vehicles are commonly associated with fuel cells, hydrogen can also be used in a hydrogen internal combustion engine, a transitional technology promoted by some carmakers including Ford and BMW.

While hydrogen-fueled vehicles are commonly associated with fuel cells, hydrogen can also be used in a hydrogen internal combustion engine (HICE), a transitional technology promoted by some carmakers including Ford and BMW. This approach has also been used in public transit applications.

Transportation and Storage

The Department of Energy has cited the transportation and distribution of hydrogen as two barriers to the commercial development of hydrogen fuel cells. Various delivery methods are being studied and demonstrated by vehicle manufacturers, governmental agencies, energy companies and the industrial gases industry.

At present, the U.S. does not have a widespread distribution network for hydrogen. As a result, most hydrogen is produced near or at the place it is used.

The energy in one kilogram of hydrogen is equal to that in one gallon of gasoline. At normal temperature and air pressure, however, the energy density of hydrogen is low, meaning that relatively large volumes of it must be used to generate power in useful amounts. For example, about 11 tube trailer trucks carrying pressurized hydrogen at 2,400 pounds per square inch would be needed to move the energy equivalent of one gasoline tanker truck.[20]

Hydrogen generally is distributed via pipelines, tube trailers and liquefied hydrogen tankers. According to DOE, transporting hydrogen gas over the road is cost-prohibitive beyond 200 miles because the energy used to move the trailers carrying the heavy tanks costs so much. Hydrogen, like natural gas, also can be super-cooled and transported more efficiently by barge.[21]

DOE and others have identified pipelines as the most cost-effective way to deliver hydrogen, but the U.S. has relatively few lines of this type, at least compared to the web of oil and natural gas pipelines that crisscross the country. The Texas Gulf Coast petrochemical complex, by contrast, has about 1,000 miles of hydrogen pipeline network, as well as a skilled work force experienced in its handling.[22]

There is some potential for conversion of existing natural gas or liquids pipelines to hydrogen. Because of the smaller molecular size of hydrogen, these pipelines would need modification – especially for seals and compression equipment. The tendency of hydrogen to diffuse into and weaken high carbon steels (known as hydrogen embrittlement) will eliminate some pipeline materials from consideration for conversion for hydrogen service; however, a number of natural gas lines have been successfully converted to hydrogen.

Because it is so diffuse, hydrogen is hard to store in relatively small spaces. Efficient, compact and safe storage is major hurdle to the widespread use of hydrogen for energy purposes. This is perhaps the most important key to the wider use of hydrogen, particularly in vehicles. According to DOE, the minimum acceptable driving range for a fuel cell-powered vehicle is 300 miles. With current technology, this would require a tank the size of an average car trunk, which would add considerable weight to the vehicle, reducing fuel economy. In addition, fueling must take only a few minutes to meet consumer expectations.

Existing options for storage include compressing the gas in high-pressure tanks (up to 10,000 pounds per square inch) or cooling it (to -253° C) in insulated tanks. Each approach presents challenges. Compressed gas tanks are very large and heavy, while liquefying hydrogen takes significant amounts of energy, as well as insulated tanks that, again, add to weight and reduce usable space within the vehicle.[23]

Because storage is such as critical technical issue inhibiting hydrogen commercialization, DOE has initiated a multi-year program to research and engineer new methods for storing hydrogen. This initiative directs about $150 million over a five year period toward promising hydrogen storage technologies such as carbon nano-technologies, metal hydrides, and chemical hydrides that may be better alternatives.[24]

Availability

Texas is the nation's second-largest producer of hydrogen, behind California. It is commonly used by Texas industries for refining petroleum, in particular to remove sulfur, as well as for manufacturing fertilizers. The increasing use of "sour," or higher-sulfur, crude oil is increasing the demand for hydrogen production. As a result, petrochemical companies are the largest producers of hydrogen in the world.

In addition, major industrial gas companies including Praxair, Air Products and Chemicals and Air Liquide have hydrogen production operations in Texas. Air Liquide recently announced an expansion of its production, storage and pipeline capacity on the Gulf Coast, including 90 miles of new pipeline to support petroleum-refining operations.[25] Praxair also has started supplying hydrogen to its customers from a unique storage facility in an underground cavern located northwest of Winnie.[26]

Despite its extensive use along the Gulf Coast, however, the use of hydrogen for transportation and power generation in Texas is very limited, as it is in the rest of the country and the world. Texas has only recently begun constructing its first hydrogen fueling station to support a small number of hydrogen-fueled vehicles in Austin. Texas has only a few stationary power facilities that employ hydrogen.

The U.S. Department of Defense (DOD) has used hydrogen fuel cells to create nine stationary power stations at locations in Texas, including Fort Bliss in El Paso; Fort Hood, near Killeen; Brooks City Base in San Antonio; and Camp Mabry in Austin. In addition, DOD previously funded an incentive program that provided $1,000 per kilowatt of electricity to encourage the installation of fuel cells in various locations for demonstration purposes, up to a maximum of $200,000 per project. This program, funded as part of a federal climate change initiative, resulted in the installation of fuel cells at Austin Energy's facilities in Austin and at a Chevron office park in Bellaire.[27]

In 2006, the Texas Commission on Environmental Quality (TCEQ) provided a grant to Gas Technology Institute (GTI) to build the state's first hydrogen fueling station and a fuel cell-powered medium- or heavy-duty vehicle. GTI teamed with the University of Texas, Center for Electromechanics (CEM) to install the station at Austin's J.J. Pickle Research Campus. CEM provided additional funding through a Federal Transit Administration program to complete the cost of building and operating a hybrid electric fuel cell shuttle bus.

Texas is the nation's second-largest producer of hydrogen, behind California.

The bus is designed so that an onboard fuel cell and battery pack jointly operate an electric drive train, resulting in a true zero-emissions vehicle (the first in the state). The bus initially will operate only on the research site, but the university eventually plans to put it into service either on a local metro bus route or perhaps as a shuttle for a local mall (**Exhibit 22-3**).

Greenfield Compression, a Richardson, Texas-based company, provided major equipment components for the fueling station and plans to commercialize GTI's integrated fueling station design. Other sponsors in the project include DOE, GTI, University of Texas, the U.S. Department of Transportation, and the Texas State Energy Conservation Office (**Exhibit 22-4**).

Project goals include validating the technology, providing hydrogen fuel for other demonstration uses and establishing a hydrogen education program. At this writing, the bus manufacturer, Ebus, has completed the vehicle; the hydrogen supply station, which will use natural gas to manufacture hydrogen, is undergoing testing and expected to begin operation in 2008. GTI asserts that the station design can attain the DOE's goal

Private companies, research organizations and Texas universities are involved in research projects concerning hydrogen and fuel cells.

Exhibit 22-3

Hybrid Electric Fuel Cell Shuttle Bus

Source: Gas Technology Institute.

of commercial hydrogen costs between $2 to $3 per gallon of gasoline equivalent (gge).[28]

The bus and supply station are estimated to cost about $2.5 million.[29] Most of the project's funding went for research and design.

Private companies, research organizations and other Texas universities are involved in other research projects concerning hydrogen and fuel cells. Dow Chemical and General Motors, for instance, have created a fuel cell demonstration project at Dow's Freeport chemical plant that is running endurance tests on fuel cells to simulate real-world driving conditions. This privately funded venture also tests fuel cells intended for stationary power.

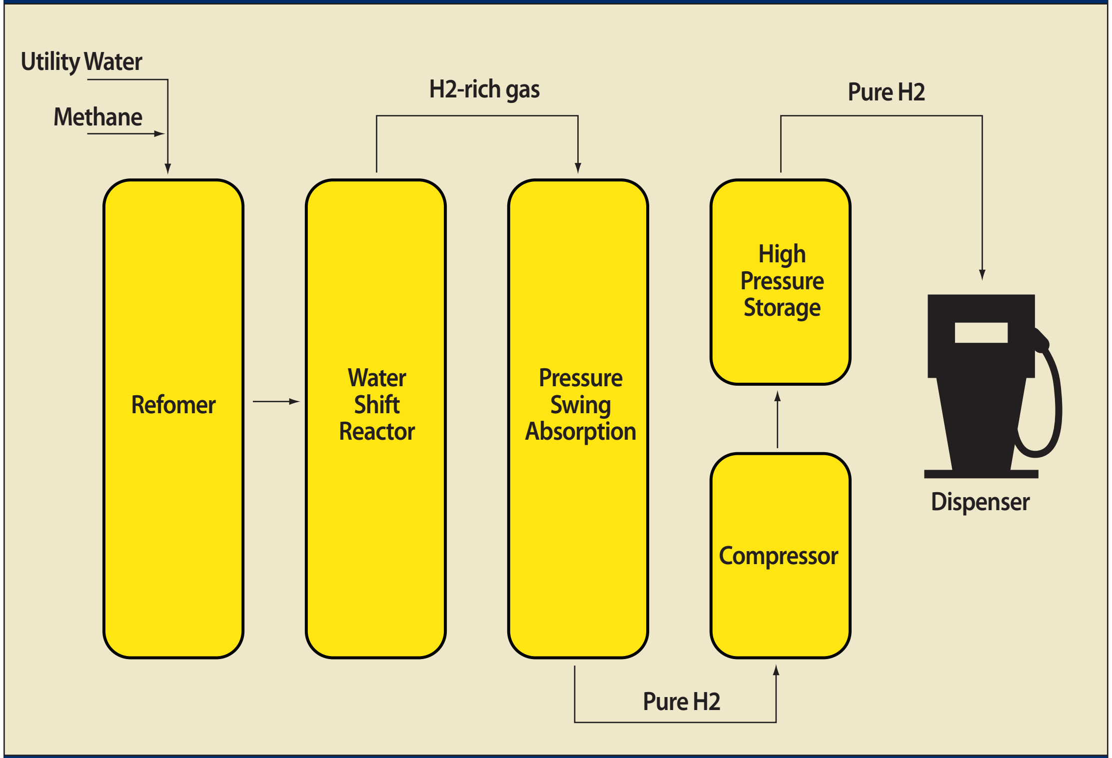
Both the Houston Advanced Research Center and the Southwest Research Institute in San Antonio have programs to test fuel cells. Texas State Technical Institute in Waco and Lamar University in Beaumont have fuel cells for demonstration and training purposes.[30]

In 2002, the Texas State Energy Conservation Office (SECO) completed a legislatively mandated study on fuel cell commercialization. The report described the promise of hydrogen fuel cells and the classic problem facing emerging technologies: the need for money for research and development *before* mass marketing, which would provide sales needed to accumulate capital.

SECO's report described the benefits of and obstacles to hydrogen power and called for the state to support research and demonstration projects and to buy fuel cells as they become available.[31] Other recommendations included the creation of a

Exhibit 22-4

GTI/Greenfield Fueling Station



Source: Gas Technology Institute.

public-private partnership to guide fuel cell policy and the creation of a plan to foster its commercialization. The report's major recommendations have not been implemented, however.

In 2006, the Texas Department of Transportation (TxDOT) completed a strategic plan for hydrogen vehicles and fueling stations in response to a 2005 legislative mandate requiring the agency to seek funding from public and private sources to operate hydrogen-fueled vehicles and establish hydrogen fueling stations. The plan discussed the potential benefits of hydrogen and the significant technical hurdles to such a program. Since then, however, there has been no movement toward the creation of a hydrogen fuel fleet at TxDOT or any other Texas public agency. The key hurdle cited in the TxDOT report is the immaturity of the technology.[32]

In 2006, industry and university groups formed the Texas H_2 Coalition to promote hydrogen power in Texas. Its goal is to move the state into a leadership role in this nascent industry, building on its significant advantages in hydrogen. The coalition's focus is to establish Texas as an early market for the commercial use of hydrogen and fuel cell products and to produce economic opportunities for the state. The organization is pursuing a demonstration project that would operate a hydrogen-fueled public transportation bus in Houston, as well as a separate hydrogen-powered shuttle at the San Antonio airport.

Legislation introduced in the 2007 session of the Texas Legislature would have spurred the development of hydrogen vehicles. Several bills would have issued bonds to support a $250 million loan program to expand the use of hydrogen energy in Texas, and would have partially exempted hydrogen-related property from local property taxes. While these bills did not pass, a provision to exempt hydrogen vehicles from sales taxes did become law.[33]

In 2008, the Houston Advanced Research Center expects to begin work on a State Energy Conservation Office funded hydrogen study that could serve as the first step to a hydrogen "roadmap" — a strategic plan — similar to those developed in several other states. The final report is expected in fall 2008.

COSTS AND BENEFITS

The costs of widespread commercial applications using hydrogen for power generation or transportation appear prohibitive in today's energy market. Because of the industry's developmental nature, estimates of its costs vary widely. There are, however, some specific applications for which hydrogen-powered vehicles appear to be commercially viable. The nearest-term application is for fuel cell lift trucks (forklifts). Several industrial truck companies have announced commercial fuel cell products that can replace battery-powered forklifts. These have been extensively tested and are available for commercial purchase today. The federal government has been a major buyer of these systems.

One likely early path for the development of hydrogen is using the wide availability of natural gas and its distribution pipelines to create hydrogen for on-site fueling.

There is no market price for hydrogen intended for alternative energy use comparable to that for gasoline, for example. Hydrogen as an alternate energy carrier is in an early phase of development. Estimates of the cost of hydrogen per gallon of gas equivalent range from \$2.10 to \$9.10.[34] According to DOE, hydrogen produced from natural gas, the cheapest available method, is three to four times as expensive as gasoline, in terms of equivalent amounts of energy. In response to a recent survey, DOE said that it received some information on hydrogen prices. The average price per gasoline gallon equivalent from seven respondents was \$17.69.

Fuel cells are up to 10 times more expensive than internal combustion engines.[35] According to the U.S. Government Accountability Office, a fuel cell vehicle stack costs about \$35,000 and a fuel cell-powered vehicle costs about \$100,000.[36] Five years ago, the stack price alone would have exceeded \$100,000, indicating the progress being made toward cost reduction.

DOE's goal is to reduce the cost of hydrogen to \$2 to \$3 per gasoline gallon equivalents by 2015. Its previous goal of \$1.50, set before gasoline prices went up, was based on the use of natural gas as a source for hydrogen. The new goal is independent of the method of production, in response to questions about the environmental effects of using natural gas for hydrogen production.[37]

Environmental Impact

The environmental benefits of hydrogen are a very positive attribute. When used in a fuel cell to power an electric vehicle, the emissions include only water and heat. But hydrogen is produced using energy from natural gas, coal, solar, wind or nuclear power, each of which has its own environmental effects; the tradeoffs are much like those related to fuels used for electricity production.

One likely early path for the development of hydrogen is using the wide availability of natural gas and its distribution pipelines to create hydrogen for on-site fueling. This is the concept being used for the first Texas station in Austin. Similarly, hydrogen can be produced from the nation's abundant coal reserves. Most analyses show that the higher efficiency of hydrogen applications can result in lower greenhouse gas emissions, even when the hydrogen is produced from coal. Observers say transitional approaches relying on natural gas could facilitate the use of hydrogen technologies until production methods using other, more environmentally friendly resources become available.[38]

Other Risks

Safety is often mentioned in any discussion of hydrogen as a fuel or energy carrier.

Like many other fuels, hydrogen is highly flammable and must be handled properly to ensure its safety. In this way it is comparable to fuel sources such as gasoline or compressed natural gas (CNG), all of which are subject to safety codes and standard industrial safety practices.

Hydrogen's lightness can be an advantage in case of a leak. Since hydrogen is 14 times lighter than air, it will float upward and disperse quickly, unlike heavier fuels that may pool at ground level. But its unique properties — its small molecular size and buoyancy — mean that different techniques are required to transport, store and use hydrogen.

Hydrogen is made, shipped and used today in many industries worldwide and has an established track record in industrial use. It is only beginning to be implemented as an energy carrier on a commercial basis, however. As a result, DOE sees development of codes and standards as essential for bringing hydrogen energy systems to market.

Although some codes and standards do exist, many of these are under further development at the national level, including regulations being developed by the U.S. Department of Transportation, National Highway Traffic Safety Administration, and Environmental Protection Agency in cooperation with industry groups. The goal is to have the necessary codes and standards in place by 2012 to support the early commercialization of hydrogen energy technology.[39]

State and Federal Oversight

The National Energy Policy Act of 2005 (EPAct 2005) authorized federal funding and laid out the priorities for the development of a national hydrogen program. It also provides a guideline for federal agencies to manage specific activities related to the program.[40]

Subsidies and Taxes

The federal government has no production incentives for hydrogen. Instead, it is funding basic research and demonstration projects. Again, federal funding for the nation's Hydrogen Fuel Initiative totaled $274 million in 2007, and the administration has requested more than $309 million for 2008.[41]

Hydrogen fuel cells are eligible for funding under TCEQ's Texas Emissions Reductions Plan program and the New Technology Research and Development Program. These programs, which distribute more than $150 million annually, are primarily focused on near-term diesel engine breakthroughs to reduce vehicle emissions, but fuel cells are eligible as well.

The 2007 Texas Legislature considered several initiatives to fund hydrogen incentives; the one bill that passed provides a sales tax exemption for hydrogen vehicles.

OTHER STATES AND COUNTRIES

California is arguably the world leader in adopting hydrogen power. In 2004, an executive order by California Governor Arnold Schwarzenegger initiated the California Hydrogen Highway Network, to facilitate the transition to what state leaders describe as a "clean hydrogen transportation economy."

The program, which comprises a series of hydrogen fueling stations, fleet vehicle demonstration projects and state purchases of hydrogen vehicles, is intended to create a hydrogen infrastructure to support the commercialization of this technology. It is expected to reduce emissions of greenhouse gases, improve air quality, spur economic growth and reduce the state's dependence on foreign oil. The California Air Resources Board is in charge of the program.

Today, largely as a result of these efforts, California has more hydrogen fuel cell-powered cars and buses on the road and more fueling stations than any other place in the world. At the end of 2006, 126 hydrogen vehicles and eight hydrogen buses were operating in California. The state had 24 hydrogen fueling stations in operation and another 13 in the planning stages. Fifteen of the 24 stations are open to the public, while the rest are used by vehicle fleets or in demonstration and test projects. The state goal is to have 50 stations operating by 2010.

At present, these vehicles and stations are clustered in the state's two largest population centers, the San Francisco Bay area and greater Los Angeles. In 2005, the California Legislature allocated $6.5 million for purchase of more fueling stations and vehicles. Recent legislation also included a goal that at least 33 percent of the hydrogen used in the new transportation system should be produced from renewable resources.[42]

New York and Florida also have taken steps to encourage the development of hydrogen power.

The New York State Energy Research and Development Authority (NYSERDA) produced *The New York State Hydrogen Energy Roadmap* in 2005. This plan defines the state's goals for using hydrogen as both a transportation fuel and a stationary power source by 2020.

Strategies proposed by NYSERDA include supporting research and development, demonstrating innovative technologies, developing a supportive business climate and promoting early adoption of the new technologies. The plan calls for placing hydrogen

California has more hydrogen fuel cell-powered cars and buses on the road and more fueling stations than any other place in the world.

fueling stations along roads running from Buffalo to New York City to complement the development of commercially available hydrogen-powered vehicles. In 2007, NYSERDA funded 11 research and demonstration projects valued at $2.9 million.[43]

In 2003, Florida launched "H_2 Florida" to speed the commercialization of hydrogen technology. The program's goal is to showcase new technologies and educate consumers about hydrogen. In May 2007, Florida Governor Charlie Crist and other dignitaries officially opened the state's first hydrogen energy demonstration station. Located in Orlando, it fuels shuttle buses at the Orlando International Airport and Orange County Convention Center. These Ford shuttle buses burn hydrogen in internal combustion engines.[44]

European countries have made significant efforts, individually and collectively, in hydrogen-related research and demonstration activities. Perhaps the best-known project is Clean Urban Transport for Europe (CUTE). This 2003 through 2005 project was co-financed by the European Commission (EC) and its member nations. Its focus was a demonstration project that put 27 fuel cell buses into operation in public fleets in nine cities in seven countries. Companion projects took place in Australia, China and Iceland.

Many energy industry participants say that hydrogen has a potentially important role as part of a the state's energy portfolio.

The CUTE project used various approaches to fuel its buses. Natural gas was used to generate hydrogen, as was the electrolysis of water; in some instances, hydrogen was trucked in from refineries. All of the buses used PEM fuel cells.[45] Since the conclusion of the first demonstration project, the EC has initiated another public-private partnership with industry for hydrogen research and development. The plan is to create more hydrogen supply and improve fuel cell technology for stationary as well as portable applications. The EC will provide the equivalent of $664 million while industry matches that amount. The goal is to develop the technology enough to make it commercially viable.[46]

Japan's Ministry of Economy, Trade and Industry (METI) is planning to spend the equivalent of $1.7 billion over the next five years to develop new power trains and fuels to cut reliance on petroleum and cut carbon dioxide emissions. The plan includes work on batteries and clean diesel but the biggest focus is on hydrogen. METI's goal is to spend the equivalent of $1.3 billion on research and development to create fuel cell vehicles that could be produced at the same cost as gasoline vehicles by 2030.[47]

OUTLOOK FOR TEXAS

There are no major controversial public issues related to hydrogen in Texas today. While most of the proposed legislation related to hydrogen failed in the 2007 legislative session, there was no negative testimony or public controversy.

Many energy industry participants say that hydrogen has a potentially important role as part of a the state's energy portfolio, and may provide a reasonable alternative for specific transportation applications such as fleet vehicles and for certain power generation applications requiring "clean" power. Stricter vehicle emission standards have been a key factor in spurring hydrogen research by carmakers.

Supporters of hydrogen power cite three major benefits: energy security, environmental benefits and economic growth.[48] Hydrogen can be produced from various domestic energy sources including both fossil and renewable fuels. If it is produced using renewable or nuclear sources, or fossil fuels with carbon-capturing technology, it will produce almost no emissions. The technology is flexible and can be used for transportation and large or small-scale power needs.

Fuel cells are two to three times more efficient in converting fuel to power than internal combustion engines. They yield almost no pollutants and are quiet.[49]

According to DOE, "the greatest technical challenge to hydrogen is cost reduction."[50] Costs for fuel cells and the hydrogen needed to run them are significantly higher than costs for internal combustion engines and fossil fuels. The durability of fuel cells poses another hurdle to commercialization, because they do not yet operate as long as a gasoline or diesel engine. The size and weight of hydrogen storage tanks and the resulting costs are the biggest barriers to hydrogen production and distribution.[51]

The U.S. government has chosen to invest significant public funds to overcome these barriers. With the completion of the President's Hydrogen

U.S. Vision for a Hydrogen Economy

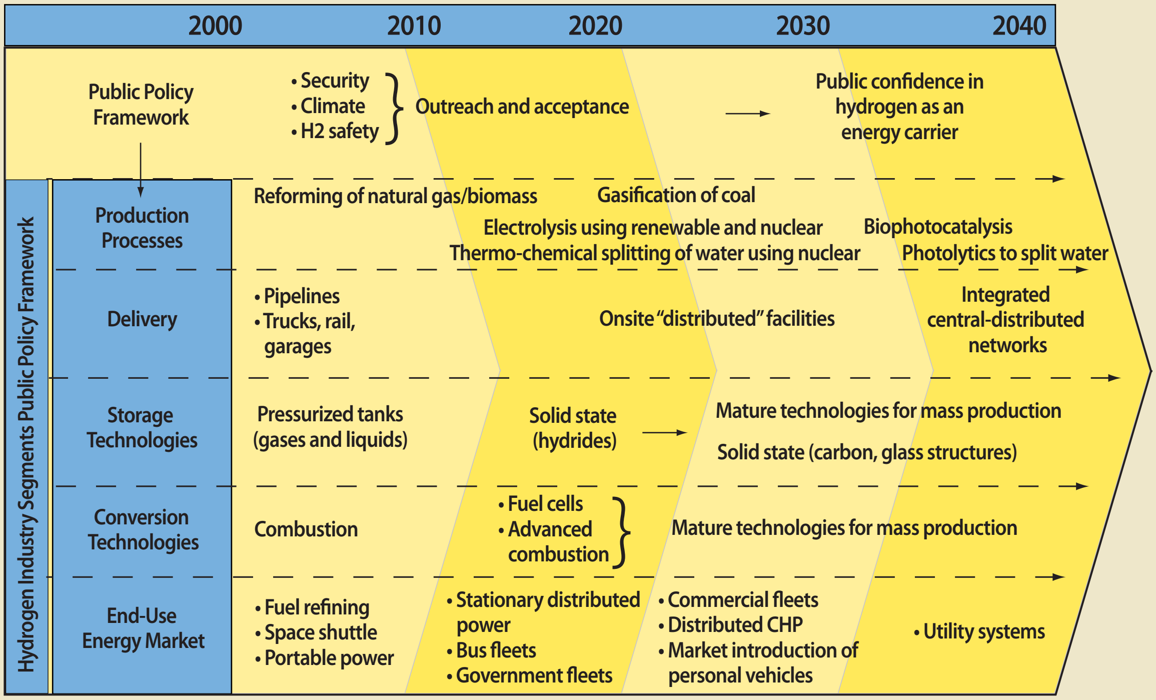
In 2001, the U.S. Department of Energy held a meeting of 53 senior executives representing energy and transportation industries, universities, environmental organizations, federal and state agencies and national laboratories to discuss the potential role of hydrogen systems in America's energy future. Billed as a forum to create a national vision for hydrogen, the meeting's participants discussed the timeframe and key milestones that would have to be met for hydrogen to become a premier energy carrier. The five major findings of the report are quoted verbatim below:

- Hydrogen has the potential to solve two major energy challenges that confront America today: reducing dependence on petroleum imports and reducing pollution and greenhouse gas emissions.
- There is general agreement that hydrogen could play an increasingly important role in America's energy future. Hydrogen is an energy carrier that provides a future solution for America. The complete transition to a hydrogen economy could take several decades.
- The transition toward a so-called "hydrogen economy" has already begun. We have a hydrocarbon economy, but we lack the know-how to produce hydrogen from hydrocarbons and water, and deliver it to consumers in a clean, affordable, safe, and convenient manner as an automotive fuel or for power generation.
- The "technology readiness" of hydrogen energy systems needs to be accelerated, particularly in addressing the lack of efficient, affordable production processes; lightweight, small volume, and affordable storage devices; and cost-competitive fuel cells.
- There is a "chicken-and-egg" issue regarding the development of a hydrogen energy infrastructure. Even when hydrogen utilization devices are ready for broad market applications, if consumers do not have convenient access to hydrogen as they have with gasoline, electricity, or natural gas today, then the public will not accept hydrogen as "America's clean energy choice."[52]

Exhibit 22-5 summarizes DOE's vision of the transition to a hydrogen economy.

Exhibit 22-5

Transition to a Hydrogen Economy



Source: U.S. Department of Energy.

Fuel Initiative in 2008, however, it is not certain that the current level of federal funding available to the field will continue. It appears, though, that higher energy prices have again stirred at least a temporary national interest in alternative and renewable energy, as they did in the aftermath of the energy crisis of the 1970s. Even more importantly, growing interest in carbon reduction strategies at the national level may spur hydrogen's use as an alternative energy carrier or fuel.

California has embraced hydrogen's potential and has committed significant state resources to become a leader in this new industry. As a result, if the transition to hydrogen indeed occurs, the state will be well placed to enjoy its economic benefits. New York, Ohio, Michigan, South Carolina, and Florida have chosen to support development of hydrogen as well.

Texas has some potential advantages over these states in the development of hydrogen as an energy source. Texas has a large and knowledgeable energy sector with experience in handling hydrogen, as well as a hydrogen pipeline network. It also has an extensive natural gas production and transmission infrastructure, important since natural gas is the most common material used to create hydrogen. On the demand side of the equation, Texas has both metropolitan bus fleets and passenger vehicle fleets that could use hydrogen.

But the state has made relatively few investments to capitalize on its advantages, and has lagged behind other states in attracting federal funds for research and demonstration projects, probably because many federal grants require local or state matching contributions.

Hydrogen power presents significant technological challenges, and its further development will depend upon advancements that may require a longer time frame than other options such as biofuels. New, lower-cost technologies needed to commercialize it may never materialize. But many in industry and the research community remain convinced that these hurdles will be overcome, and without additional financial commitments, Texas may be left behind in the transition to a new energy source — and a new economy.

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CHAPTER 23
Efficiency and Conservation

INTRODUCTION

Energy efficiency and conservation recently have been receiving increased attention — and not only in discussions about national energy policy and the impact of global climate change, but in television ads for light bulbs and cars, on the labels of new refrigerators and in monthly electric bills.

Energy conservation means using less energy and avoiding excessive or wasteful uses. Efficiency, on the other hand, means using less energy *while getting the same results*. Efficiency is therefore a subset of conservation; one way to conserve energy is to use it more efficiently.

Sometimes the two concepts are distinguished by how the savings are achieved. The U.S. Department of Energy (DOE) says that "energy efficiency is technology-based" (compact fluorescent light bulbs, for example), while conservation "is rooted in behavior" (such as turning off unneeded lights). Moreover, the energy savings from efficiency are easier to predict, measure and especially to sustain, making efficiency easier to treat as an energy resource.[1] This distinction, however, is not entirely clear cut; there are efficiency measures that rely on behavior, such as combining car trips to save gasoline. Nonetheless, the focus of this chapter is on conserving energy through broad-based, long-term efficiency programs.

In light of a rapidly growing demand for power, higher energy prices and increased awareness of environmental and energy security concerns, the concept of doing more with less offers an approach that seems both feasible and affordable. Governmental agencies, nonprofit organizations, utilities and their regulators, manufacturers, lawmakers and consumers across the country and internationally are considering energy efficiency and how to achieve it.

In July 2006, DOE and the Environmental Protection Agency (EPA) released a *National Action Plan for Energy Efficiency*, with the goal of creating "a sustainable, aggressive national commitment to energy efficiency." The action plan embodies the notion of treating increased efficiency as an energy resource; indeed, the first recommendation in the plan is for the U.S. to "recognize energy efficiency as a high-priority energy resource."[2]

As discussed in previous chapters, various fuels will help to meet Texas' growing energy needs in the coming decades. This chapter examines the potential role of efficiency in helping meet those needs by reducing energy use and offsetting the need to build new generating capacity. In general, investments in increased energy efficiency produce subtle and diffuse benefits, spread out among millions of consumers. Nonetheless, those results are quantifiable and justify the consideration of greater efficiency in energy policy development.

The concept of doing more with less offers an approach that seems both feasible and affordable.

History

The 1973 oil embargo and the resulting increased awareness of energy conservation, coupled with increasing demand and higher prices for electricity, led to a number of new federal policies and programs designed to cut energy demand. These include the Energy Policy and Conservation Act of 1975 (EPCA), the Energy Conservation and Production Act of 1976 and the National Energy Conservation Policy Act of 1978 (NECPA).

EPCA contained, among other efficiency programs, provisions for establishing the original Corporate Average Fuel Economy (CAFE) standards (discussed below). EPCA also directed DOE to establish efficiency targets for major household electrical appliances; NECPA added some commercial equipment to the call for standards. Due to resistance from manufacturers, these standards were never issued, but the legislation prompted several states including California, Florida, Kansas and New York to set such standards themselves.

The variability of these standards from state to state caused difficulties for manufacturers, spurring them to support a renewed push for a single set of national standards in the late 1980s. The National Appliance Energy Conservation Act of 1987 established minimum efficiency requirements for a dozen household appliances; the Energy Policy Act (EPAct) in 1992 added 12 more products, and EPAct 2005 another 16. Some states (not including Texas) continued to push beyond the national law, establishing standards for more electrical equipment; some of these standards were subsequently adopted nationally, preempting the state laws.[3]

NECPA, however, had a more significant effect than its impetus toward appliance efficiency standards. The law also required electric utilities to offer their residential customers energy audits in their homes to help them find ways to conserve electricity. This mandate marked the beginning of the demand-side management (DSM) programs that would grow quickly in scope and importance through the 1980s to the mid 1990s.[4]

The electricity market of the 1970s and 1980s was buffeted by volatile conditions, including an energy shortage; high construction costs, interest rates and electricity prices; slower growth in demand; and initial moves toward electricity deregulation. These events, combined with federal energy conservation legislation, all led to a new emphasis by regulators on demand-side management — that is, reducing the demand for electricity by changing the level or timing of its use — and new considerations in utility planning. Utilities' former reliance on increasing supplies in response to rising demand shifted with the emergence of DSM and gave rise to "least-cost" or integrated resource planning (IRP).[5]

IRP is defined in the 1992 Energy Policy Act:

> The term "integrated resource planning" means, in the case of an electric utility, a planning and selection process for new energy resources that evaluates the full range of alternatives, including new generating capacity, power purchases, energy conservation and efficiency, cogeneration and district heating and cooling applications, and renewable energy resources, in order to provide adequate and reliable service to its electric customers at the lowest system cost. The process shall take into account necessary features for system operation, such as diversity, reliability... and other factors of risk; shall take into account the ability to verify energy savings achieved through energy conservation and efficiency and the projected durability of such savings measured over time; and shall treat demand and supply resources on a consistent and integrated basis.[6]

IRP aims to find the most economical means of supplying sufficient electricity to consumers, weighing the costs of supply-side methods (e.g.,

In Texas, integrated resource planning (IRP) did not take hold until 1995, when the Legislature added it to the Public Utility Regulatory Act. The legislation required utilities to prepare, every three years, integrated resource plans covering a 10 year period. It also contained a one-line provision that had surprising consequences. The statute, in laying out the rules the Public Utility Commission (PUC) needed to establish to begin the IRP process, added some rules the commission *could* set if it wanted to. The commission could "define the scope and nature of public participation in the development of the [utility's integrated resource] plan."[7]

The PUC did, in fact, formulate a process for obtaining informed public feedback on priorities and directions for the utilities' IRP plans. The results of this two-year process surprised both PUC and the utilities: customers from all over the state showed a consistent preference and willingness to pay more for renewable and efficiency resources. Furthermore, when presented with a choice between energy sources with lower construction and higher operating costs, and those costing more up front but with level or lower costs for operation, they strongly preferred the latter.

As a result of this feedback, "the utility companies began to integrate customer values about energy choices into their IRP filings," according to the National Renewable Energy Laboratory. In the year after the conclusion of the public participation process, the Legislature considered and passed an electric restructuring bill; solid evidence of the public's inclinations undoubtedly had some influence on the lawmakers' decision to include a renewable portfolio standard (RPS) and efficiency requirements in the statute.[8]

building new power plants or buying electricity from other generators) against demand-side programs (e.g., increasing the energy efficiency of buildings and appliances and educating the public on saving electricity).

Electric utility efficiency programs developed from modest informational efforts, home energy audits and low-cost loan programs of the late 1970s and early 1980s, to more effective methods such as rebates for energy-saving home improvements, free installations of energy-efficient technology and technical assistance such as site-specific recommendations following energy audits. These programs also expanded from the residential market into the commercial and industrial sectors.

Early advocates of IRP for utilities emphasized that demand reduction programs were often more cost-effective than building new power plants, and high interest rates also added a disincentive to such large capital investments. Nationally, DSM spending by utilities rose sharply in the early 1990s, going from $900 million in 1989 to $2.7 billion in both 1993 and 1994. The resulting energy savings likewise increased significantly; from 1992 to 1996, total DSM savings went from 35.6 billion kilowatt-hours (kWh) to 61.8 billion kWh, more than 90 percent of which came from energy efficiency.[9] Over the same time period, the peak load reduction due to efficiency programs almost doubled, from 7,890 megawatts (MW) to 14,243 MW.[10] These results were not, however, uniform across the country; utilities in Washington, California, Wisconsin, Massachusetts, New York, North Carolina and Florida had the most DSM activities.[11]

The rise of efficiency programs did not continue unabated, however. According to some observers, the "stall" in DSM spending after 1994's peak was due to moves toward deregulation by large segments of the electric utility industry. The prospect of market competition and uncertainty as to its effects caused many utilities to cut spending on efficiency and also to delay investments in new generating capacity.[12]

Even so, the impetus for greater efficiency in energy use remained strong. The Energy Policy Act of 1992 (EPAct 1992), in addition to providing "encouragement of investments in conservation and energy efficiency by electric [and gas] utilities," set efficiency standards and guidelines for buildings, lighting, heating and cooling systems, windows, some electric motors and transformers and industrial facilities.[13] The more recent EPAct 2005 built on those programs, reauthorizing several and expanding the list of facilities and products covered by the federal efficiency standards. And the states have continued to push beyond the national standards by adding appliances not covered by national law, sometimes working in regional coalitions, often replicating California's efficiency standards.[14]

Thirty years of energy efficiency efforts have had an effect. The U.S. economy is significantly more energy-efficient than it was in the mid-1970s. The amount of energy needed to produce one dollar's worth of goods (known as the "energy intensity") fell by about 50 percent between 1970 and 2003, though about half of that drop is attributable to the shifts in the economic base such as the change from manufacturing to service industries (whose "goods" are not in physical form).[15] DOE has developed a new economy-wide energy intensity index to reflect only those changes in energy intensity resulting from energy efficiency improvements. According to that index, energy intensity dropped by 10 percent from 1985 to 2004, meaning that because of increased efficiency, the same amount of goods is produced with 10 percent less energy.[16]

The U.S. economy is significantly more energy-efficient than it was in the mid-1970s.

In the area of transportation, the National Academy of Sciences and the U.S. Department of Transportation studied the effects of the CAFE standards in 2001. The study concluded that the program "has clearly contributed to increased fuel economy of the nation's light-duty vehicle fleet," and that in their absence, gasoline use would have been "about 2.8 million barrels per day greater than it is" [in 2001].[17]

Uses

Efficiency improvements can affect every type of energy use, although they vary widely in their ease and the amount of energy savings they can yield. Considerations such as cost versus benefits, length of the "payback" period for investments, the potential for public funding, maintainability and technological questions must be weighed carefully.

Generally speaking, areas of high energy use are prime targets for efficiency improvements. Most efficiency programs and proposals have focused on electricity use, but there have been improvements in natural gas use as well. Transportation also offers an obvious potential for savings, but other than the CAFE standards there have been relatively few efforts in this area.

ENERGY EFFICIENCY IN TEXAS

Texas, with its heavy industrial base, large population and hot climate consumes more energy than any other state, with more than half of the state's energy use going to industry. Demand for residential electricity for air conditioning, combined with the fact that the state relies more heavily on electricity for residential energy needs than most states, raises the per capita residential electricity use above the national average, according to the U.S. Energy Information Administration.[18]

Texas ranked eleventh overall among the states in the American Council for an Energy-Efficiency Economy's 2006 state efficiency scorecard. The ranking would have been higher but the state scored only 13 percent in the "utility spending on energy efficiency" category. Texas' score on transportation policies also was low, at 20 percent, although most states scored 20 percent or less in this category. As stated previously, however, improving transportation efficiency has not generated the same level of interest as has electricity.[19]

A July 2007 report on the results of the state's energy efficiency programs found that IOUs not only met, but exceeded, mandated savings.

It should be noted that Texas scored well (80 percent) for the efficiency in building codes and the state's use of combined heat and power (making use of the energy in heat put off by industrial processes). Texas' highest 2006 score was for its renewable energy and energy efficiency portfolio standards (RPS and EEPS). These standards establish state or national goals for energy source or use. An RPS sets a certain percentage of annual energy use that must come from renewable energy sources; these goals are usually set for some years in the future and can be on an increasing scale, such as 10 percent by 2015 and 15 percent by 2020.

Less generally well known, perhaps, are EEPS, standards that require certain percentages of energy needs to be met with energy efficiency. EEPS, also known as EERS (energy efficiency resource standards), are modeled after RPS and sometimes are incorporated into an existing RPS by allowing some portion of the requirement to be met with efficiency improvements. The energy savings can be a percentage of the total sales (total load) or of the projected increase of use in coming years (load growth or demand growth). An EEPS can cover gas utilities as well as electricity and can include an efficiency credit trading system. As with an RPS, the percentages can increase over time; for example, in 2007 Illinois' legislature passed an EEPS requiring a reduction of total electricity use of 0.2 percent in 2008 that grows to 2 percent by 2015.[20]

According to DOE, Texas' EEPS pioneered the policy of requiring electric utilities to meet a portion of their load growth through greater efficiency. In 1999, the Legislature created an EEPS that requires investor-owned electric distribution utilities to cover 10 percent of each year's projected growth in demand with efficiency programs.[21] For 2003, this was 136 MW.[22]

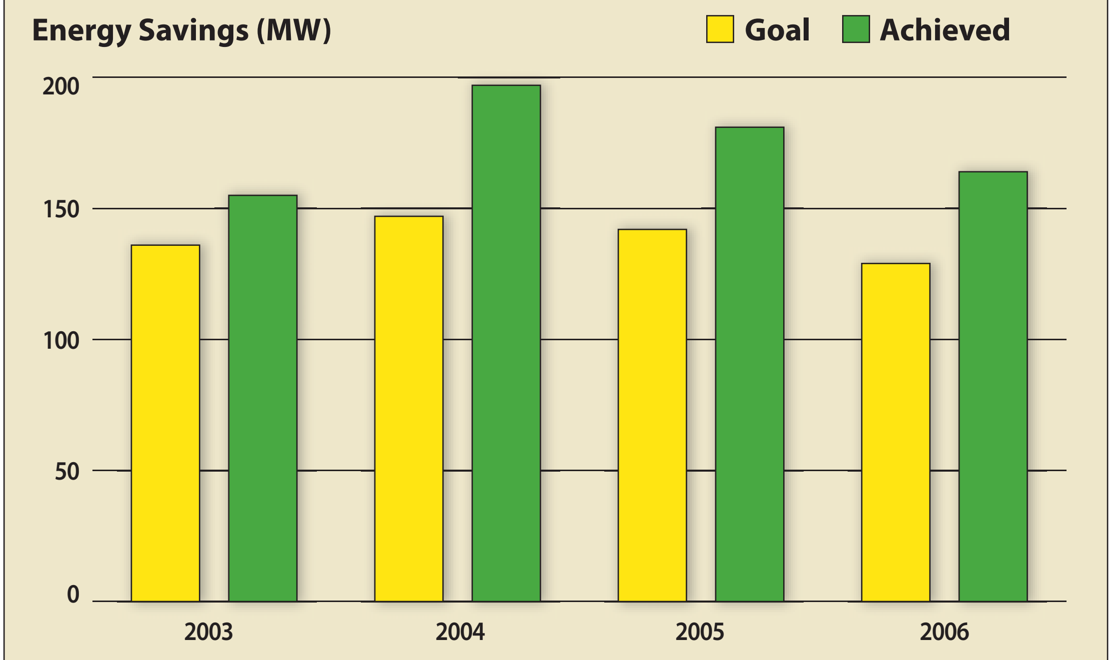
The 1999 legislation (Senate Bill 7) that established the Texas EEPS for most investor-owned electric utilities (IOUs) also introduced competition into the state's electricity market. S.B. 7 required the IOUs to create programs that would "acquire cost-effective energy efficiency equivalent to at least 10 percent of the electric utility's annual growth in demand," and that the Texas Public Utility Commission [PUC] "shall provide oversight and adopt rules and procedures, as necessary, to ensure that the goal of this section is achieved by January 1, 2004."[23] The Legislature gave the PUC and the IOUs those three years to decide on the types of efficiency programs and incentives to use, offer them to the customers and measure the results.

A July 2007 report on the results of the state's energy efficiency programs found that IOUs not only met, but exceeded, the mandated savings in each of the four years running from 2003 to 2006 (**Exhibit 23-1**). Even in the first year of the program, EEPS generated reported savings 11 percent above the goal. In addition, these efficiency efforts produced a reduction in air pollution; the report calculates that the creation of Texas' EEPS has kept about 2,660 tons of nitrous oxide (NO_X) out of the air.[24]

Although utilities self-report savings from the efficiency programs, the utilities have oversight procedures in place to measure and calculate the results and PUC also has a review process to verify

Exhibit 23-1

Total Energy Savings by IOUs, 2003-2006



Source: Frontier Associates.

their numbers. A contractor reviewed the 2003 and 2004 savings figures produced by six participating utilities for PUC; in January 2007, the consultant reported that, while some values were too high, others under-reported savings, and in all the utilities had actually achieved 102 percent of the demand reduction they reported.[25]

Efficiency programs generate costs as well as savings. The cost-effectiveness of spending on energy efficiency can be examined through PUC's annual reports on emission reduction to the Texas Commission on Environmental Quality. The findings of the 2005 and 2006 reports are summarized in **Exhibit 23-2**.

In addition to calculating the NO_X reductions from reduced electricity use due to efficiency, PUC also reports the value of the energy savings. The efficiency measures are required to have at least a ten-year lifespan, and the reports show the electricity cost savings achieved in the first year and over ten years. The utilities, in addition to exceeding their MW reduction goals, produced cost savings that will be cumulatively greater than 350 and 150 percent of the '05 and '06 program costs, respectively. [26]

Availability

Texas' demand for electricity has grown along with its population, which in recent years increased at nearly twice the national rate. Both the population and electricity demand are projected to continue their strong growth in the coming decade. These projections have prompted increased interest in trimming the growth in demand through energy efficiency programs.

Another impetus to using energy more efficiently is the rise in energy prices, due in part to the sharp increase in power plant construction costs. According to Cambridge Energy Research Associates (CERA), those costs are up 27 percent in the year preceding February 2008, 19 percent in the latter

Exhibit 23-2

Energy Efficiency Program Costs and Savings

Summary – 2005 Energy Efficiency Program

Expenditures	Customer Energy Cost Savings		Demand Savings (MW)		Annual Energy Savings (MWh)
$78,929,907	initial year – 2005	$53 million	goal	142.17	496,890
	ten-yr project life	$290 million	achievement	180.75	

Summary – 2006 Energy Efficiency Program

Expenditures	Customer Energy Cost Savings		Demand Savings (MW)		Annual Energy Savings (MWh)
$58,376,786	initial year – 2006	$19.64 million	goal	128.30	357,000
	ten-yr project life	$90.3 million	achievement	161.68	

Source: Public Utility Commission of Texas.

six months alone. For utilities, the comparative costs for efficiency programs to save electricity and building new generation capacity increasingly favor efficiency.[27]

In January 2007, Optimal Energy, an energy efficiency consulting firm, released a report, commissioned by the nonprofit groups Natural Resources Defense Council and Ceres, called *Power to Save: An Alternative Path to Meet Electric Needs in Texas*.[28] In March 2007, the American Council for an Energy-Efficient Economy (ACEEE) released *Potential for Energy Efficiency, Demand Response, and Onsite Renewable Energy to Meet Texas' Growing Electricity Needs*. Both reports examined the potential savings from efficiency programs in the residential and commercial sectors, as well as from other energy saving techniques such as "demand response," which refers to strategies for cutting energy use at the time of peak demand. For example, utilities can offer incentives to customers in exchange for allowing them to cycle off residential appliances or air conditioning systems for brief amounts of time. Demand response also can employ pricing tools such as time-of-use rates, critical peak pricing or real-time pricing, all of which require customers to pay more for power during peak demand periods.[29]

Programs that vary the cost of electricity to consumers depending on when it is used, like the time-of-day pricing for cell phone use, require the ability to gather new information. Not only do the consumers need to know about the different costs associated with their usage patterns, but the electric company must have the data on when and how much power each customer is using at any time. This information is gathered by advanced electrical meters often called "smart meters" (see sidebar).

Programs that vary the cost of electricity to consumers depending on when it is used, like the time-of-day pricing for cell phone use, require the ability to gather new information.

According to *Power to Save*, "ambitious" energy efficiency efforts could eliminate more than three quarters of the projected growth in demand for electricity over the next 15 years with the costs of implementing the efficiency programs being "substantially" lower than new supplies of electricity. The report found that the residential sector accounts for the largest amount of potential efficiency savings, followed by the commercial sector and then industrial uses. It also stated that:

> …[an additional] 20,000 megawatts of potential combined heat and power (CHP) capacity exists in Texas. Combined heat and power refers to the generation of both electricity and useful heat energy, usually by an industrial energy consumer for use at their own facility. This reduces the consumer's need to purchase power from a utility.

Power to Save estimated that demand response programs could further reduce Texas' peak demand by 3,200 megawatts.[30] Lowering peak demand carries a large benefit because maintaining adequate capacity for peak usage, as well as actually generating the electricity to meet that level of demand, are both very costly.

The *Power to Save* report recommended that Texas:

- increase its EEPS from 10 percent to at least 50 percent and preferably to 75 percent, which would cover at least half of the predicted load growth;
- increase its overall investment in energy efficiency programs;
- raise efficiency standards for appliances such as swimming pool pumps and DVD players;
- update residential and commercial building codes to increase energy efficiency by 15 percent;
- require utilities "to invest in all cost-effective efficiency resources;"
- eliminate disincentives for these investments through changes in the regulatory structure;
- allow utilities flexibility in design and delivery of efficiency programs; and
- require PUC to review and update the state's efficiency potential savings, goals and programs every two years.[31]

Although the *Power to Save* recommendations addressed energy efficiency only, the report also estimated gains from demand response and CHP in its total potential savings (**Exhibit 23-3**).

The ACEEE study proposed a series of nine "effective and politically viable" policies, two-thirds of them concerning energy efficiency, to reduce energy consumption and demand growth over the next 15 years. Some of these proposals echo and expand upon the recommendations in *Power to Save*, such as expanding utility energy efficiency programs; setting additional standards for electric appliances and equipment; and drafting more stringent building codes (as studied by Texas A&M per legislative direction). In addition, the report proposes initiating an advanced energy efficiency training program for architects, engineers and builders of new homes and commercial buildings; an expanded LoanSTAR

Smart meters are actually electrical meters combined with wireless or radio communication devices that allow for much more detailed information to be exchanged between electricity providers and consumers. The initial type of advanced meters simply allow one-way communication, enabling remote meter-reading. Now, meters capable of two-way communication offer the possibility of a greater exchange of data. These meters, when combined with data management systems such as billing or information storage, create the opportunity for electricity to be sold at prices that vary throughout the day, rather than in month-long chunks at one price. In that case, retail electricity providers (REPs) can charge their customers prices that more closely reflect the REPs' costs to obtain the electricity (which vary according to the load, or demand, on the system). And, with the information that the meters gather, electricity consumers can see how much power they are using any particular time, what the cost of that electricity is and what effect conservation efforts, such as raising the thermostat a couple of degrees, can have on their costs.

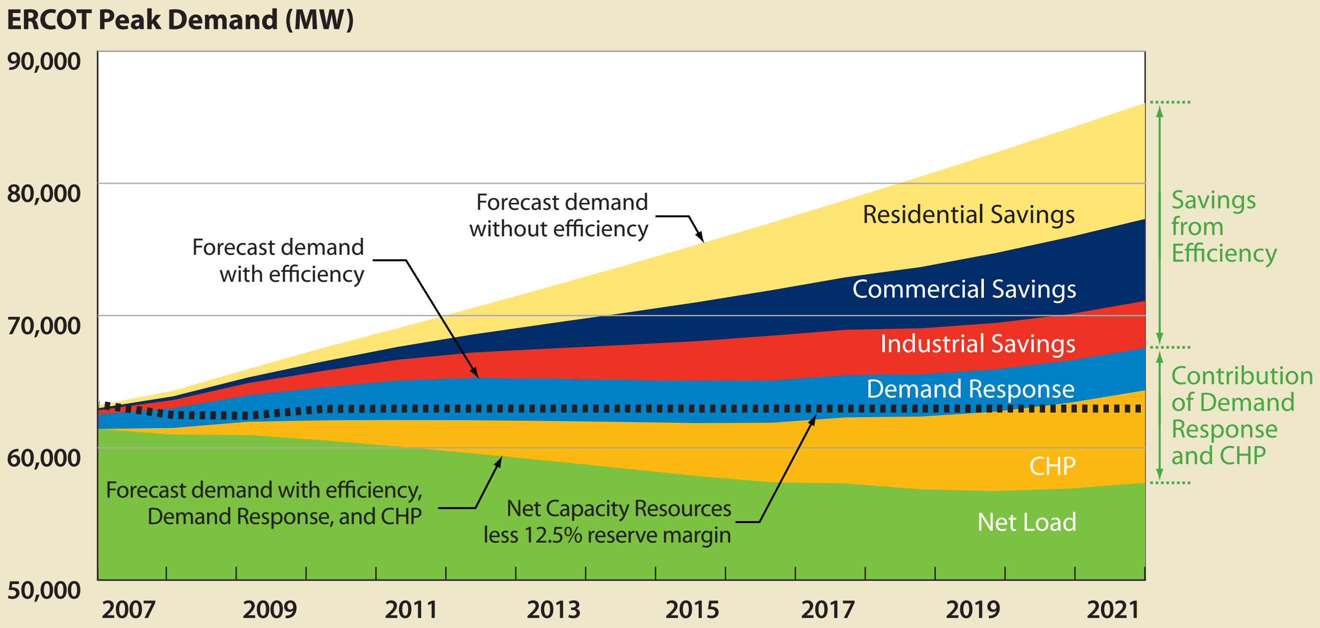
REPs also can use the advanced meters to better monitor the distribution system for problems like outages. The information about customers' usage patterns and how (or whether) they respond to different prices can help the utilities manage the system and add to demand predictability. The meters are the major first step in building what is called the "smart grid," which, like the meters, will enable greater capacity for data collection and fine-tuned control of the flow of electricity over the grid.

Smart meters capable of two-way communication for data gathering and differential pricing are more expensive than the traditional meters or even the more recent versions that can be read remotely or that allow a REP to cycle off residential electricity for a short time during highest demand. In California, where the Public Utilities Commission initiated an Advanced Metering Infrastructure project in 2005, some of the largest utilities have received approval for their plans to install millions of smart meters at a cost of billions of dollars; cost per meter ranges roughly from $150 to $350 and these costs will be passed on to the ratepayers. Some opponents to widespread installation of the meters say that the cost is too high for the consumers to offset with unproven savings, that load-shifting is not the same thing as actually conserving energy and that some types of customers, like the elderly, homebound or ill, cannot shift their energy use to avoid peak prices.[32]

In Texas, two investor-owned utilities thus far, Center Point and Oncor, are proposing to install smart meters; PUC started holding workshops in late 2007 to address how the advanced meter systems (AMS) will be implemented in the state. And Austin's municipal utility, Austin Energy, has been installing remote-reading meters since 2004 and plans to have smart meters installed throughout the rest of their system by late 2008 or early 2009. The data systems for fully utilizing the capabilities of the meters will be added over the next few years. San Antonio's municipal utility is implementing a similar program.[33]

Exhibit 23-3

Effect of Efficiency, Demand Response and Combined Heat and Power (CHP) on Demand Forecasts



Source: Optimal Energy.

program and fund for state and municipal facilities on the waiting list for loans to make efficiency improvements; and a market transformation initiative consisting of a series of short-term programs to educate the public on energy efficiency and offer them rebates on energy efficient products.

ACEEE asserted that if its policies (including those concerning demand response, CHP and on-site renewable energy) are implemented, “Texas can meet its summer peak demand needs without any additional coal-fired power plants or other conventional generation resources.” ACEEE also says that its energy-saving policies “would meet 8% of Texas’s electricity consumption in 2013 and 22% in 2023.” The report notes that of its projected savings, 30 percent would come from utility efficiency programs; 30 percent from improved CHP policies; and 22 percent from appliance standards and building-related programs (the remainder would come from on-site renewables).[34] It should be noted that there is always debate among energy experts about what level of energy savings is achievable from efficiency programs and what economic costs and savings will result. The results reported from previous years’ utility requirements shown above, however, indicate that savings have resulted from Texas’ early EEPS. The question is which additional programs would meet their estimated goals without negative unintended consequences.

The Texas Public Policy Foundation (TPPF) released a report in January 2008 that takes issue with some of the recommendations and their estimated savings and costs in *Power to Save* specifically, along with the ACEEE report more generally. The report, entitled *Power for the Future: The Debate Over New Coal-Fired Power Plants in Texas*, casts doubt on the ability of the efficiency measures recommended in those reports to offset most of the need for new generating capacity. First, TPPF says that it is uncertain whether efficiency gained from new technology will lead to reduced electricity use, because historically consumers use more energy if their energy costs go down.

The TPPF report does agree about the need for more demand response capacity in Texas, especially in light of the amount of time it takes for new power plants to be built and come online. TPPF says that an increase in interruptible electricity supplies, whereby companies allow their power to be cut for brief times in exchange for price breaks, in particular, would help reduce the demand for new capacity. The report points out that the amount of interruptible supply available to the grid during peak demand is down by almost two-thirds since 2000.

The main reason TPPF rejects the projections of energy savings and avoided need for new plants is cost — higher prices for homes built to more stringent efficiency standards are pricing buyers out of the market, and more expensive energy-efficient appliances are causing consumers to delay replacing their older models. In addition, the report predicts that appliance manufacturers would sue the state if Texas requires higher energy efficiency standards, on the basis that the requirements would interfere with interstate commerce. And TPPF maintains that using other states as examples for Texas, as done by proponents of regulatory efficiency measures, can be misleading. California, Massachusetts, Connecticut and Vermont, states with efficiency programs mentioned in the reports discussed above, all have milder summers, less industrial expansion and, except for California, slower population growth. The report states that all four of those states have higher average electricity prices.[35] Energy use tends to decrease with higher energy prices.

The *Power to Save* and ACEEE studies were not alone in concluding that Texas can achieve significant energy savings. A January 2006 report from the Western Governors' Association (WGA), *Clean and Diversified Energy Initiative*, concluded that a "Best Practices" scenario of energy efficiency standards and programs could reduce electricity demand growth in the western states by about 75 percent over 17 years. These best practices were derived from existing programs in WGA states and the scenario assumes similar measures are implemented region-wide, with the estimated savings then proportionally applied to the other states and localities after time allowed for "ramping up" the programs.

WGA reviewed different efficiency studies and energy projections applicable to their region along with recent electricity use and price data. Many of the 19 states in the WGA region (all the states west of and including the Texas to North Dakota line) are growing fast, not only in population but also in energy use. Electricity prices have risen steeply in the western states since 2000, climbing by more than 20 percent in some states, including Texas. WGA predicted that its recommendations for efficiency best practices would reduce total electricity consumption by 20 percent by 2020, compared to a "Reference" scenario, a forecast based on the Energy Information Administration's *Annual Energy Outlook*, that includes national efficiency policies and programs.

It is important to note that in addition to the Reference and Best Practices scenarios, WGA included a "Current Activities" scenario that estimates the impact of efficiency measures enacted by 2005 within the WGA region at the state, regional, local and utility levels. (The report was commissioned in February 2005.) This scenario's estimated savings accounts for nearly half of the 20 percent cut in consumption in the Best Practices total (**Exhibit 23-4**).[36] Naturally, any efficiency programs initiated since 2005 (such as those included in Texas legislation described below) are not included in the Current Activities estimates.

The WGA report also examined the major barriers and market failures that limit or prevent greater investment in energy efficiency improvements, as does the *National Plan for Energy Efficiency*, a 2006 EPA report that said energy efficiency "remains critically underutilized in the nation's energy portfolio."[37] Barriers to achieving efficiency savings and other benefits are discussed later in this chapter.

An increase in interruptible electricity supplies, whereby companies allow their power to be cut for brief times in exchange for price breaks, would help reduce the demand for new capacity.

Recent Texas Legislation

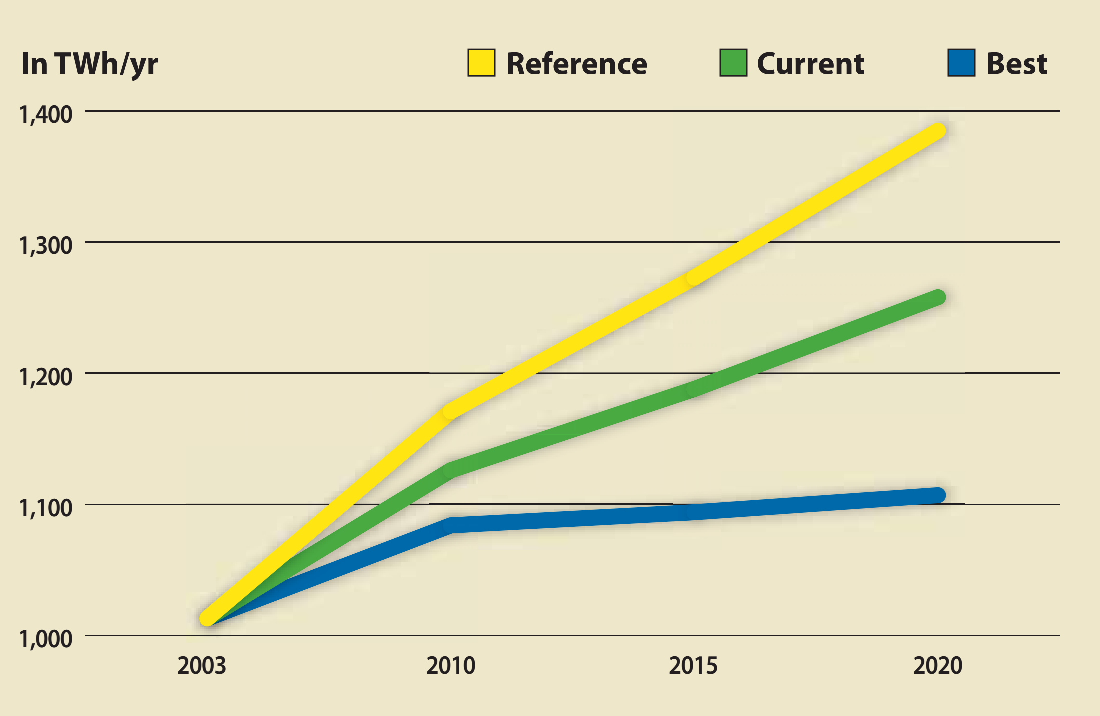
In June 2007, the Texas Legislature approved House Bill 3693, "relating to energy demand, energy load, energy efficiency incentives, energy programs, and energy performance measures," to implement some of the recommendations included in the efficiency reports discussed above. Among numerous other efficiency measures, H.B. 3693 requires electric utilities to run energy efficiency incentive programs that will "acquire additional cost-effective energy efficiency equivalent to" 15 percent of annual residential and commercial demand growth by the end of 2008. This requirement, which went into effect in September of 2007, increases to 20 percent by the end of 2009. Thus, the state's energy efficiency portfolio standard is being increased from the current 10 percent to 20 percent over the course of two and one third years. This increase is undoubtedly a result of the ease with which the utilities' efficiency programs met and exceeded the energy reduction goals of the original EEPS.

It is important to note, however, that the H.B. 3693 efficiency requirements apply to residential and commercial electricity only and do not include industrial electricity use, which has been subject to the standard set forth in S.B. 7. Texas' industries account for about 30 percent of the electricity consumed in the state; the ACEEE report estimated that the industrial sector could cut that consumption by about 26 percent by adopting a set of efficiency measures ACEEE found to be cost-effective. More than 70 percent of this savings potential is due to measures that cost three cents or less per kilowatt-hour of energy saved.

The PUC established the rules for implementing H.B. 3693 in March 2008 after taking public input from interested parties. The rules exclude the utilities' industrial customers from eligibility for efficiency programs except for programs that will be completed by the end of 2008. The utilities also are allowed to add qualified industrial customers to programs that started before May 1, 2007, in order to maintain participation levels in those programs.[38] Otherwise, as the statute now stands, industrial electricity demand growth will no longer be subject to efficiency savings requirements and that sector of the savings potential will

Exhibit 23-4

Electricity Consumption in the Western Governors' Association States by Scenario



Source: Western Governors' Association.

not be realized unless industry initiates efficiency efforts on its own. Industrial facilities have an incentive to cut energy costs and one way to do so is to implement efficiency programs, but since they are not included in the new law, they will not have access to the financial incentives that utilities provide to their customers to meet the EEPS goals.

To counteract the effect of the disincentive on utilities for investing in efficiency programs and thus selling less electricity, PUC developed new rules to ensure that the costs of these programs can be passed on to the customers who will receive the benefit of efficiency improvements. This included the creation of an "energy efficiency cost recovery factor" so that utilities can recoup the expenditures; this factor will be monitored and, if necessary, adjusted yearly to be sure that no "over-recovery of costs" occurs.

H.B. 3693 also directs PUC to study whether further increases in these targets (to 30 percent before 2011 and 50 percent by the end of 2015) are achievable. Again, it should be noted that these percentages do not include the industrial sector's electricity consumption and demand (but do apply to electricity use in the entire state).

H.B. 3693's utility mandates apply only to investor-owned utilities (IOUs) and not to municipally owned utilities or electric cooperatives, although "munis" that sold more than 500,000 megawatt-hours (MWh) of electricity in 2005 are required to have and to report on "energy savings incentive programs." Coops must "consider adopting" such programs, and those with sales of more than 500,000 MWh in sales in 2005 must also report on the effects of their "energy efficiency activities."[39] The ACEEE report specifically mentioned the municipal and cooperative exemption from the existing EEPS requirements and recommended that "all [sectors] should contribute to meeting the state's needs."[40]

H.B. 3693 has other goals, such as reducing consumption by state agencies, higher education institutions and school districts by 5 percent each fiscal year for six years; requiring efficient lighting and vending machines; and establishing efficiency standards for new residences built with public funding assistance.[41] The bill's requirements should reduce demand growth significantly.

Another piece of legislation that passed in 2007 is H.B. 3070, creating an advisory committee to study how to rate the energy efficiency of homes, new or existing, going up for sale. The rating process would also provide information on improvements that could be made and how they would change the efficiency rating, and the rating would be included in the real estate listing for the home.

The committee is also charged with studying how to educate both homebuyers and lenders (mortgage brokers and financial institutions) on energy efficiency mortgages, in an effort to make them more available. These mortgages have monetary advantages for borrowers based on the fact that the loans on efficient homes carry less risk because the homes cost less to operate. Finally, the committee is to determine whether having information about the energy efficiency of homes be part of the real estate market is likely to lead to more efficient residences. The report is due October 1, 2008.[42]

COSTS AND BENEFITS

Efficiency improvements can be considered as investments, with upfront costs and some level of return in terms of savings or avoided costs. Research indicates that efficiency is very cost-effective. The WGA report found that most of the energy efficiency programs in its region are "saving electricity at a total cost of 2-3 cents per kWh saved." In addition, it estimates that, in WGA's 18 states, the savings in electricity costs to the residential, commercial and industrial sectors by 2020 under the Best Practices scenario would be $9 billion, $11 billion and $1 billion, respectively.[43]

These savings are not, of course, spread evenly among the states, and two of the states merit a closer look. California holds nearly half of all the potential electricity savings from the Current Activities scenario, due to its large electricity demand and aggressive efficiency policies. Its savings under Best Practices, however, are barely over a quarter of the total because many of those practices are already California programs. Texas, on the other hand, would see its portion of the region's electricity savings rise from about 20 percent with current policies to 31 percent with adoption of the best practices, providing the largest amount of additional savings.

Efficiency improvements can be considered as investments, with upfront costs and some level of return in terms of savings or avoided costs.

In all, WGA claims that the net economic benefit over the 15-year period (2005-2020) would outweigh costs by 2.4 times under Current Activities and 2.5 times with Best Practices.[44] The *Power to Save* report included a cost-benefit analysis of efficiency savings that found a $4.40 return for every dollar invested.[45]

The ACEEE report calculated that the efficiency policies it recommends (not including demand response programs) would cost $29.6 billion by 2023; if incentive programs were added to ensure reaching the highest efficiency savings, the total cost would be $34.4 billion. Of this total, however, only around a quarter, or $8.6 billion from 2008 to 2023, represents public funding for incentives and program and administration costs. The remainder of the cost is paid by electricity consumers, as an investment that returns savings in energy costs. This investment would save a cumulative 672,825 million kWh. (This includes savings only from 2008 through 2023, not beyond.) The report points out that the Texas average retail electricity cost was 9.1 cents per kWh in 2005. Thus, the avoided expense of the electricity alone would be roughly $61.2 billion; if total program costs (including incentives) are subtracted, savings from avoided electricity costs alone would total $26.8 billion.[46]

Transportation efficiency efforts have primarily focused on improving mileage.

This basic calculation does not take into account any of the additional economic impacts that were explored in a follow-up report from ACEEE, *The Economic Benefits of an EE/RE Strategy in Texas*. The report includes job growth (because of savings spent outside the electric utility sector, which has a low employment coefficient), lower electricity prices and reduction of air pollution (and carbon emissions) as side-effects of investments in and savings from energy efficiency and renewable energy that would benefit the Texas economy.[47]

Some analysts, however, dispute the savings projections of the various sources pushing for increased efforts for energy efficiency, and disagree with an approach that includes government mandates for reduced energy consumption and the incentives and subsidies that often accompany them. Critics point to higher consumer costs for more energy-efficient products and reduced choices that can result from regulations such as appliance efficiency standards. One analyst with the Competitive Enterprise Institute claimed that "measures enacted in the name of energy efficiency … have accomplished nothing," and asserted that "a quarter century of federal energy-efficiency mandates has increased, not decreased, total energy use." The reasoning behind this assertion is that consumers with energy efficient vehicles or appliances might tend to use them more: more driving if in a fuel-efficient car; a bigger (or second) refrigerator if it costs less to operate; or higher thermostat settings on an energy-efficient heater.[48]

Others simply believe that mandates are not the most cost-effective way to achieve higher levels of energy efficiency and can even stifle innovation. Some advocate for the power of the marketplace to provide incentives for improved efficiency without the "unintended consequences" of government regulations.[49] And there are those who believe that there is a "simple, elegant and cost-effective way" to increase energy efficiency – "make energy more expensive [through] a carbon tax."[50] These differing viewpoints about government intervention, costs of mandates, publicly funded programs, market distortions and effective means of reaching even a common goal are not unique to the issue of energy efficiency.

TRANSPORTATION EFFICIENCY

Given that 28.5 percent of the U.S.'s energy is used for the transportation of people and goods, higher efficiency in the transportation sector has the potential for significant energy savings. Road vehicles use about three-quarters of transportation-related energy, with more than 58 percent of it used by cars and light trucks.[51] This, of course, represents enormous expenditures for fuel as well as vehicle maintenance and roadway construction.

Transportation efficiency efforts have primarily focused on improving mileage — traveling more miles on each unit of fuel. Other factors come into play, however; the purpose of transportation, after all, is not to move the vehicle some distance, but rather to move its contents. The density of a vehicle's load, whether it is goods packed in a semi-trailer or passengers in a car or bus, determines its overall efficiency.

Public Transportation

Cars and light trucks accounted for 17.8 percent of all U.S. energy use in 2005, and road congestion in urban areas costs the nation billions of dollars each year in lost productivity and added fuel costs.[52]

Shipping Efficiency

Efforts to improve transportation efficiency involve many facets of modern life. Consider, for example, the packaging of goods and its effect on shipping "density" — that is, how many units fit into a shipping container.

Hewlett-Packard ships a variety of electronic equipment around the world and pays considerable attention to the way its products are packaged. The company has described examples of how that attention pays off:

> Improved packaging can…bring benefits in product transportation. For example, we reduced the weight of our standalone camera packaging from 396g/unit in 2003 to 164g/unit in 2006. The smaller size allowed us to increase the number of units per pallet from 200 to 720, which translated into less energy required to ship each item. … In 2005, HP developed the ROSe (Robust Orientation Size effect) calculator to help engineers develop packaging designs that minimize the amount and cost of materials used. ROSe also optimizes packaging for more efficient loading on pallets and trucks, based on product size, weight, the required protection level and the arrangement of the pack contents. For example, we reduced the quantity of packaging materials by 20% per unit for one category of PCs shipped from China, while increasing the number of PCs per pallet from 28 units to 40 units. The energy required to ship each unit fell by 40%.[53]

Any discussion of transportation efficiency and conservation, then, would be incomplete without considering the potential benefits of public transit.

The Texas Transportation Institute's (TTI's) *2007 Urban Mobility Report* documents some of these benefits. The report examined traffic congestion in 85 major U.S. cities and gathered traffic data for all 437 urban areas in the country. Overall, the report shows that the problems of congestion and its costs, are growing everywhere.

According to TTI, the amount of fuel "wasted" due to road congestion amounted to 2.9 billion gallons in 2005. This results from the time delays on the road, which totaled 4.2 billion hours that year; together these effects cost the nation $78 billion. Without existing public transportation systems, however, it would have been worse. TTI calculates that transit travel in 2005 prevented 541 million hours of delay and saved $10.2 billion in congestion costs.

The TTI report emphasizes that there is no one solution to traffic congestion because congestion is not *one* problem. It offers a set of approaches to reducing congestion and recommends consideration of all of them, acknowledging that solutions will be different for different locations. Three of the six categories of solutions TTI recommends — adding capacity in critical corridors, providing choices and diversifying land development patterns — include potentially expanding public transportation. According to TTI, public transportation service, particularly in the most congested urban areas, provides "substantial and increasing benefits."[54]

Just as with major roads and highways, expanding existing transit systems is an expensive and time-consuming proposition and building new systems is even more so. These costs must be carefully weighed against the potential benefits. In combination with other measures, as recommended by TTI, public transportation can be an effective way to increase transportation efficiency and also reduce some of the detrimental effects of our energy-intensive ground transportation system.

Fuel Economy

The federal Corporate Average Fuel Economy standards, introduced in response to the 1973 oil crisis, are designed to reduce gasoline consumption and our dependence on foreign oil. The definition of CAFE is "the sales weighted average fuel economy, expressed in miles per gallon (mpg), of a manufacturer's fleet of passenger cars or light trucks with a gross vehicle weight rating of 8,500 lbs. or less, manufactured for sale in the United States, for any given model year."

CAFE testing is the responsibility of the U.S. Environmental Protection Agency, which provides the stickers displayed on new vehicles reporting the gas mileage that can be expected from them. The original goal for the standards, which became law in 1975, was to double the 1974 sales-weighted average fuel economy of passenger cars to 27.5 mpg by 1985. This is also the current CAFE standard for cars through the 2007 model year. Light trucks have had separate and distinct fuel standards since 1979; for the 2007 model year, the truck standard is 22.2 mpg.

If a manufacturer's fleet fails to meet the average fuel economy standard, it can be charged a penalty of $5.50 per each tenth of a mile per gallon under the standard multiplied by the number of vehicles (cars or trucks) made in that model year. Automakers are allowed, however, to offset their penalties in the previous three years or in the next three years with credits earned by exceeding the CAFE target; the credits cannot be transferred between car and truck fleets, or between manufacturers.[55]

Several recent studies and reports have analyzed the effect of the CAFE standards, as well as the potential impact of raising them. In 2001, for instance, Congress asked the National Academy of Sciences to study the standards with the assistance of the U.S. Department of Transportation (DOT). The study concluded that the program "has clearly contributed to increased fuel economy of the nation's light-duty vehicle fleet," and that in their absence, gasoline use would have been "about 2.8 million barrels per day greater than it [was in 2001]." The academy recommended that the federal government continue to "ensure fuel economy levels beyond those expected to result from market forces alone," while acknowledging the "difficult trade-offs," involving costs, environmental benefits, safety, oil imports and consumer choice, that policy would require.[56]

CBO assumes a 2 percent increase in miles driven for a 10 percent improvement in average miles per gallon.

Since that study, fuel efficiency goals have continued to generate policy proposals. A 2002 Congressional Budget Office (CBO) study weighed the potential effects of increasing the CAFE standards against two alternative policies: raising the federal gas tax and establishing a "cap and trade" system on carbon emissions from gasoline.

Under the cap and trade proposal, the government would set a limit or "cap" on the amount of carbon dioxide emissions that could be emitted by gasoline nationwide. A federal agency (probably EPA) would issue "emission allowances" for that limit. Gasoline manufacturers would receive these allowances for the emissions of the gasoline they sell, and would be able to trade, buy or sell those allowances amongst themselves.

CBO concluded that all three policy options would reduce gasoline consumption, but would produce different consequences. Specifically, CBO found that higher CAFE standards would not be as "cost-effective" as a higher gas tax or a cap and trade program because the focus on fuel economy of vehicles does not bring about gas-saving changes in driving behavior. In fact, researchers find that improved fuel efficiency can result in more miles driven; based on other research, CBO assumes a 2 percent increase in miles driven for a 10 percent improvement in average miles per gallon. CBO's definition of cost-effectiveness is "keep[ing] losses in producers' profits and consumers' welfare to a minimum for any given level of gasoline savings." This definition of cost-effectiveness does not, CBO admits, include consideration of externalities by weighing costs against additional benefits of reduced gasoline use, such as reduced pollution and carbon emissions.[57]

More recently, a July 2007 report from the National Petroleum Council (NPC), noted that although the cars and trucks produced now are more "technically" efficient than those dating from the inception of the CAFE standards, this efficiency has not been used to increase fuel economy. Instead, the industry has made larger, heavier and more powerful vehicles with a number of energy-consuming features. NPC calls for a "doubling of fuel economy of new cars and light trucks by 2030 [which is] possible through the use of existing and anticipated technologies." In fact, the report recommends using increased energy efficiency to moderate demand as the first of its five U.S. energy policy strategies.[58]

On December 19, 2007, President Bush signed the Energy Independence and Security Act which requires that the CAFE standard for light-duty vehicles be increased to 35 mpg by 2020.[59]

ENVIRONMENTAL IMPACT

Efficiency, as an energy resource, has a unique impact on the environment, compared to other energy sources. Efficiency is not just benign in its environmental impact; reducing energy use through efficiency has clear and, in some cases, measurable environmental benefits. Cutting air pollution is perhaps the most obvious benefit of improved efficiency in transportation and electricity use. Others include reduced carbon emissions, less transportation of fuels and reduced need for additional power plants — in sum, every form of environmental impact caused by using energy can be lessened by reducing energy use through greater efficiency.[60]

BARRIERS TO EFFICIENCY

The National Action Plan for Energy Efficiency notes that underinvestment in efficiency programs is due to known barriers that include:

- *market barriers,* such as the well-known "split incentive" barrier, which limits home builders' and commercial developers' motivation to invest in energy efficiency for new buildings because they will not be paying the energy bill;

- *customer barriers,* such as a lack of information on energy-saving opportunities, or a lack of funding to invest in energy efficiency; and

- *public policy barriers,* such as statutes and regulations that provide disincentives for utility support of and investment in energy efficiency.[61]

Overcoming these barriers can be difficult for policy-makers. Educating the public, including business and industry, about the environmental (and economic) benefits is an obstacle. Nonetheless, the growing concern about climate change presents an opportunity to meet that challenge.

OUTLOOK FOR TEXAS

The state of Texas has, over the years, enjoyed some of the lowest energy prices in the nation, helping to fuel economic growth and building an industrial base with a national, even global impact. The abundance and relatively low cost of energy supplies fostered a climate where reducing energy use was not considered a priority. In today's world, with consideration of numerous factors such as higher prices, energy security and environmental and climate impacts, energy efficiency is viewed by many as an attractive and low-cost energy resource. Texas has a large, untapped reservoir of this resource available. While the actual numbers associated with

Texas Industries of the Future

One barrier to implementation of efficiency measures is the intense competition between companies within certain industries, which can act to compound a lack of access to complete information about energy-saving practices. In Texas, where industry accounts for half of all the state's energy use, the potential for savings is large. To help overcome the obstacles to information sharing, Texas Industries of the Future was established in 2001 with grant funding from the U.S. Department of Energy (DOE) through a contract with the State Energy Conservation Office.

The purpose of the Texas Industries of the Future program is to facilitate the development, demonstration and adoption of advanced technologies and adoption of best practices that reduce industrial energy usage, emissions, and associated costs, resulting in improved competitive performance. The bottom line for Texas industry is savings in energy and materials, cost-effective environmental compliance, increased productivity, reduced waste and enhanced product quality.

The state program, managed by the University of Texas at Austin, leverages the programs and tools of the DOE's Industrial Technologies Program (ITP), which focuses on energy intensive industries. These tools include access to technology resources of the national laboratories and to information and training on ITP's national Best Practices. In Texas the initial focus has been primarily on the chemical manufacturing and refining industries, as well as the forest products and biomass sectors, because these account for 86 percent of the industrial energy use in Texas.

Texas Industries of the Future brings benefits for the state, the economy and the environment. The program builds partnerships among the industry, university and government sectors to target and solve pressing technological problems within and across key industries. It also provides a forum for identifying longer-term technology issues of interest to Texas industries and positions Texas to successfully compete for national funding of technology research and demonstration and commercialization projects.

A closely related program, also from ITP, is the "Save Energy Now" program, initiated in 2006, in which experts from DOE assess industrial plant operations and identify opportunities for saving energy. There also is follow-up for these assessments to check for implementation of energy-saving practices and quantify the savings achieved. In April 2008, Texas Industries of the Future recognized a dozen "Saver" industries and three "Champion" industries in Texas that saved a total 1.1 trillion Btu of energy through the Save Energy Now program.

estimates of efficiency potential may be debatable, the fact that the potential exists is not in dispute. Texas, once again, finds itself in the enviable position of having a big energy resource to develop, given the determination to do so.

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CHAPTER 24

Overview: Energy Uses

The chapters in the preceding sections of this report examine the potential of various resources to meet Texas' energy needs. The chapters of this section will discuss energy uses and their implications.

Throughout human history, the control, storage and use of energy has helped people survive, improved their quality of life and advanced civilization. For thousands of years before the industrial revolution, our energy use was modest and production was simple. For heat, we relied on the sun or burned organic materials such as wood and straw. For transportation, people walked, animals pulled carts and wind pushed boats across the water. For labor, animals performed the work we could not, and wind and water powered simple machines.

In the eighteenth century, with the perfection of the steam engine, the world began to understand the power of machines. Steam-driven machines could do the work of hundreds of men and dozens of animals. Coal became the fuel of choice for steam-powered machines because it was convenient, portable and readily available, and burned efficiently. Soon coal was powering locomotives, factories and farm implements around the nation. Coal was also used to heat buildings and smelt metal ores. In 1880, a coal-fired steam engine powered the world's first electric generator, Thomas Edison's plant in New York City.

In the latter part of the 1900s, petroleum came to prominence as a cheap, reliable fuel. When Henry Ford created the assembly-line method of mass production for the Model T, cars became available to the general public and petroleum use skyrocketed. And with low-cost automobiles and the spread of electrification, our society changed significantly.

Power plants became larger, and transmission lines extended hundreds of miles between cities, bringing electricity to rural areas. Energy use rose quickly, doubling every 10 years from the early 1900s through 1970. During this time, the cost of energy production declined steadily, and the efficient use of energy was rarely a concern.[1]

ENERGY USE TODAY

Energy is used in four distinct sectors: transportation, industry, residential and commercial use and electric power generation. Three major types of energy are consumed by these four sectors: direct heat, transportation fuel and electricity.

Direct heat use is the burning of combustible materials to heat buildings, cook food and transform raw materials by melting them and combining them to make finished products. *Transportation fuel* is used to power vehicles. *Electricity* is used to provide heat, power and light to industry, homes and businesses.

Exhibit 24-1 shows the amount of direct heat, transportation fuel and electricity used in the U.S. for 2000 through 2006.[2]

Exhibit 24-2 shows the amount of direct heat, transportation fuel and electricity used in Texas for 2000 through 2005.[3]

Energy production today continues to be dominated by non-renewable sources. Petroleum, natural gas, coal and nuclear power account for about 93 percent of all energy production.[4] The use of renewable energy sources, however — including conventional hydroelectric power, wood and waste, ethanol blended into motor gasoline, geothermal, solar and wind power — has grown steadily, from 5.52 quadrillion Btu in 2001 to 6.79 quadrillion Btu in 2006.[5]

The U.S. Department of Energy (DOE) expects total U.S. energy consumption to increase by 1.2 percent annually from 2003 through 2030.[6] Transportation fuel is expected to decline by 0.3 percent, while electricity consumption is projected to grow at a rate of 0.7 percent during 2008. EIA is expecting demand for transportation fuel to increase by 0.9 percent in 2009 and electricity demand to increase to 1.3 percent in 2009.[7] Texas,

Energy production today continues to be dominated by non-renewable sources.

EXHIBIT 24-1

Types of Energy Used for the U.S., 2000-2006, In Trillions of British Thermal Units (Btu)

Year	Direct Heat Use	Transportation Fuel	Electricity	Other*	Total
2000	34,267	26,492	38,214	2	98,975
2001	32,751	26,215	37,366	-6	96,326
2002	32,895	26,787	38,171	5	97,858
2003	33,067	26,928	38,218	-3	98,210
2004	33,655	27,820	38,876	0	100,351
2005	32,638	28,249	39,799	6	100,692
2006**	31,916	28,313	39,653	-10	99,872

*Other is a balancing item, the total energy consumption does not equal the sum of the three energy use components due to the conversion factors for natural gas and coal.
**Preliminary data.
Source: U.S. Energy Information Administration.

EXHIBIT 24-2

Types of Energy Used for Texas, 2000-2005 In Trillions of British Thermal Units (Btu)

Year	Direct Heat Use	Transportation Fuel	Electricity	Total*
2000	5,982	2,566	3,524	12,072
2001	5,798	2,677	3,426	11,901
2002	6,134	2,780	3,489	12,403
2003	6,247	2,664	3,425	12,336
2004	5,802	2,701	3,467	11,970
2005	5,289	2,730	3,539	11,558

*Totals have been rounded to nearest whole number.
Source: U.S. Energy Information Administration.

with its growing population and large industrial sector, is expected to meet or exceed the national pattern.

ENDNOTES

[1] Union of Concerned Scientists, "A Short History of Energy," http://www.ucsusa.org/clean_energy/fossil_fuels/a-short-history-of-energy.html. (Last visited April 8, 2008.)

[2] U.S. Department of Energy, Energy Information Administration, Annual Energy Review (AER), Table 2.1a Energy Consumption by Sector, 1949–2006, http://www.eia.doe.gov/emeu/aer/consump.html, (Last visited April 9, 2008.)

[3] U.S. Department of Energy, Energy Information Administration, State Energy Consumption, Price, and Expenditure Estimates (SEDS), Texas Energy Consumption Tables, 1960–2005, http://www.eia.doe.gov/emeu/states/state.html?q_state_a=tx&q_state=TEXAS, (Last visited April 9, 2008.)

[4] U.S. Energy Information Administration, "Energy Basics 101," http://www.eia.doe.gov/basics/energybasics101.html. (Last visited April 9, 2008.)

[5] Figures drawn from U.S. Information Administration, Annual Energy Review 2001 (Washington. D.C., November 2002), p. 3, http://tonto.eia.doe.gov/FTPROOT/multifuel/038401.pdf, and U.S. Information Administration, Annual Energy Review 2006 (Washington. D.C., June 2007), p. 3, http://tonto.eia.doe.gov/FTPROOT/multifuel/038406.pdf. (Last visited April 9, 2008.)

[6] U.S. Energy Information Administration, "Table A1: World Total Energy Consumption by Region, Reference Case, 1990-2030," http://www.eia.doe.gov/oiaf/ieo/pdf/ieoreftab_1.pdf. (Last visited April 9, 2008.)

[7] U.S. Energy Information Administration, "Short-Term Energy Outlook," http://www.eia.doe.gov/emeu/steo/pub/contents.html. (Last visited April 9, 2008.)

CHAPTER 25
Direct Heat

INTRODUCTION

For most of human history, fire was mankind's main source of energy. Today, much of the energy we use comes from what are considered secondary sources: the heat generated from burning combustible materials is used to generate energy, typically in the form of electricity or transportation fuels. In addition to these secondary sources, however, heat is still used as a direct source of energy. This chapter examines the direct use of burning materials to produce energy for heat and manufacturing.

FUEL SOURCES AND USAGE

In 2005, 32.6 quadrillion British thermal units (Btu), or approximately 32 percent of all energy used nationwide, could be attributed to the burning of combustible materials to produce heat for direct use. The raw materials burned for direct uses include natural gas, liquefied petroleum gas (LPG), heating oil, kerosene, wood, biomass (waste products) and coal. In addition to these raw materials, geothermal energy, or heat produced from deep within the Earth's crust, also is used directly.[1]

Household and Commercial Buildings

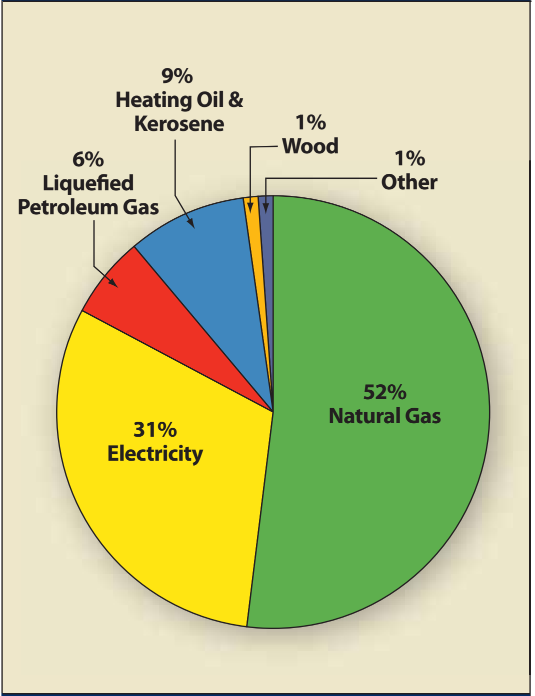
In 2005, about 6.9 quadrillion Btu of direct-use energy was used to heat homes in the U.S.; another 4.1 quadrillion Btu were used to heat commercial buildings.[2]

According to the U.S. Energy Information Administration (EIA), 69 percent of the nation's 108 million households were heated by direct-use energy (natural gas, heating oil or propane); the remaining 31 percent of homes were heated by electricity (**Exhibit 25-1**).[3]

In 2005, Texans used about 237.4 trillion Btu of direct-use energy to heat homes and another 190.4 trillion Btu to heat commercial buildings.[4]

EXHIBIT 25-1

U.S. Home Heating, 2005



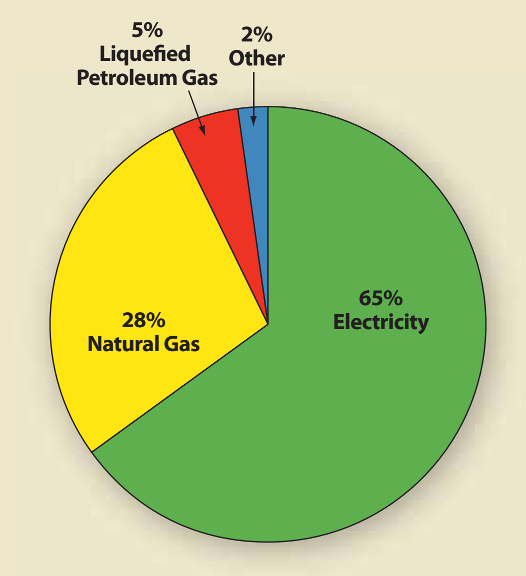
Source: U.S. Energy Information Administration.

In the same year, according to EIA, 33 percent of Texas' 8 million-plus homes were heated by natural gas or LPG (primarily propane); 65 percent were heated by electricity; and the remaining 2 percent of homes were heated by other sources such as wood and solar and geothermal energy (**Exhibit 25-2**).[5]

Natural gas and LPG, which provide the majority of the state's direct-use energy, are regulated by the Federal Energy Regulatory Commission (FERC) at the national level and by the Railroad Commission of Texas (RRC) at the state level, as FERC's designee.[6]

EXHIBIT 25-2

Texas Home Heating, 2004



Source: U.S. Energy Information Administration.

Manufacturing

The majority (68 percent nationally) of all direct-use energy is used in the industrial sector, to manufacture raw materials into finished products. Industries heat raw materials to the melting point to combine them with something else or simply to change them into a finished product. Products including chemicals, plastics, metals, food and glass all are made or changed through heating. In 2005, the nation used 21,653 trillion Btu of direct-use energy to turn raw materials into finished products.[7]

In 2002, the most recent data available for end uses or finished products, the industrial sector used 21,893 trillion Btu of direct-use energy to produce a wide variety of products (**Exhibit 25-3**).[8]

In Texas, the industrial sector used 4,756.2 trillion Btu of direct-use energy in 2005. This energy came primarily from the combustion of natural gas and petroleum (**Exhibit 25-4**).[9]

EXHIBIT 25-3

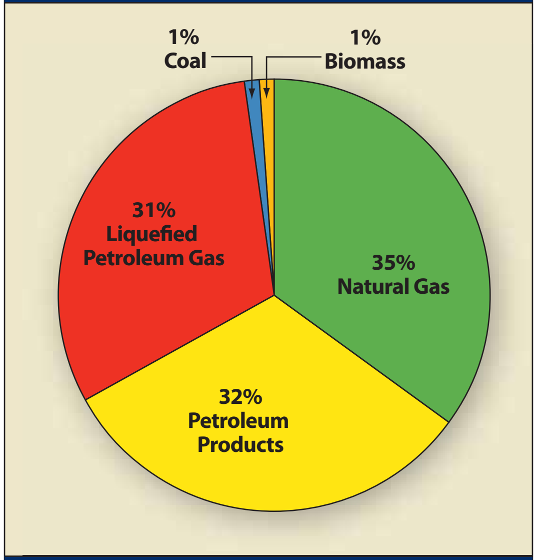
End Uses for Direct-Use Energy In the Manufacturing/Industrial Sector 2002

End Use	Amount of Direct Energy Use in Trillion Btus	Percentage of Total Direct Energy Use
Food, Beverage and Tobacco Products	1,728	7.9%
Textile Mills and Products	469	2.1
Wood Products, Furniture and Related Products	629	2.9
Paper, Printing and Related Products	3,000	13.7
Petroleum and Coal Products	3,454	15.8
Chemicals	4,803	21.9
Plastics, Rubber Products and Other Nonmetallic Mineral Products	2,038	9.3
Primary Metal and Fabricated Metal Products	3,806	17.4
Computers, Electronics, Electrical Equipment, Appliances and Components	656	3
Machinery and Transportation Equipment	1,106	5
Miscellaneous	204	1
Total	21,893	100%

Source: U.S. Energy Information Administration.

EXHIBIT 25-4

Percentage of Direct Use Energy by Fuel Source in the Texas Industrial Sector, 2005



Source: U.S. Energy Information Administration.

TRENDS AND OUTLOOK

Between 1980 and 2006, U.S. direct-use energy consumption by the residential sector fell by 14 percent; the commercial sector by 4 percent; and the industrial sector by 5 percent.[10] These reductions were made possible by advances in efficiency, conservation and a gradual shift from direct-use energy to energy provided through electricity. According to EIA, overall energy demand will increase by 0.7 percent per year through 2030; direct-use energy in the residential, commercial and industrial sectors is projected to stay flat or slightly decrease.[11]

ENDNOTES

[1] U.S. Energy Information Administration, "Energy Consumption by Sector: Table 2.1a, Energy Consumption by Sector, 1949-2006," http://www.eia.doe.gov/emeu/aer/consump.html. (Last visited April 10, 2008).

[2] U.S. Energy Information Administration, Table 2.16, "Residential Sector Energy Consumption, 1949-2006," http://www.eia.doe.gov/emeu/aer/txt/ptb0201b.html. (Last visited April 10, 2008.)

[3] U.S. Energy Information Administration, "Energy Consumption by Sector: Table 2.7, Types of Heating in Occupied Housing Units, 1950-2005," http://www.eia.doe.gov/emeu/aer/consump.html. (Last visited April 10, 2008.)

[4] U.S. Energy Information Administration, Table 8, "Residential Sector Energy Consumption Estimates, 1960-2005, Texas," http://www.eia.doe.gov/emeu/states/sep_use/res/use_res_tx.html. (Last visited April 11, 2008.); U.S. Energy Information Administration, Table S5, "Commercial Sector Energy Consumption Estimates, 2005," http://www.eia.doe.gov/emeu/states/sep_sum/html/sum_btu_com.html.

[5] U.S. Energy Information Administration, Table S4, "Residential Sector Energy Consumption Estimates, 2005," http://www.eia.doe.gov/emeu/state/sep_sum/html/sum_btu_res.html. (Last visited April 11, 2008.)

[6] Texas Railroad Commission, "Q & A Regarding Natural Gas Prices," http://www.rrc.state.tx.us/divisions/gs/rap/gsrap.html. (Last visited April 11, 2008.)

[7] U.S. Energy Information Administration, "Energy Consumption by Sector: Table 2.1a, Energy Consumption by Sector, 1949-2006," http://www.eia.doe.gov/emeu/aer/consump.html. (Last visited April 10, 2008.)

[8] U.S. Energy Information Administration, "Table 2b: End Uses of Fuel Consumption for Selected Industries, 1998 and 2002," http://www.eia.doe.gov/emeu/efficiency/mecs_trend_9802/mecs9802_table2b.html. (Last visited April 10, 2008.)

[9] U.S. Energy Information Administration, Table S6, "Industrial Sector Energy Consumption Estimates, 2005," http://www.eia.doe.gov/emeu/states/sep_sum/html/sum_btu_ind.html. (Last visited April 11, 2008.)

[10] U.S. Energy Information Administration, "Energy Consumption by Sector: Table 2.1a, Energy Consumption by Sector, 1949-2006."

[11] U.S. Energy Information Administration, "Annual Energy Outlook 2008 - Early Release" p. 6, http://www.eia.doe.gov/oiaf/aeo/index.html. (Last visited November 14, 2007.)

Chapter 26

Transportation

Introduction

The rapid and dependable transportation of people and materials from place to place is essential to modern American society and to Texas.

Since Henry Ford perfected the assembly line process for manufacturing in 1908, making autos affordable for the average person, Americans have come to rely on personal vehicles, freight systems, and air travel to meet transportation needs. In 2005, the U.S. accounted for 21.5 percent of the cars and 42.7 percent of the trucks and buses registered worldwide.[1]

In that year, Americans owned more than 240 million cars and light trucks.[2] Texans accounted for just over 20 million of these vehicles.[3] In addition another 5.2 million commercial vehicles — those weighing more than 10,000 pounds — use American roadways to transport people and goods. And Americans rely on more than 224,000 aircraft, about 53,000 boats and ships and hundreds of thousands of locomotives and railcars to reach places not served by roadways.[4] Nearly all of these vehicles are powered by gasoline or diesel derived from oil.

Fuel Sources and Usage

As America has become more reliant on personal vehicles for transportation, commercial air travel for personal and freight movement and trucking for freight, more and more of the nation's energy has been devoted to transportation. In 2006, the U.S. expended 28.4 quadrillion British thermal unit (Btu), or about 28.5 percent of all energy used nationwide, for transportation.

Transportation's share of the nation's total energy usage has risen steadily since 1973.[5] More than half of this increase can be attributed to a significant expansion in vehicle miles traveled (VMT). VMT per capita has risen substantially for travel other than the trip to work — increased highway travel, non-work trips and airline mileage.[6]

In 2005 (the most recent data available for both the U.S. and Texas), Americans used nearly 28.3 quadrillion Btu of fuel to transport people or goods from one place to another (**Exhibit 26-1**).[7]

Transportation's share of the nation's total energy usage has risen steadily since 1973.

Exhibit 26-1

U.S. and Texas Transportation Fuel Sources, 2005 (Trillion Btu)

Fuel Source	U.S. Amount of Fuel Used	Percent	Texas Amount of Fuel Used	Percent
Petroleum Products	27,301.6	96.5%	2,640.9	96.8%
Natural Gas*	626.3	2.2	85.4	3.1
Ethanol**	342	1.2	2.4	0.1***
Electricity	25.7	0.1	0.3	
Total	28,295.6	100.0%	2,729	100.0%

*Natural gas used in the transportation sector is consumed in the operation of pipelines, primarily in compressors and gas consumed as vehicle fuel.

**On the original EIA document, ethanol is listed twice: once as blended into motor gasoline and also separately, to display the use of renewable energy by the transportation sector.

***Ethanol and electricity used for transportation in Texas together account for 0.1 percent of all transportation fuel used in the state.

Source: U.S. Energy Information Administration.

Approximately 80.5 percent of all energy devoted to transportation in the U.S. was used on local roadways and highways; the other 19.5 percent was used for other forms of transportation, including air, water, railroads and other non-road vehicles (**Exhibit 26-2**).[8] Data on the amount of energy used on transportation modes in Texas was not available.

While motorized transportation helped build the U.S. into a global industrial power, its evolution has not been without drawbacks. The fuels used by most vehicles have an effect on human health and the environment, as discussed in previous chapters.

OIL PRODUCTION AND CONSUMPTION

As **Exhibit 26-1** illustrates, fossil fuels supply almost all of the energy used for transportation.

The U.S. Energy Information Administration (EIA) forecasts continued growth in U.S. demand for petroleum (**Exhibit 26-3**).

The nation's total petroleum consumption averaged 20.7 million barrels per day (bbl/d) in 2007, up 0.2 percent from 2006. For 2008 as a whole, EIA expects total U.S. oil consumption to average 20.6 million bbl/d. EIA expects gasoline consumption to increase by 0.9 percent in 2009.[9]

As consumption continues to climb, domestic production is expected to continue declining. In 2007, EIA estimates domestic crude oil production will average 5.1 million bbl/d, down from 5.14 million bbl/d in 2006 (**Exhibit 26-4**).[10]

While the early 1980s saw a brief increase in total U.S. oil production, Texas production has declined steadily since the 1970s (**Exhibit 26-5**).[11]

Declining production, along with supply disruptions due to regional conflicts around the world, weather and operating margins at U.S. refineries, all have pushed gasoline prices higher. EIA reports that regular grade gasoline prices averaged $2.81 per gallon in Texas in 2007 and they are expected to average $3.07 and $2.97 per gallon, respectively, in 2008 and 2009.

EIA projects that U.S. consumption of gasoline and diesel fuel will continue to rise, as the total miles traveled outweighs efficiency improvements and the slow change of the vehicle market to more fuel efficient vehicles. This will spur increasing

Approximately 80.5 percent of all energy devoted to transportation in the U.S. was used on local roadways and highways.

EXHIBIT 26-2

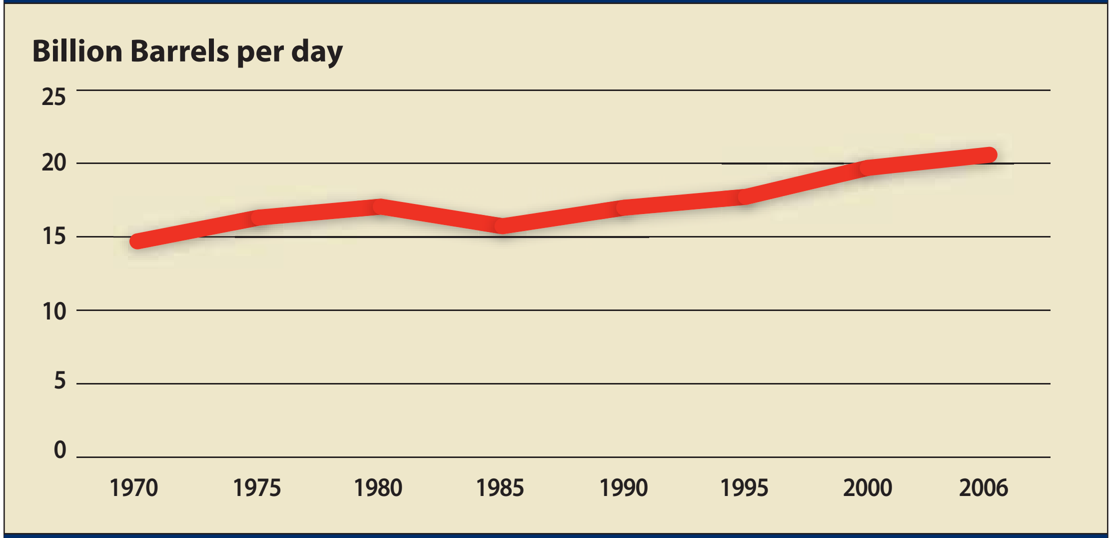
U.S. Transportation Energy Use by Mode*
In Trillions of Btu, 2005

Use by Mode	Amount of BTU Used	Percentage of Total
Highway	**22,042.7**	**80.5%**
Cars, Light Trucks & Motorcycles	17,275.1	63.1
Buses	190.7	0.7
Medium/Heavy Trucks	4,576.9	16.7
Non-Highway	**5,341.9**	**19.5%**
General, Domestic & International Aviation	2,476.6	9.0
Water	1,366.1	5.0
Pipeline	842.4	3.1
Rail	656.8	2.4
Highway & Non-Highway Total	**27,384.6**	**100.0%**

*Includes civilian consumption only.
Source: U.S. Department of Energy.

Exhibit 26-3

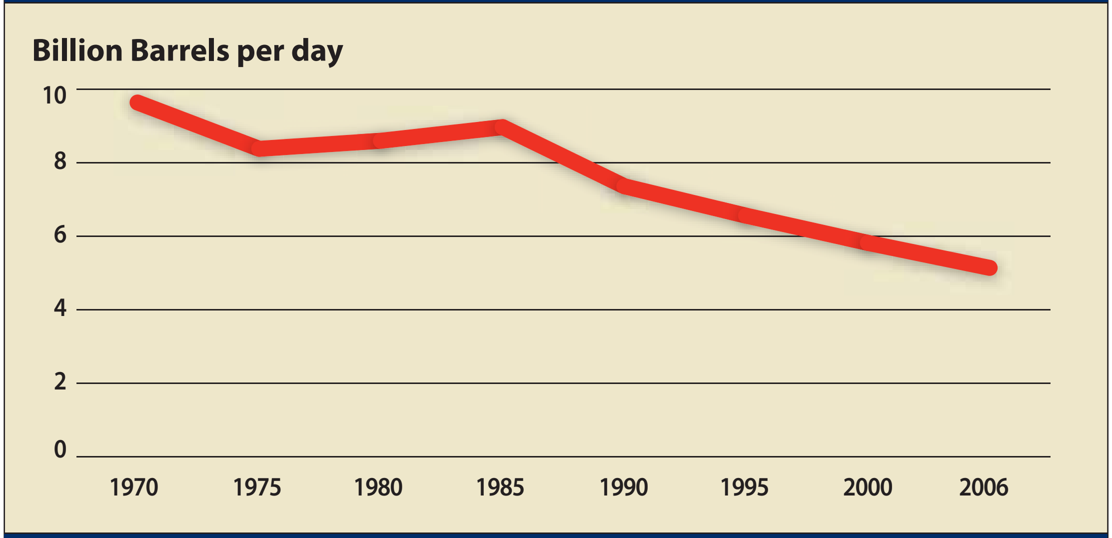
U.S. Petroleum Consumption



Source: U.S. Department of Energy, Transportation Energy Data Book.

Exhibit 26-4

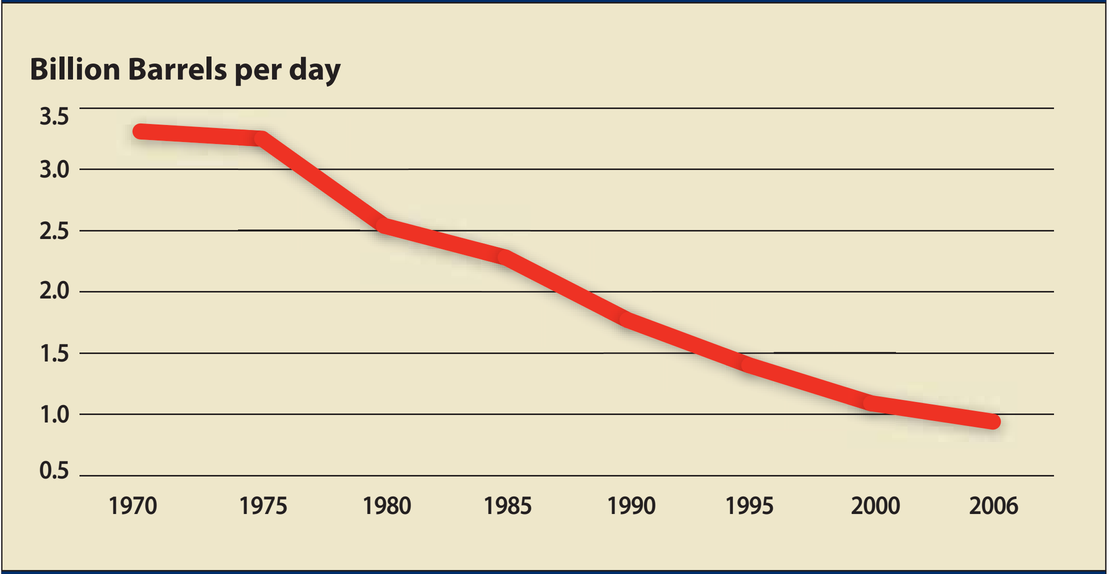
U.S. Crude Oil Production



Source: U.S. Department of Energy, Transportation Energy Data Book.

Exhibit 26-5

Texas Crude Oil Production



Source: Texas Railroad Commission.

The Energy Information Administration is projecting that energy use in the transportation sector will continue to grow at rates that are considerably larger than other sectors of the U.S. economy.

imports of crude oil and refined products over the next 25 years. EIA predicts that the current share of oil that is imported (60.3 percent) will rise to more than 61 percent by 2030.[12]

EIA is also projecting that energy use in the transportation sector will continue to grow at rates that are considerably larger than other sectors of the U.S. economy (**Exhibit 26-6**).

Light duty vehicle (cars and light trucks) travel is a significant contributor to this growth. EIA's 2008 projections assume that light duty vehicles' fuel economy standards will increase to only 30.0 miles/gallon, which is 4.7 miles/gallon above previous standards. Recent federal legislation, however, requires light duty vehicle standards to increase to 35 mpg by 2020, which could offset part of this growth.[13]

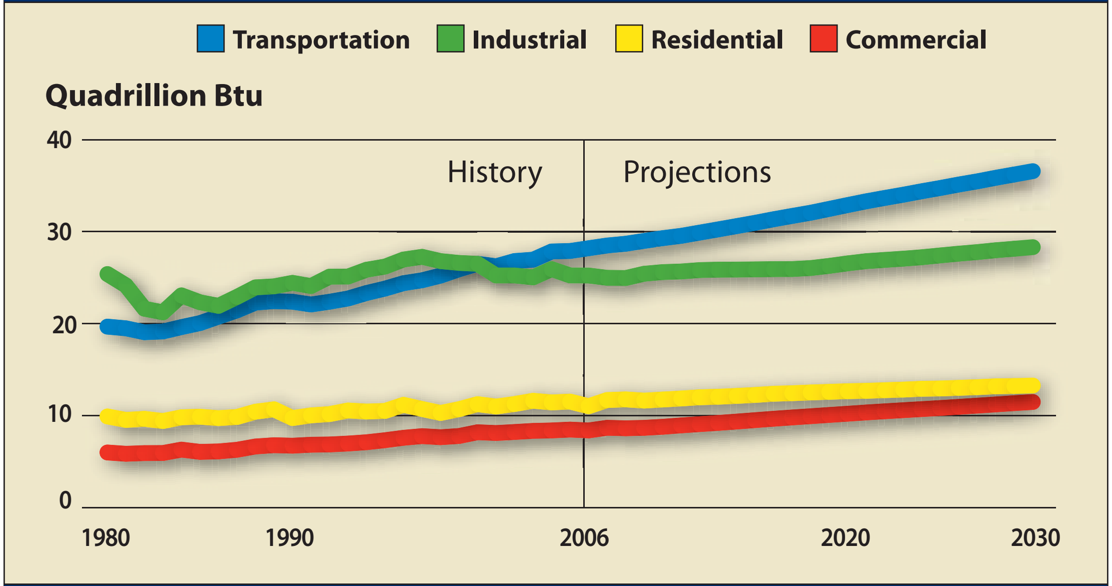
In 2004, world consumption of crude oil reached 82.6 million barrels a day. U.S. demand accounted for just over 25 percent of the total world demand. EIA estimates that total world oil consumption will rise by 1.4 million bbl/d in second-quarter 2007 (over the same quarter in the previous year). China and the U.S. remain the primary contributors to growth in world oil consumption. Preliminary data indicate that annual U.S. consumption rose by 200,000 bbl/d as of second-quarter 2007, while China's oil demand rose by an estimated 500,000 bbl/d over the same period. In all, EIA estimates that world oil consumption will rise by 1.3 million bbl/d in 2007 and 1.5 million bbl/d in 2008.[14] At present, about 68 percent of all petroleum consumed by the U.S. is used for transportation.[15]

TRENDS AND OUTLOOK

Increased demand for oil, tight oil supplies and increased oil prices have led the U.S. Government, consumers and automakers to seek alternatives to gasoline powered vehicles. Alternatives to gasoline powered vehicles are generally defined as vehicles that use non-petroleum fuels or other alternatives to conventional gasoline or diesel. Alternative fuels include natural gas, ethanol, methanol, electricity, hydrogen/fuel cells, propane, LPG, non-petroleum diesel (from vegetable and animal fats), and fuel blends such as biodiesel and gasoline/ethanol mixtures. They may also include hybrid vehicles that combine smaller gasoline or diesel engines with electric power.

EXHIBIT 26-6

Delivered Energy Consumption



Source: U.S. Energy Information Administration.

Of the 20.1 million registered vehicles in Texas, many are capable of using bio-fuels, such as ethanol/gasoline blends or biodiesel that can be made from a variety of plants or animal fats.[16] About 4.7 percent or about 966,000 of those vehicles are considered alternative fuel autos by the Auto Alliance because the vehicles run either partially or totally on a fuel other than gasoline. These vehicles include automobiles powered by hybrid technology, clean diesel, biodiesel, ethanol, hydrogen and compressed natural gas. (Hybrids supplement a conventional gasoline engine with power from electric batteries; flexible-fuel vehicles can use multiple fuels to power their engine, such as either regular gasoline or an ethanol-gasoline mix.)

A closer review of the 966,000 vehicles in Texas classified as alternative fuel autos by the Auto Alliance, shows that approximately 22,500 of the over 966,000 vehicles are hybrids and the remaining vehicles have the capability to operate on clean diesel technology, biodiesel, natural gas and flexible fuel.[17] Because clean diesel, biodiesel, natural gas and flexible fuel are not widely available in Texas most of these vehicles rely on the standard gasoline and diesel products.

According to the U.S. Department of Energy (DOE), alternative transportation fuels such as ethanol, biodiesel and natural gas currently account for the equivalent of about 1 percent of the nation's annual consumption of petroleum products. Under the most optimistic projections, DOE estimates that these technologies could displace the equivalent of 4 percent of the nation's annual U.S. oil consumption by 2015 and 34 percent by 2030, if the technological challenges facing these alternative approaches can be overcome.[18]

The Federal Energy Independence and Security Act of 2007 sets a goal of increasing the current 6.5 billion gallons of bio-fuels (primarily ethanol) produced in the U.S. annually to 15.2 billion gallons in 2012 and 36 billion gallons in 2022.[19] Increasing the use of alternative fuels will require significant improvements in the production and refinement of alternative fuels as well as the distribution network for these fuels. Ethanol production is not widely available in Texas or other areas outside the Midwest because ethanol cannot be transported by the current pipelines available to oil and gasoline. Ethanol absorbs water, which is present in all pipelines, and is corrosive to the current type of pipelines used.[20] In effect, an entirely new distribution system of pipelines would be required to drastically increase ethanol consumption.

In addition, many alternative fuels have a lower energy content than traditional gasoline and diesel; in other words, it takes more fuel to provide the same or equivalent power. **Exhibit 26-7** shows the Btu content of different fuels and the number of units needed to equal a gallon of regular unleaded gasoline.[21]

Many alternative fuels have a lower energy content than traditional gasoline and diesel.

The goals set out in the Energy Independence and Security Act of 2007 to use alternative transportation fuels are ambitious and some observers note they have had some side effects. For example, the cost of corn has risen as demand for ethanol has increased. The rising cost of corn has, in turn, caused increases in food and feed prices.[22]

It took nearly 12 million acres to produce 6.5 billion gallons of corn based ethanol in 2007.[23] To meet the goals set out in the Act, it could require up to six times the current amount of land used or 72 million acres to produce 36 billion gallons of ethanol. In addition, corn-based ethanol production requires large amounts of water — between 2,500 gallons and 29,000 gallons per million Btu of energy produced.[24]

Before the general public can be expected to adopt alternative fuels, significant improvements in the production, refining and distribution network of these fuels must be made to make them both economically and environmentally attractive alternatives.

GOVERNMENT

Several U.S. governmental agencies are engaged in activities to encourage reduced oil consumption. For example, DOE funds research into alternative fuels and advanced vehicle technologies. The U.S. Department of Agriculture is collaborating with industry to identify and test the performance of potential biomass feedstocks and conducting research to evaluate the cost of producing biomass fuels.

The U.S. Department of Transportation (DOT), moreover, provides funding to encourage the development of bus fleets that run on alternative fuels; promote carpooling among consumers; and conduct outreach and education to encourage telecommuting. And DOT sets fuel economy standards for automobiles and light trucks sold in the U.S.[25]

Another significant step the U.S. government has taken in an attempt to reduce gasoline consumption is to adopt higher corporate average fuel economy (CAFE) standards. U.S. fuel efficiency

EXHIBIT 26-7

Fuel Equivalency Measures

Fuel Type	Btu Per Unit*	One Gallon of Gasoline is Equivalent to:	U.S. Average Price at Pump, per Gallon January 2008	U.S. Average Price of Fuel in Gallon of Gasoline Equivalents (GGE)** January 2008
Regular Unleaded Gasoline	115,400	1.00 gallons	$2.99	$2.99
Diesel	128,700	0.90 gallons	3.40	3.05
Bio-Diesel (B-20)	126,800	0.91 gallons	3.37	3.43
Compressed Natural Gas (CNG)	87,600	1.32 gallons	1.47	1.93
Liquefied Petroleum Gas (LPG)	83,500	1.38 gallons	3.12	4.31
Ethanol (E-85)	81,800	1.41 gallons	2.51	3.55
Electricity	3,400	33.53 kWh	n/a	3.47

*Btu values were rounded to nearest 100. Equivalency measures are based on current engine designs and abilities to convert fuel into energy.

**Average price equivalents for all fuels excluding electricity are based on January 2008 national average prices. Electricity numbers are based on December 2007 national average price per kWh for residential service. The Texas residential electric average per kWh for December 2007 was higher, (11.79 cents/kWh) than the national average, (10.31 cents/kWh).

Sources: U.S. Department of Energy, Clean Cities Alternative Fuel Price Report, National Association of Fleet Administrators, U.S. Energy Information Administration and Comptroller calculations.

standards for light duty vehicles, passenger cars and light trucks, are currently at 27.5 miles per gallon (MPG) but new legislation requires those standards to be increased to 35 MPG by 2020.[26] Vehicles in several other countries have higher MPG standards for new cars due in large part to the exceedingly high price of gasoline and diesel and government imposed regulations in those countries.

High gas prices and government regulations such as fuel efficiency standards in these countries have contributed to the development and introduction of many more fuel-efficient cars. For example, a recent Civil Society Institute study, *Fuel-Efficient Car Gap*, noted that in 2005 there were 86 commercially available car models that could achieve 40 MPG in Europe and that number increased to 116 car models by 2007. By contrast, in the U.S. there were five car models sold in the U.S. that achieved 40 MPG in 2005 and by 2007 there were only two car models that could achieve that standard.

Many European car models cited in the Civil Society Institute report run on diesel, however, which is difficult to sell in the U.S. due to environmental concerns. On the other hand, several car models powered by gasoline could be sold here in the U.S., but they have not been offered here due to their size and perceived U.S. consumer preference.[27]

AUTO INDUSTRY

Automakers have dedicated resources and time to developing vehicles that are more efficient and operate on alternative fuels.

In the near term, auto manufacturers are focusing on improving the performance of internal combustion engines through improved variable valve timing; improvements in power trains; more sophisticated six-speed transmissions; alternative fuels, including advanced diesel technology; and more efficient management of fuel use through cylinder cutoff (which allows engines to automatically stop using some of the cylinders in an engine when they are not needed to move the vehicle).

Some U.S. automakers are promoting flexible-fuel vehicles, which use E-85 a gasoline-ethanol blend of up to 85 percent ethanol. Some countries such as Brazil and Sweden require all new vehicles to be at least E-85 flex-fuel capable, and require fueling stations to devote at least a fourth of their pumps to flex-fuels. Diesel also is growing in popularity as an alternative to gasoline. According to auto giant DaimlerChrysler, if half of the current U.S. auto fleet used diesel, the nation could save about 8.5 percent of all auto fuel consumed, or about 12 billion gallons of fossil fuels annually.

Automakers also are developing hybrid electric technologies that employ both gasoline and electric motors for propulsion, as well as electric-only vehicles. Hybrids have distinct benefits over gasoline-only vehicles, including reduced oil consumption and exhaust emissions. Batteries which store energy on the hybrids contribute to the higher cost of the vehicles, one of the big factors holding them back. But automakers are striving to reduce their cost by increasing the volume of cars produced and educating consumers on the unique attributes of hybrids.

Not all hybrids are the same; varying widely in fuel economy and performance depending on their design. According to the DOE, hybrid vehicle miles per gallon (MPG) efficiency for 2008 models range from a high of 48 MPG in the city/45 MPG on the highway in a Toyota Prius to a low of 20 MPG in the city/20 MPG on the highway for a GMC Yukon hybrid. In general, hybrids provide better fuel economy in city driving, but less fuel economy on the highway.[28] Automakers are attempting to improve hybrid batteries and create smarter battery management so that they can run entirely on electric power in urban settings.[29] Plug-in hybrid vehicles, for example, store sufficient energy in their batteries to make most local trips (less than 40 miles), and then rely on a small gasoline or diesel engine for longer trips. Some drivers could almost entirely rely on home recharging of the vehicle. GM's Volt is an example of a recently announced advanced plug-in hybrid electric vehicle that will use lithium-ion batteries.

While most hybrid electric vehicles use nickel metal hydride batteries (NiMH) to store energy, electric vehicle designers would prefer lithium-ion batteries, the same technology used in laptop computers and cell phones. These batteries are lighter and recharge more quickly than other batteries. At present, however, lithium-ion batteries that are

Automakers have dedicated resources and time to developing vehicles that are more efficient and operate on alternative fuels.

powerful enough to propel an all electric car for any reasonable length of time are cost-prohibitive for mass production by automakers.

According to a recent *Wall Street Journal* article, some carmakers including France's Renault SA and Japan's Nissan Motor Co. and Honda Motor Co. have expressed skepticism about the economic wisdom of hybrids and are instead backing all-electric cars. They argue that all-electric vehicles make more sense, environmentally, politically and economically, than do hybrids, provided there are continuing advances in lithium-ion battery technology. Renault and Nissan believe that many major urban areas in Europe, such as London and Paris, will ban cars unless they have zero emissions. To meet the transportation needs of such cities, carmakers are actively researching and testing new and improved technologies for all-electric vehicles, and expect to have a significant number of them available to the public by 2012.[30]

Historically, American drivers have preferred performance to fuel economy, but high gasoline prices can prompt shifts in consumer preference.

For the longer term, several companies including General Motors, Toyota, Honda, Kia, and Chrysler are working on various designs powered by hydrogen fuel cells, and some of which will be tested in the U.S. in 2008. While the hydrogen fuel cell is a promising innovation, it entails many technical challenges, including an appropriate storage system for hydrogen.

In addition, some automakers are researching a biofuel-boosted turbo gasoline engine. The idea is to use smaller, turbo-charged engines that employ direct fuel injection to increase horsepower while allowing engines to be made smaller and more efficient — so much so that cars with these engines could rival hybrid vehicles in fuel efficiency.[31]

CONSUMERS

Carpooling, telecommuting and simple measures such as proper tire inflation and slower driving speeds all can help reduce overall fuel consumption. DOE estimates that drivers could improve fuel economy by 7 to 23 percent by traveling no faster than 60 miles per hour. In addition, aggressive driving (speeding, rapid acceleration and braking) can lower gas mileage by 33 percent at highway speeds and by 5 percent around town.[32] The International Energy Agency estimates that telecommuting could reduce total fuel consumption in the U.S. and Canada by 1 to 4 percent.[33]

Historically, American drivers have preferred performance to fuel economy, but high gasoline prices can prompt shifts in consumer preference. The U.S. Congressional Budget Office (CBO) recently issued a report on the effects of gas prices on consumer behavior and purchases. The CBO report found that while consumer response to high gas prices have been relatively small with regards to driving habits (such as driving slower, reducing or combining trips, and increased use of public transportation) consumer purchasing habits are changing significantly. The report found that purchases of light trucks, SUVs and minivans have been in decline since 2004, purchases of smaller more efficient vehicles have increased during this same time, and purchases of mid-grade and premium grade gas products at the pump have been down since 2000. The study noted that partly as a result of consumers wanting and buying more fuel efficient cars, the average fuel economy of new vehicles has increased by more than half a mile per gallon since 2004.[34] In addition, purchases of hybrid vehicles rose by more than 130 percent from 1995 to 2004.[35]

Gasoline demand also rose more slowly in 2005 and 2006 — by 0.95 and 1.43 percent, respectively — than in the preceding decade, when gasoline demand rose at an average rate of 1.81 percent per year. In addition, EIA's February 27, 2008 edition of *This Week in Petroleum*, an online weekly update of petroleum production and demand, indicated that the 4-week moving average for gasoline demand was down 1.1 percent from the same time period in 2007. EIA attributed the decrease in demand to changing consumer behavior resulting from sustained high fuel prices and a struggling economy.[36] This pattern of decreased oil demand has occurred in the past as well; U.S. consumption of oil fell by about 18 percent from 1979 to 1983, in part because consumers purchased more fuel-efficient vehicles in response to high oil prices and fuel efficiency standards enacted in 1978.[37]

Continued high fuel prices, concerns about dwindling fuel supplies, government regulation and the environmental impacts of oil will all influence consumer choice and behavior. Consumers ultimately will determine whether more fuel-efficient vehicles are built, whether alternative fuels achieve a significant market share, and how many resources auto manufacturers devote to developing alternatives such as gas-electric hybrid cars or fuel cells.[38]

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CHAPTER 27

Electricity

INTRODUCTION

Electrical power is of great importance in Texas, due to the state's climate and industrial base. Electricity is essential for Texas factories, businesses, homes and most recreational facilities. Even a temporary loss of electricity can cause not only minor and major inconveniences for our citizens, but significant losses to our economy.[1] Texas leads the nation in the generation and consumption of electricity.[2]

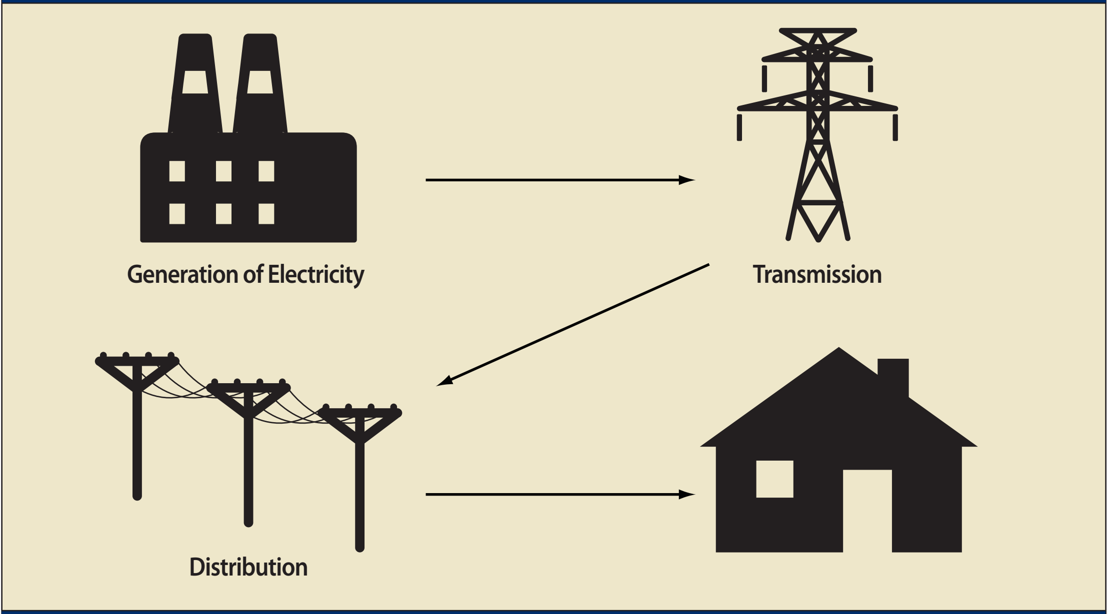
Electricity is a *secondary* energy source, meaning that it comes from the conversion of other sources of energy, such as coal, natural gas, oil, wood and nuclear power. The energy sources used to make electricity can be renewable or non-renewable, but electricity itself is neither. It can be considered a *carrier* of energy rather than an energy source.[3]

Electricity is the flow of energy in the form of electrically charged particles that are repulsed by similarly charged particles and attracted by particles of the opposite charge. All electric power flows through an integrated system of transmission and distribution lines. This system has physical boundaries, making it "the electric grid."

Large-scale electric generators, such as coal plants or large wind farms, are connected to transformers that increase the electricity's voltage, or potential energy, enabling it to be sent via transmission lines over long distances. Transmission lines carry electricity to substations equipped with other transformers that decrease the voltage; from there, the low-voltage electricity is carried on distribution lines to industrial, commercial and residential customers (**Exhibit 27-1**).

EXHIBIT 27-1

How Electricity Flows To Its Users



Source: Energy Information Administration.

The energy sources used to make electricity can be renewable or non-renewable, but electricity itself is neither.

Three electric grids, or interconnections, serve North America, and all cover a portion of Texas. The Western Interconnect includes the El Paso region; the Eastern Interconnect includes the Panhandle, the Beaumont area, and portions of Northeast Texas; and the Electric Reliability Council of Texas (ERCOT) region covers everything else — 75 percent of Texas's land area and 85 percent of the electric load.[4] The Public Utility Commission of Texas (PUC) is responsible for regulating nearly all aspects of the ERCOT market, and certain aspects of the other regions, such as ensuring consumer protection.

The Texas Legislature's restructuring (sometimes called "deregulation") of the retail electricity market, which began in 2002, applies *only* to investor-owned utilities (IOUs) within the ERCOT region. Utilities owned by cities and rural cooperatives may join the deregulated market but are not required to do so, and so long as they have not, they are known as "non-opt-in entities" (NOIEs); at this writing, only one Texas cooperative and no city-owned utilities have opened to competition.

About 60 percent of Texas residents purchase retail electricity in the deregulated market.

In the ERCOT areas that have opened to retail competition, the electric industry has been "unbundled" and structurally separated into three segments: wholesale generation, transmission/distribution and retail. In these areas, suppliers of *wholesale generation* are companies that own power-generating plants and sell electricity to retail electric providers (REPs); the *transmission and distribution* segment comprises companies that own the power lines electricity flows through; and the *retail* segment comprises REPs that sell electricity to end users.

Outside of ERCOT, and in the areas of ERCOT served by NOIEs, one entity may generate, transmit, distribute and sell electricity to all retail customers. These companies are called "vertically integrated" utilities.

In all of Texas, the transmission and distribution of electricity over wires remains regulated. This is because transmission wires and poles are viewed as a natural monopoly, in that it would not be economically efficient for multiple companies to duplicate transmission-line networks.

Wholesale electricity sales (between power generators and REPs) were deregulated within Texas in 1995. The wholesale market within ERCOT is subject to only limited regulation by PUC, while the Federal Energy Regulatory Commission (FERC) oversees wholesale markets in the non-ERCOT portions of Texas. Under a 2005 federal law, FERC also assumed reliability oversight over the entire state.

About 60 percent of Texas residents purchase retail electricity in the deregulated market. The remainder are served by a traditional, regulated market outside of ERCOT, or a NOIE.[5]

POWER GENERATION

Steam turbines, internal combustion engines, gas combustion turbines, water turbines and wind turbines are the most common mechanisms for generating electricity in power plants. Most of the electricity in the U.S., including Texas, is produced by steam turbines. Steam turbines are two machines connected by a shaft, a turbine and a generator set. Electricity is produced by a steam turbine essentially by heating water (with a fuel source such as coal, nuclear fission or natural gas) to create steam. The steam generated is forced against blades mounted on the shaft of the turbine. As the blades rotate, the shaft rotates the coils in the generator to produce an electrical current.

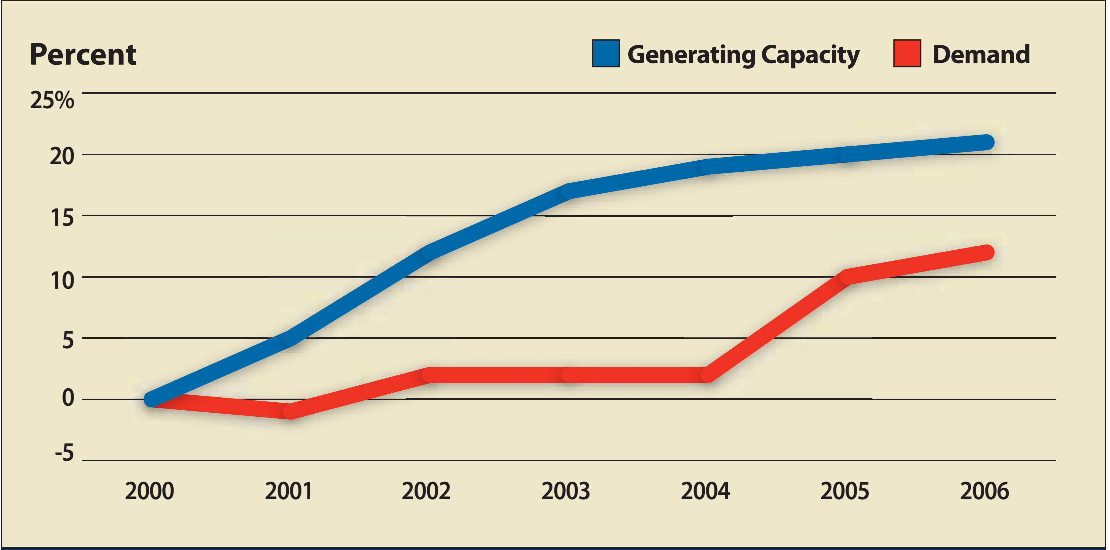
Texas has more than 230 electric providers and over 850 electric generating units and all of them are responsible for ensuring adequate and reliable electricity to consumers in their service areas.[6]

The total U.S. "nameplate" electric generating capacity (that is, the installed generating capacity running at 100 percent) was 1,075,677 megawatts (MW) as of January 1, 2007, about 1.7 percent more than on January 1, 2006.[7] Texas' total nameplate generating capacity was 109,666 MW in 2006.[8]

Most thermal power plants do not meet 100 percent of the nameplate capacity of their generators; instead, their actual output varies depending on planned and unplanned outages, the cost of power production, weather, transmission-grid constraints and system demand. Nationally, the net generation capacity (minus planned and unplanned outages) totaled 986,215 MW in 2006, or 91.7 percent of the total nameplate capacity. The nation's net generation capacity has risen by 78 percent since 1995, while demand has increased 12 percent.[9]

Exhibit 27-2

Cumulative Change, U.S. Electricity Generating Capacity and Demand, 2000-2006



Sources: U.S. Energy Information and Texas Comptroller of Public Accounts.

In Texas, 2006 net generation capacity totaled 100,754 megawatts.

Exhibit 27-2 shows the change in net U.S. generation capacity and demand for the last six years.

In Texas, 2006 net generation capacity totaled 100,754 MW, or 91.9 percent of total nameplate capacity. Net generation capacity has risen by 72 percent since 1995.[10]

Exhibit 27-3 shows the change in Texas' net generation capacity and demand for the last six years.

New generating capacity added during 2006 totaled 12,860 MW nationally and 1,667 MW in Texas.[11]

Demand for electricity varies throughout the year, with the greatest demand coming during the summer. During 2006, for example, ERCOT's system demand ranged from a low of 21,309 MW (Nov. 24) to a peak of 62,339 MW (Aug. 17).[12] It is not uncommon in the summer for demand to fluctuate by more than 25,000 MW within a 12-hour period and require the coordinated contributions of more than 400 electric generating units.

Texas has hundreds of electricity generating facilities and a number of entities involved in the retail sale of electricity. **Exhibit 27-4** lists the state's five largest retail sellers of electricity.

Exhibit 27-5 lists Texas' ten largest electricity generating facilities.

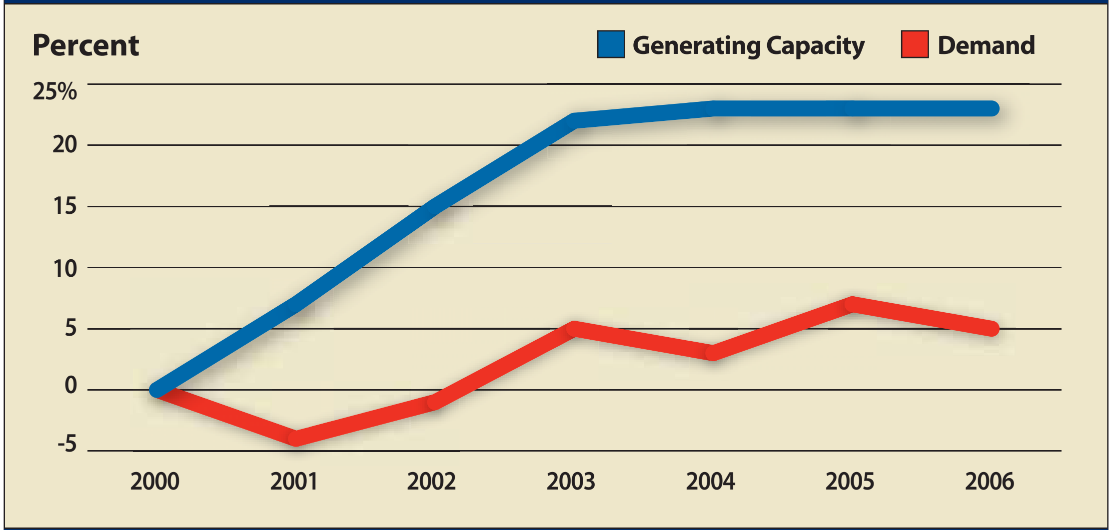
Electricity sold to utilities or REPs is called "wholesale electricity," the sale of which is deregulated in all areas of Texas and for all types of utilities.

TRANSMISSION AND DISTRIBUTION

Moving electricity from generators to consumers requires numerous components, including conductors, towers, transformers, relays, breakers and switches, as well as rights of way to the land over which the lines pass.[13] Within ERCOT, transmission and distribution service providers (TDSPs) move electricity along transmission lines to local REPs. They are required to provide nondiscriminatory access to the network of transmission lines collectively known as the "grid."[14]

Exhibit 27-3

Cumulative Change, Texas Electricity Generating Capacity and Demand, 2000-2006



Sources: U.S. Energy Information Administration, Electric Reliability Council of Texas and Texas Comptroller of Public Accounts.

The ERCOT grid contains 38,000 miles of transmission lines.

The ERCOT grid contains 38,000 miles of transmission lines. Again, the ERCOT power region covers about 75 percent of Texas' land area and is one of only three grids in the U.S.

The 38,000 miles of lines in ERCOT's region include 8,100 miles of 345-kilovolt (kV) lines, 16,000 miles of 138-kV lines and 11,500 miles of 69 kV lines. Distribution lines that distribute power to homes and businesses are below 69 kV; individual REPs manage these.[15] Data were not available to determine the mileage of transmission and distribution lines outside the ERCOT power region.

The cost of transmission and distribution comes from the capital cost of required equipment and operating and maintenance expenses. PUC reviews proposals for new transmission lines and setting rates for transmission services in all parts of Texas. These are charged to all REPs or utilities that receive power from the generation companies.

Within the ERCOT power region, the "postage stamp" rate is used for transmission costs. The postage stamp rate is a shared expense paid by all REPs, and ultimately the end user, in the ERCOT power region to TDSPs for the cost of transmission services. In 2007, the total cost for transmission approved by PUC was $1.2 billion. The total

Exhibit 27-4

Five Largest Texas Retail Sellers of Electricity, 2006

Companies/Entities	Retail Sales
Reliant Energy Retail Services	55,864,759 MWh
TXU Energy Co. LP	51,502,028 MWh
Constellation NewEnergy, Inc.	20,137,227 MWh
City of San Antonio	19,142,270 MWh
Entergy Gulf States, Inc.	15,383,226 MWh

Source: U.S. Energy Information Administration.

Exhibit 27-5

Ten Largest Electricity Generating Facilities in Texas, 2006

Plants/Facilities	Generating Capacity	Primary Fuel Source
W.A. Parish	3,681 MWh	Natural Gas
South Texas Nuclear Project	2,560 MWh	Nuclear
Comanche Peak	2,300 MWh	Nuclear
Cedar Bayou	2,258 MWh	Natural Gas
Martin Lake	2,250 MWh	Coal
P.H. Robinson	2,211 MWh	Natural Gas
Sabine	1,890 MWh	Natural Gas
Monticello	1,880 MWh	Coal
Limestone	1,700 MWh	Coal
Fayette Power Project	1,641 MWh	Coal

Source: U.S. Energy Information Administration.

amount paid by each REP is determined by their percent of load (total kWs). For example, if a retail provider accounts for 20 percent of the electricity uploaded onto the ERCOT grid, that provider would be responsible for 20 percent of the approved total cost of transmission services paid to TDSPs. Likewise, if a TDSP is responsible for carrying 15 percent of the ERCOT power region's total load, 15 percent of each REP's transmission service payment would go to that TDSP.

Any new transmission lines built or any increases in line maintenance in the ERCOT power region will result in an increase in the postage stamp rate.

Included in capital costs are the considerable sums to lease or buy easements to the land over which transmission and distribution lines travel. According to ERCOT, installing one mile of 138-kV transmission line costs approximately $1 million; installing one mile of 345-kV transmission lines costs approximately $1.5 million; and installing one mile of 765-kV transmission line costs approximately $2.6 million; land easement acquisition accounts for 5 to 10 percent of that cost in rural areas and 10 to 20 percent of the cost in urban areas.[16] A recent study completed by ERCOT on the potential costs to build transmission lines to West and Northwest Texas to transport electricity generated from wind power estimated that it would cost between $3 and $6 billion depending on the amount and capacity of transmission lines built.[17]

Land easement acquisition for transmission and distribution lines becomes significantly more complicated and costly when eminent domain authority — the ability to take privately owned land through a legal process for the public good — must be asserted to obtain the land.

In a typical eminent domain easement acquisition, the PUC of Texas has already identified the land easements needed for the lines; the TDSP is responsible for acquiring the land easement and offering the landowner an appropriate amount of money for the land easement purchase. More often than not, the amount offered for the easement is based on the fair market value of the taking (land easement) including any damage to the land tract. If the landowner does not want to sell or thinks the offer is too low, the utility company may proceed with an eminent domain process through the county.

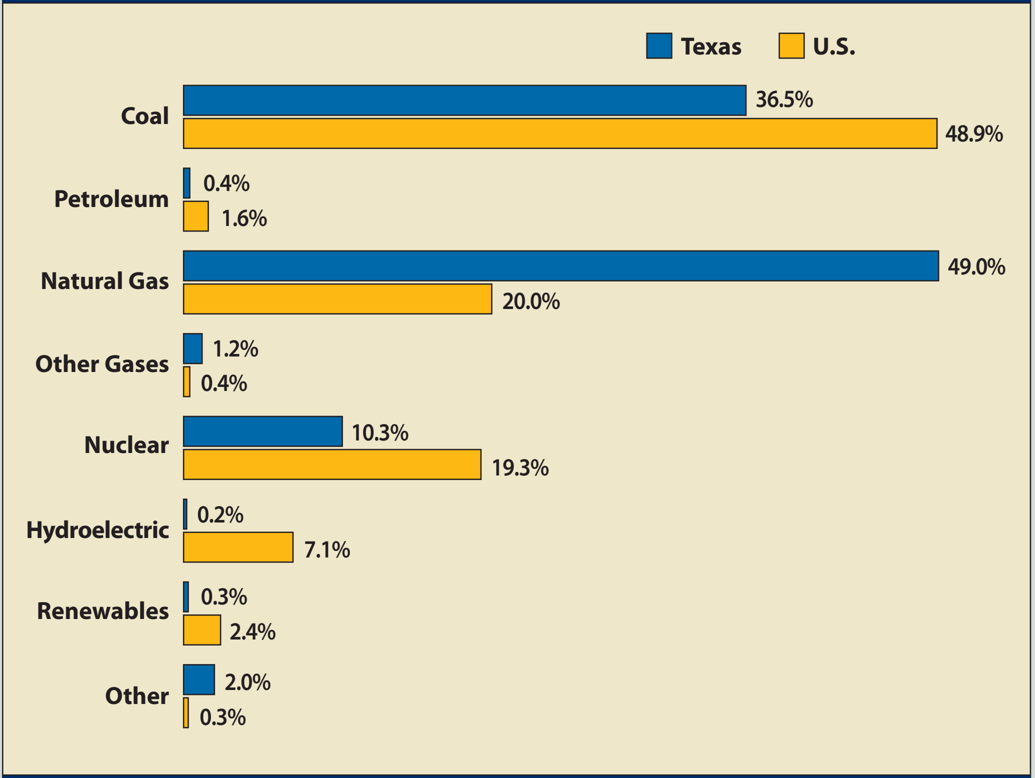
Disputes between landowners and utilities requiring eminent domain proceedings are heard by a condemnation court – a panel of three people appointed by the county judge who are knowledgeable about easement acquisitions and land values in the county. The condemnation court determines the appropriate amount owed to the landowner for the easement. If either party disputes the condemnation

In addition to the generating capacity, Texas has a significant amount of *cogenerated power,* also called combined heat and power (CHP). CHP systems provide both electricity and heat to buildings next to or close to the system. According to the Gulf Coast CHP Application Center, a federal center charged with promoting the development and use of CHP, Texas has 137 cogeneration facilities with an installed capacity of 16.7 gigawatts.[18]

Exhibit 27-6 shows the relative shares of all electricity produced by various fuel sources, including cogeneration, in Texas and the U.S. in 2006.

Exhibit 27-6

Percent of Total Electricity Generated by Fuel Source, 2006



Note: Numbers may not total due to rounding.
Source: U.S. Energy Information Administration.

Cogeneration facilities are not new technology; instead, these types of facilities are common in large industrial applications, hospitals, university campuses and district energy systems in urban areas.

court findings, they can appeal the process to the civil court that has jurisdiction over that county.

According to the Lower Colorado River Authority (LCRA), a general wholesaler in Central Texas eminent domain authority is typically used in 6 to 15 percent of land easement acquisitions for transmission lines.[19]

RETAIL SALES

Electric customers include industrial, commercial, governmental and residential consumers. Typically, commercial and industrial customers consume significantly more electricity than residential customers. Some industrial plants generate their own electricity to offset the amount of electricity they obtain from the grid. Any additional or excess electricity produced by these plants can be sold back to utilities.

Industrial and commercial customers typically pay a lower price per kilowatt-hour than residential customers, in part because increased usage means increased bargaining power, and in part because residential usage varies according to weather, time of day and other factors, requiring power generators to account and be ready for wide fluctuations in power demand.[20]

POWER CONTROL AND RELIABILITY

Meeting the ever-changing electric needs of Texas is achieved through a complex, interrelated network of power plants, fuel supplies, and energy delivery systems that collectively is expected to operate continuously, flawlessly, under any weather conditions, and as inexpensively as possible. This formidable challenge is complicated by fluctuations in electric demand by season, day and instant time.

A variety of entities throughout the country control and administer the nation's power grids. In many areas, grids are controlled by independent system operators (ISOs) or regional transmission operators (RTOs); in all, there are ten ISOs and RTOs in the U.S. and Canada.[21]

According to the ISO/RTO Council, ISO/RTOs:

> …schedule the use of transmission lines; manage the interconnection of new generation without any possible conflict of interest; and provide or support market monitoring services to ensure fair and neutral market operations for all participants.[22]

ISOs/RTOs were created to ensure fair access to transmission lines. As a result, creating an ISO or RTO requires utilities to separate their transmission ownership from transmission control. The ISO/RTO then assumes control of the transmission while the utility retains ownership of the lines. In areas without an ISO/RTO, the grid is controlled by vertically integrated utilities that also own the transmission lines.

FERC advocates the use of ISO/RTOs in all areas of the country, although not all utilities have voluntarily acted to form them for their regions. ERCOT acts as an ISO for its region, and is the only ISO not created by FERC, while the Southwest Power Pool (SPP) is the only FERC-chartered RTO that operates in Texas. According to EIA, the benefits of ISO/RTOs include:

- performing and coordinating transmission planning on a region-wide basis to ensure that system reliability is met in an efficient and non-discriminatory manner.
- operating competitive markets to ensure the reliability of customer service, providing information to market monitors to identify market manipulation, expose anti-competitive behaviors and provide comprehensive market analysis to enhance market design.
- providing more efficient methods for pricing transmission services, resulting in lower transmission costs to customers. This is possible because an ISO/RTO administers a uniform transmission rate for all transmission facilities under its control instead of maintaining multiple utility transmission prices and policies in the region. (See below for an in-depth discussion of transmission pricing.)
- managing and resolving transmission congestion efficiently through market-oriented approaches. This is possible because the ISO has operational oversight of a large regional transmission system. (Transmission congestion also is discussed in depth below.)
- simplifying procedures for transmission customers to obtain transmission services, allowing "one-stop shopping."
- encouraging the entry of competitive generation resources, both through "open access" guarantees and by providing more transparent price signals to encourage needed investment.
- facilitating the growth of renewable resources, again through open-access transmission policies

Meeting the ever-changing electric needs of Texas is achieved through a complex, interrelated network of power plants, fuel supplies, and energy delivery systems that collectively is expected to operate continuously, flawlessly, under any weather conditions, and as inexpensively as possible.

and also by creating markets in which renewables can compete.

- laying the groundwork for demand response by providing rapid and accurate grid and market data.[23]

North American Electric Reliability Councils

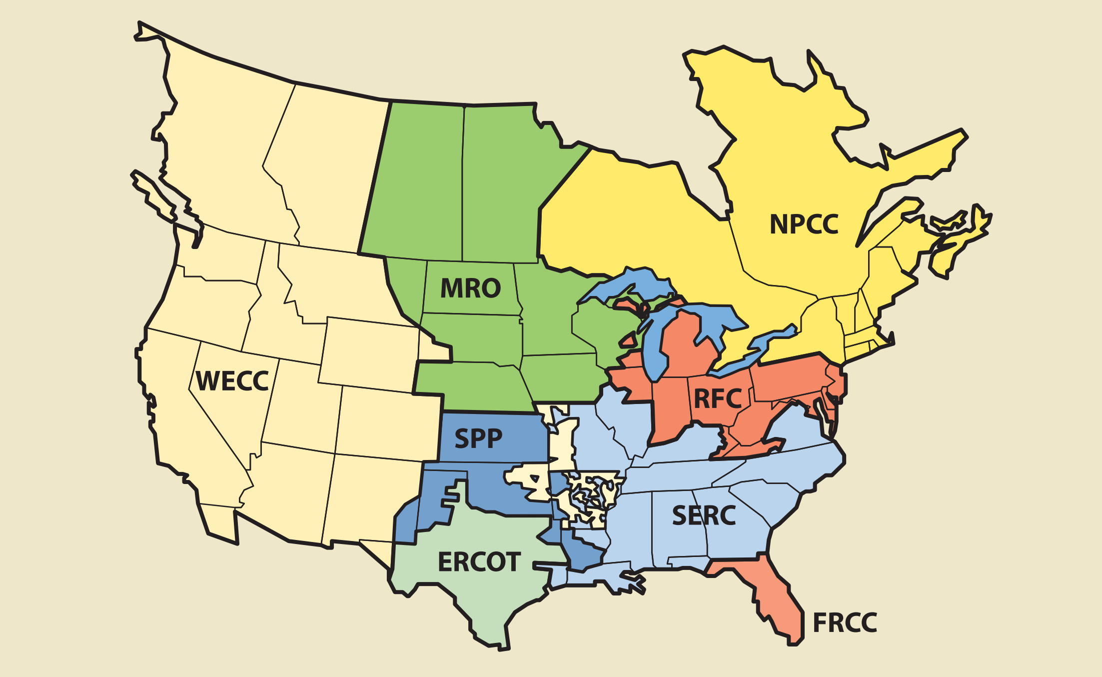
Until recently, eight different reliability councils administered reliability standards in their respective regions. The North American Electric Reliability Corporation (NERC) adopted national standards and supervised these councils to ensure reliable electricity networks.

Most regional reliability councils serve multiple states, and some reach into Canada and Mexico as well (**Exhibit 27-7**). The Western Electric Coordinating Council (WECC) serves the western third of the U.S., Baja California and western Canada. The Midwest Reliability Organization (MRO) serves the upper Midwest and central Canada. The Northeast Power Coordinating Council (NPCC) serves New England and eastern Canada. The Reliability*First* Corporation (RFC) serves the central eastern U.S. from New Jersey to Michigan. The Southwest Power Pool (SPP) serves all of Kansas and portions of Arkansas, Oklahoma, Texas, Louisiana, New Mexico, Missouri and Mississippi. The Southeastern Reliability Council (SERC) serves the southeastern U.S. including Southeast Texas. The Florida Reliability Coordinating Council (FRCC) broke away from SERC in 1996 to serve all of Florida except the western Florida Panhandle. The Florida Public Service Commission regulates electric utilities within FRCC.[24]

Four councils operate in Texas — ERCOT, SERC, SPP and WECC.

Exhibit 27-7

The North American Electric Reliability Corporation Regions



Source: North American Energy Reliability Corporation.

In response to the 2003 Northeast blackout, the Energy Policy Act of 2005 required FERC to designate a privately and independently owned electric reliability organization (ERO) to implement and enforce the complex market, engineering and infrastructure rules needed to keep all grids up and running at all times. It further provided for the creation of "regional entities" to assist the ERO.

NERC was designated as the ERO in 2006, and Regional Entities for the various areas of Texas were designated in 2007. The first federal reliability standards took effect in June 2007 and can carry penalties of up to $1 million per violation. These standards apply throughout Texas, and represent the first significant FERC regulation within the ERCOT market.

NORTH AMERICAN ELECTRIC GRIDS

As noted above, three interconnected physical grids of transmission lines serve North America — the western grid, the eastern grid and ERCOT (**Exhibit 27-8**).

ERCOT

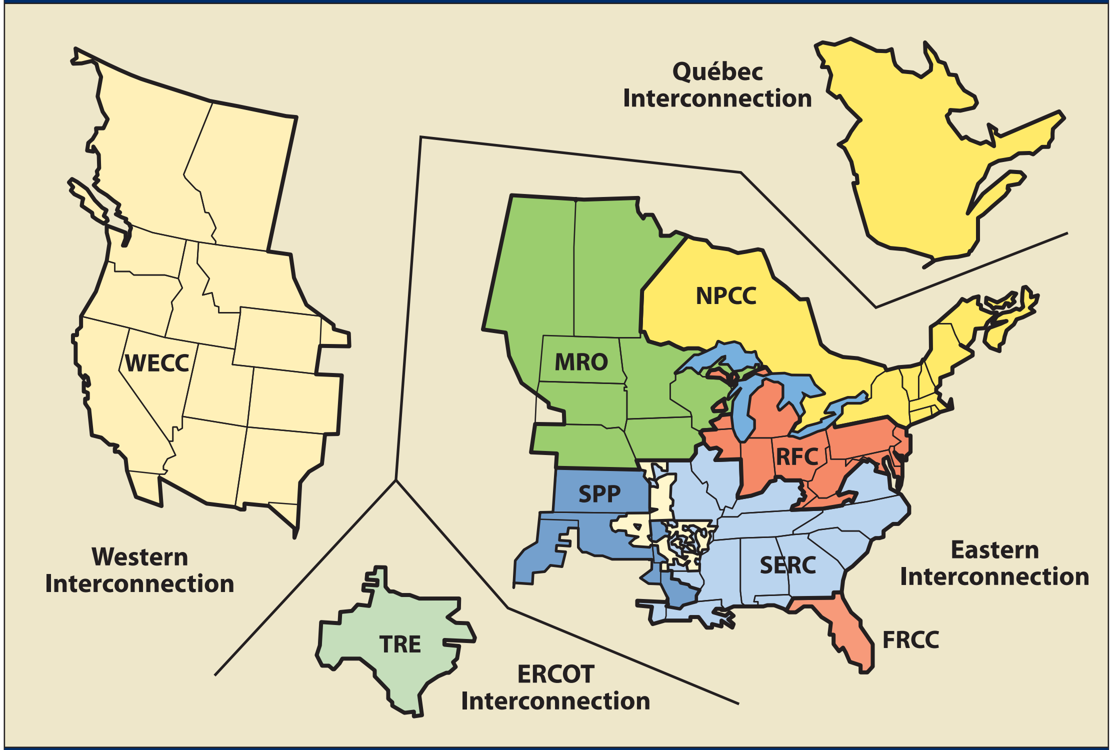
The ERCOT grid is the only entirely intrastate grid, in which ERCOT serves as a reliability council and an ISO, and an independent division of ERCOT is the Regional Entity under the ERO.

Because ERCOT is considered intrastate, its market is subject to regulation by the Texas PUC and not by FERC. All of the other RTOs and regional entities responsible for reliability span multiple states. Under the 2005 legislation, all of the Regional Entities are subject to FERC as their regulating authority, and all of the RTOs other than ERCOT are subject to FERC as their regulating authority for wholesale market issues. State regulatory commissions have jurisdiction over retail issues and certain transmission issues, such as licensing of new facilities.

The ERCOT grid is the only entirely intrastate grid.

EXHIBIT 27-8

U.S. Electric Grids



Source: North American Energy Reliability Corporation.

Areas of Texas not within the ERCOT region fall into three different multi-state regional entities. WECC includes the El Paso area, while the other regional entities, SPP and the Southeastern Electric Reliability Council (SERC), include the Panhandle, northeast Texas and southeast Texas (**Exhibit 27-9**).

ERCOT's sphere of authority is defined by its electric grid and the customers it serves (**Exhibit 27-10**).

Texas regions outside of ERCOT and SPP have no ISO/RTOs. The vertically integrated utilities that own the power lines there operate the system; end users pay these utilities for power delivered to their homes and businesses.

PUC chose ERCOT to perform ISO services for the ERCOT grid in addition to the reliability council services it was already performing. PUC regulates the system administration fees that ERCOT charges its market participants for these services.

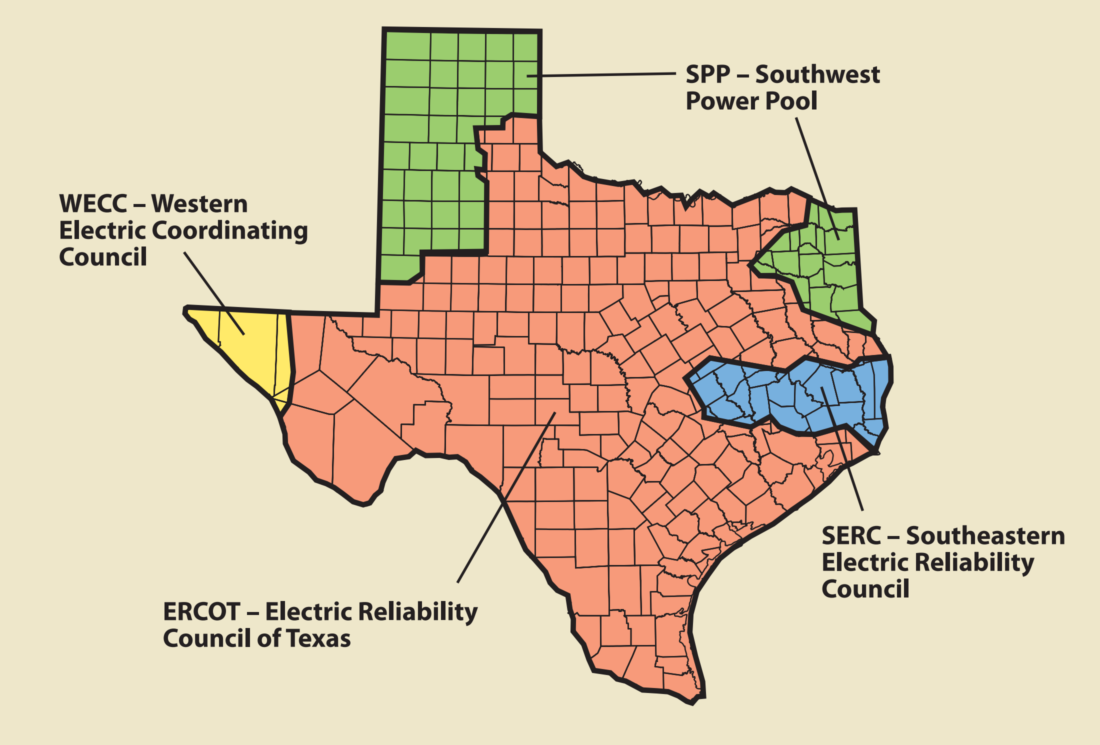
ERCOT's primary mission is to direct and ensure reliable and cost-effective operation of the electric grid and fair and efficient market-driven solutions to customers' electric service needs.[25] With retail deregulation in 1999, the Legislature assigned four key responsibilities to ERCOT:

- ensure open access for all competitors to the transmission and distribution systems;
- ensure reliability of the grid and transmission of power for all;
- convey timely information to consumers to allow them to make informed choices among electricity providers; and

ERCOT's primary mission is to direct and ensure reliable and cost-effective operation of the electric grid and fair and efficient market-driven solutions to customers' electric service needs.

EXHIBIT 27-9

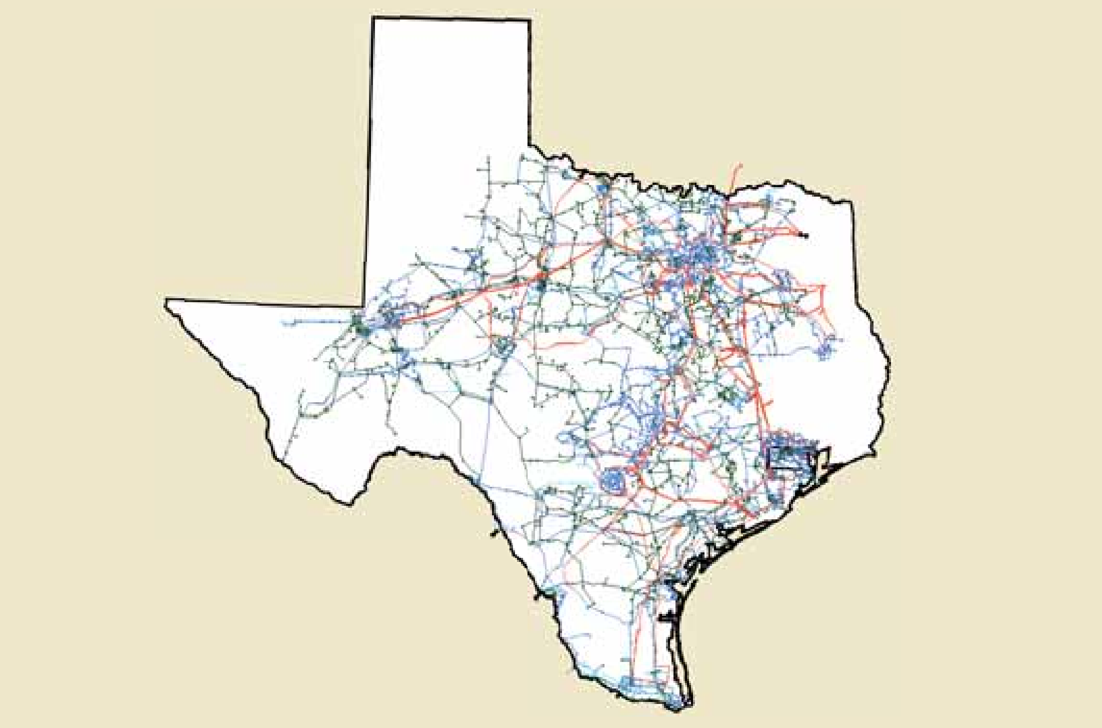
Texas Electric Reliability Council of Texas Boundaries



Source: Electric Reliability Council of Texas.

Exhibit 27-10

The ERCOT Electric Transmission Grid



Source: Electric Reliability Council of Texas.

- ensure accurate accounting for electricity production and delivery.[26]

ERCOT's unique status as a state-regulated grid has been protected carefully. One example of the avoidance of federal regulation occurred in fall 2005, after Hurricane Rita struck southeast Texas, knocking out electrical power and infrastructure in the Entergy service area outside of ERCOT. Entergy, the local utility, operates within SERC's electric grid, and Entergy's Louisiana and Texas grid were badly damaged by both Rita and Hurricane Katrina a few weeks earlier. To move electricity to southeast Texas, the state and ERCOT utilities sought and received a waiver from the U.S. Department of Energy to allow ERCOT companies to provide electricity temporarily to some of Entergy's customers without jeopardizing ERCOT's intrastate status.

ERCOT is responsible for:

- managing the flow of electricity in a grid area representing 85 percent of the state's electric load and 75 percent of its land, in both regulated and deregulated markets;
- scheduling power across a grid connecting 38,000 miles of transmission lines and more than 500 generating units, in both regulated and deregulated markets;
- reliably operating the grid to ensure it can accommodate scheduled energy transfers;
- supervising transmission planning to meet existing and future electricity demands;
- administering electricity markets in its area for services needed to ensure reliability;
- maintaining a database to record the relationship between retail electricity providers and their customers; and
- administering the state's Renewable Energy Credit program.

Keeping the overall electric system reliable requires accommodating many kinds of unexpected events, including:

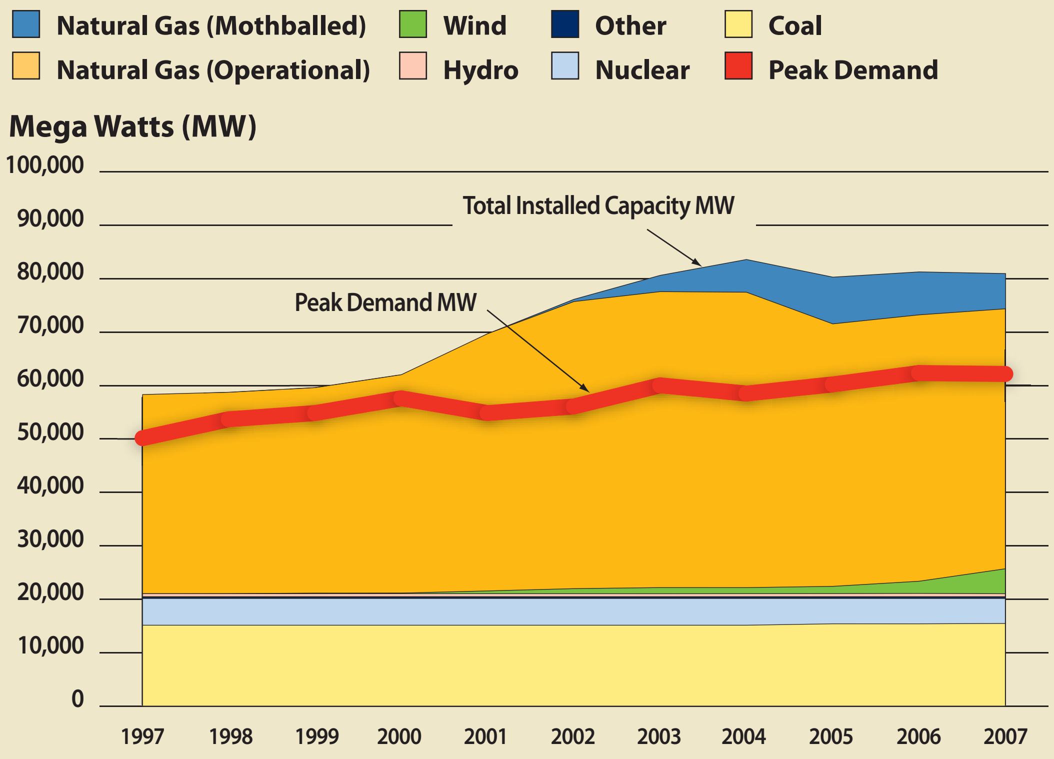
- not enough power plants available;
- not enough fuel available, including problems with fuel delivery systems;
- power line outages or congestion;
- unexpected changes in demand (extreme hot or cold weather); and
- violent conditions such as thunderstorms, tornados, accidents, or attacks.[27]

Meeting these challenges reliably requires a robust array of operating practices and safeguards, including encouraging a surplus level of power plants (reserve margin) to be built for the years ahead (capacity adequacy), arranging for the availability of extra power plants ahead of time that can be deployed within hours or days (replacement reserves or unit commitment), and availability of power plants to start putting power to the grid within seconds during emergencies (responsive reserves). **Exhibit 27-11** shows the fuel mix supplying the state's total installed electric generation capacity, and compares it to peak demand.

ERCOT considers electric capacity to be "adequate" at a 12.5 reserve margin; that is, when forecast installed capacity exceeds the forecast peak

Exhibit 27-11

Generation Capacity in the ERCOT Power Grid by Fuel Type, 1997-2007



Source: Electric Reliability Council of Texas.

hourly demand by at least 12.5 percent. In ERCOT's service area, this peak load usually occurs on afternoons in July and August. ERCOT does not expect the reserve margin to drop below 12.5 percent between 2008 and 2011.[28] This guideline is prudent to account for many uncertainties, such as extreme weather conditions that can drive up demand more than anticipated, and the fact that all power plants can break down. Fossil-fueled power plants are typically out for scheduled maintenance about 4 percent of the time and out for unexpected reasons about 6 percent of the time.[29]

Outages and Blackouts

Insufficient capacity can result in problems meeting electricity demands. In April 2006, for example, ERCOT ordered rotating outages across the state due to unseasonably high temperatures and limited available generation capacity. Many generators were offline for seasonal (pre-summer) maintenance, and emergency conditions were triggered by the sudden, unexpected loss of multiple generators. Rotating outages are not "blackouts," they are controlled and managed, and in this case resulted in targeted 10- to 45-minute power outages for some non-critical residential and commercial customers. Within ERCOT, TDSPs controlled the outages, and continued "rolling" the outage to different sets of customers.

Rotating outages such as these help the electrical grid avoid "cascading" blackouts, which are uncontrolled outages that can shut down power across entire regions and take days to correct. Even intentional power outages can disrupt transportation and commercial activities, but cascading outages can be far more troublesome and potentially dangerous. Such an event occurred on August 14, 2003, when the largest blackout in American history affected eight states in the northeastern U.S. and parts of Canada. The blackout affected 50 million people and caused the loss of between $4.5 billion and $12 billion in economic activity.[30]

In all, however, the U.S. electricity grid is extremely reliable, delivering uninterrupted power to customers more than 99 percent of the time each year.[31] Prior to April 2006, the ERCOT grid had not experienced rotating outages since 1989.

But even brief outages and disruptions can cause significant problems for some manufacturers. For example, Samsung, a multi-national technology company with a manufacturing plant in Austin, experienced a 10-minute localized outage in June 2006. This brief outage forced Samsung to shut down for a week to clean, test and recalibrate its equipment before resuming production. Another technology company in Austin, Freescale Semiconductor, Inc., reports that four power outages over four years have cost it between $15 million and $20 million.[32]

Such outages are particularly difficult for high-tech companies such as chip makers, data centers and manufacturers of sensitive equipment and digital components. Evidence shows that businesses will relocate if their power is not reliable. Thirty-four percent of companies responding to a Connecticut Business and Industry Association Survey said they would move their businesses out of state if they experienced ten or more one-hour to one-day unanticipated power losses over a three-month period.[33] As Texas moves toward a more service-oriented, high-tech economy, reliable energy sources will be vital to continued economic development.

Despite its current reliability, experts say that the nation's power system is under increasing pressure, as demand for power outpaces improvements in grid transmission capacity. In the next decade, U.S. demand is projected to increase by 19 percent, while capacity is estimated to increase by just 7 percent.[34] ERCOT demand is projected to increase by 21 percent — very close to the national average — but ERCOT has been far more successful in adding transmission capacity, reporting that it will add $6.1 billion in transmission improvements over the next ten years.[35]

REGULATION AND OVERSIGHT

PUC was created by the 1975 Texas Legislature to regulate telecommunication and electric services in Texas. Texas was the last state to create a utility commission. PUC comprises three commissioners appointed by the governor, each serving a six-year term.

In 1995, the Legislature restructured (or "deregulated") the state's wholesale electric market to begin September 1, 1995, and in 1999 deregulated the retail segment in some parts of Texas to begin on January 1, 2002 (see below for a more detailed consideration of deregulation).[36] The term "de-

ERCOT considers electric capacity to be "adequate" at a 12.5 reserve margin; that is, when forecast installed capacity exceeds the forecast peak hourly demand by at least 12.5 percent.

regulated" as applied to the retail segment of the industry means the Legislature removed monopoly regulations from the investor-owned utility areas within ERCOT to allow new entrants to compete for customers in a free market. Deregulated areas are also called "competitive areas" or areas "open to electric choice" because their electric service is no longer provided by one utility.

Deregulation brought new rules intended to ensure fair competition and protect consumer's rights. As noted above, areas within ERCOT that are served by publicly owned or member owned utilities, such as cooperatives and municipalities, known as NOIEs, were not automatically opened to retail competition, although these utilities may choose to opt into the competitive market. Nueces Electric Cooperative is the only entity to opt in thus far.[37]

Under retail competition, retail electric providers sell electricity to consumers and businesses, and provide customer service functions such as billing, rate plans and choices of renewable or other energy sources. All REPs must be certified to do business by PUC. REPs may compete for customers, both residential and commercial/industrial, by offering lower prices, a variety of service plans, different renewable energy choices or better customer service and can operate in any deregulated area.

Under retail competition, retail electric providers sell electricity to consumers and businesses, and provide customer service functions such as billing, rate plans and choices of renewable or other energy sources.

PUC is responsible for:

- regulation of rates and terms for intrastate transmission service and for distribution service in areas where customer choice has been introduced;
- oversight of the ERCOT market, including market monitoring and the ERCOT administrative system administration fee;
- adopting and enforcing rules relating to retail competition, including customer protection and the state's renewable energy goals;
- retail rate regulation outside of ERCOT;
- licensing of new transmission facilities for investor-owned utilities and cooperatives; and
- licensing of retail electric providers.[38]

Regardless of which REP provides electric service to a customer, PUC continues to enforce consumer protections for residential and small commercial customers and regulates electricity delivery to ensure that the relevant TDSP — the "wires" company — delivers power reliably and without discrimination. (PUC has adopted minimal customer protection rules for industrial and large commercial customers but leaves most of these issues to be resolved by contract between the REP and customer.)

PUC has adopted customer protection rules that affect retail electric providers in several ways. REPs:

- must follow PUC standards to investigate customer complaints;
- may not discriminate;
- may not switch a customer's service without his or her permission. This practice is called "slamming" and it is illegal;
- may not release any customer-specific information to any other company without the customer's permission;
- must provide customers with an Electricity Facts Label (discussed below);
- must provide customers with a terms-of-service agreement;
- must disclose to customers their rights concerning choice of providers and the ability to switch;
- must provide customer information in English and Spanish; and
- must offer customers an average payment plan option to help distribute electricity payments evenly over the year, rather than billing customers for usage by month.[39]

INDUSTRY STRUCTURE

The electric industry's structure varies depending on the ownership of the entity providing the electric service (NOIE or competitive) and the geographic location of the customer (inside or outside ERCOT).

In most traditionally-regulated retail areas of Texas (outside of ERCOT), vertically integrated utility companies control the complete process of providing electricity, including electric generation, transmission, distribution and retail customer sales. (It should be noted that some NOIEs may not participate in all three areas.)

In deregulated retail areas, these functions have been separated into distinct units so that multiple power companies can sell power to any retail provider, and so that multiple retail electric providers, in turn, can sell electricity to consumers within the same geographic location.

Again, the transmission and distribution function remains regulated throughout the state.

Texas has four basic types of utilities: investor-owned utilities (IOUs), publicly owned municipal utilities (MOUs), cooperatives and river authorities.[40]

Investor-Owned Utilities

IOUs are private, shareholder-owned companies ranging in size from small local operations to large multi-state holding companies. An IOU in a regulated area can offer all electricity functions from generation to retail sales, but in deregulated areas IOUs have been required to separate their generation functions from their transmission functions and their retail sales.

Within the deregulated ERCOT power region, the state can license more than one entity to sell retail electrical services within a particular area. These entities are free to set their own rates and compete with one another for customers.[41] IOUs outside the ERCOT power region continue to be regulated by PUC, meaning that the agency typically has granted only one IOU a license to provide electrical services within an area and sets the rates that can be charged to customers. There are a few areas, however, where service territories overlap, and an IOU and cooperative or an IOU and MOU may both have the right to provide electric service.

Municipally Owned Utilities

MOUs are publicly owned, nonprofit utilities that generate or purchase power and control its distribution to area residents. Municipal utilities began in the 1800s as a way to bring power to cities that lacked investor-owned utilities. Municipal governments either set their electric rates or approve the rates set by their utilities.

Texas has 73 municipal utilities serving more than 3 million Texans, or roughly 15 percent of the state's retail electric customers.[42]

Electric Cooperatives

Electric cooperatives are private, nonprofit utilities owned and controlled by the members they serve. Cooperatives pay no federal taxes, but do pay state property taxes.

Cooperatives began in the 1930s, to bring power to rural communities where investor-owned utilities could not operate profitably. Public municipal utilities, moreover, could not afford to build electric facilities in rural areas. Federal legislation created the Rural Electrification Administration, which allowed people in sparsely populated areas to join together to borrow money at low-interest rates and build facilities to bring electricity to their homes and farms.

Texas has 74 cooperatives, mostly but not entirely serving areas that are still rural. Texas' co-ops own more than 286,000 miles of lines serving nearly 3 million Texans in 232 of the state's 254 counties.[43]

River Authorities

Between 1929 and 1949, Texas formed four river authorities to manage water resources and produce electricity. These are the Lower Colorado, Brazos, Sabine and Guadalupe-Blanco river authorities, all of which still operate today.

The Legislature created all four authorities as conservation and reclamation districts. However, in addition to their conservation and reclamation responsibilities each authority produces electricity. They are considered public entities, although they are not state agencies. Each operates as an independent nonprofit organization, without any taxing authority. Utility revenues and fees generated from supplying energy, water and community services cover their operating expenses. A governor-appointed board of directors manages each organization.[44]

The LCRA, created in 1934, with more than 3,600 megawatts of installed electrical capacity, is by far the largest of these authorities. LCRA does

Texas has four basic types of utilities: investor-owned utilities, publicly owned municipal utilities, cooperatives and river authorities.

not sell electricity directly to any retail customers but instead sells wholesale electricity to more than 40 retail utilities, including MOUs and electric cooperatives that serve more than 1 million people in 53 counties. In addition, LCRA operates more than 3,300 miles of transmission lines statewide.[45]

Deregulation in Texas required formerly vertically integrated investor-owned utilities to divide into independent business units to generate power, transmit it or sell it to retail customers.

The remaining river authorities, (Brazos, Sabine and Guadalupe-Blanco), are primarily conservation and reclamation entities. Each of these authorities has some electrical power generation capabilities but none has more than 100 megawatts of installed capacity.[46]

Exhibit 27-12 details the number of customers served by each different utility type. The term "customer" represents one electric meter; for example, one residential customer represents one house or apartment.

ELECTRICITY RATES

Utility companies typically offer different electric service rates for each customer class: residential, commercial and industrial. In regulated retail areas, PUC sets rates for IOUs in each class based on their costs, allowing them to earn an approved rate of return on their investments. In deregulated retail areas, each REP sets its rates based on what the market will pay.

Texas' retail deregulation began on January 1, 2002, based on legislation passed in 1999.[47]

Texas' MOUs and cooperatives set their own rates, which typically include payments to the municipality in lieu of taxes and a margin to cover unanticipated costs and support new investments.[48] These rates are not regulated by PUC, but the agency has appellate jurisdiction over rate disputes involving municipal utilities.

DEREGULATION

Following the breakup of AT&T in the early 1980s, and the subsequent growth of new telephone vendors and providers, Congress provided for limited competition in the power generation industry with the Energy Policy Act of 1992, which allows complaints to be filed with the FERC to obtain transmission service. In 1996 FERC adopted a broad requirement that the utilities it regulates provide open transmission access that would permit other utilities and independent generators to sell electricity to any wholesale buyer. FERC adopted a code of conduct that provided a separation of the transmission personnel from the wholesale sales personnel of an integrated utility.

Deregulation in Texas required formerly vertically integrated investor-owned utilities to divide into independent business units to generate power, transmit it or sell it to retail customers.

Texas' retail deregulation of electricity in 1999 was intended to lower prices and increase choice for consumers while providing an attractive business climate for new, privately held providers of generation or retail services.[49]

Supporters pointed out that the old regulatory model created incentives for regulated IOUs to

EXHIBIT 27-12

Utilities' Share of Texas Residential, Commercial and Industrial Customers, by Type (both Inside and Outside of ERCOT), March 2007

Utility Ownership	Residential Customers	Percent of Residential Customers	Commercial Customers	Percent of Commercial Customers	Industrial Customers	Percent of Industrial Customers
Cooperatives	1,336,188	16%	211,056	14%	21,040	18%
Municipals	1,312,740	15	185,175	12	1,783	1
IOUs (Deregulated)	4,927,987	58	940,050	63	85,450	72
IOUs (Regulated)	916,394	11	165,108	11	10,872	9
Total	8,493,309		1,501,389		119,145	

Source: Public Utility Commission of Texas.

increase their capital investments, since they were allowed a percentage rate of return on the capital investments. While the rate of return percentage would remain the same, a utility could earn more profit if its capital investments were higher.

Competition tends to encourage markets to lower their costs, and therefore prices, to attract customers. Changing from a regulator's estimate of a utility's average cost pricing (under regulation) to market-driven marginal cost pricing is expected to result in lower prices, assuming other factors remain constant.

Supporters believed that competition is always a better way to set rates than government regulation. With this in mind, all customers — from small residential consumers to large industrial plants — would benefit financially from utilities competing in an open market.

Critics believed deregulation would not bring lower rates to consumers and ultimately could jeopardize the reliability of electrical supplies. They pointed to rocky deregulation experiences in other states as a warning against moving too quickly. Critics believed electric costs were declining already in a regulated market, and that deregulation would only boost profits for utilities without lowering costs for consumers.

Texas' transition from a regulated to partially deregulated industry in Texas has been a complex and lengthy process. Before 2002, PUC regulated the retail rates for all investor-owned electric utilities in the state.

IOUs were allowed to operate within a particular territory, and generally owned their own generation, transmission and distribution facilities. The IOU was obligated to serve every customer within its territory that requested service. Customers had one energy company, one bill and a "bundled" rate; that is, each bill listed rates for the electricity that were based on the operations and maintenance costs plus a regulated rate of return on the utility's capital investment for all of the functions of producing, delivering, and selling electricity to customers.

The 1995 Texas Legislature began deregulating electricity, beginning with the statewide wholesale market. Senate Bill 373 of that year had two main requirements: utilities were required to provide stand-alone, wholesale transmission service on a non-discriminatory basis, and independent generating companies (referred to as exempt wholesale generators) were explicitly permitted to compete in the wholesale market. In 1996, PUC adopted open access transmission rules to implement S.B. 373 and directed that an independent system operator be established. ERCOT became the state's ISO.[50]

Retail competition — called "Texas Choice" — began in January 2002. The 1999 Legislature deregulated retail electricity with S.B. 7, but only in areas served by IOUs. This law also permitted PUC to delay competition in areas where PUC concluded that fair competition could not be ordered. Competition was delayed in the non-ERCOT areas pursuant to this provision and other sections of the Public Utility Regulatory Act. MOUs and cooperatives within ERCOT were not required to deregulate but can opt to do so.

S.B. 7 required IOUs to separate their business activities (where retail competition was initiated) into three separate companies: a wholesale power generation company, a transmission and distribution company and a retail electric provider. This separation could take place either through the sale of assets to another party or by the creation of separate companies.[51] In addition, while the utilities were required to create separate companies to perform these functions, they could maintain common ownership through a holding company structure. These separated companies could not discriminate in favor of, or collude with, one another or make claims of superior reliability.[52]

Once the separation was complete, the newly created REP in each area was then distinguished as the incumbent or "affiliated" REP, and as the former monopoly provider it was subject to specific limitations on its behavior in the nascent market. ("Affiliated" is a reference to that REP's prior status as part of the former monopoly utility.) Affiliated REPs (AREPs) could enter one another's territories, and new-entrant companies could create new competitive REPs (CREPs) to compete with the incumbent REPs.

The most important limitation on the incumbent AREPs was PUC regulation of the incumbent AREP's price for residential and small com-

Texas' transition from a regulated to partially deregulated industry in Texas has been a complex and lengthy process.

mercial customers; this became the price new competitors had to beat to lure consumers away from their existing electric provider. This price was known as the "price to beat." For large commercial customers and industrial customers, there was no PUC-regulated rate, and prices were established by competitive forces beginning in January 2002.

For three years, AREPs were not allowed to alter their "price to beat," except to request adjustments due to increases in natural gas prices, unless or until a minimum of 40 percent of their customers within each of the two customer classes (small commercial and residential) had left for new competitors. As of September 2004, more than 18 percent of residential customers and more than 25 percent of non-residential customers switched.[53]

On January 1, 2005, AREPs were allowed to lower their prices without any approval from PUC. They could not, however, *increase* their price without PUC approval, and price increases due to natural gas prices could be requested only twice per year. After January 2005, some AREPs began offering new plans with lower rates. Customers then could choose a lower-rate plan and stay with their same REP.

As of May 31, 2007, 5.4 million Texas customers lived in areas open to electric competition.

Finally, the "price to beat" was eliminated entirely on January 1, 2007, allowing the AREPs to set whatever price they choose. At this point, the retail electric market was considered fully competitive in the applicable areas. By this time the switch rate had grown to 36 percent for residential, and more than 38 percent for commercial and 72 percent for industrial.[54]

The Competitive Market

As of May 31, 2007, 5.4 million Texas customers lived in areas open to electric competition.

Of those 5.4 million customers, 2.5 million or 39 percent had chosen to switch their electric service from the AREP to a new CREP as of May 2007 (**Exhibit 27-13**).[55] However, the 61 percent who were served by the former AREP would include many customers who had switched to a competitive product offered by that CREP, and also customers that had switched but had been "won back" by the AREP. About 84 percent of the customers with a CREP, or 2.1 million Texans, were residential customers.[56]

In September 2006, 34 percent of the customers who switched to a CREP purchased 56 percent of the electricity sold to all customers in those areas.[57] This indicates that larger customers are more likely to switch REPs than smaller customers. This hardly seems surprising, as larger customers have a greater financial incentive to find lower electricity rates. This observation is reinforced by the fact that residential customers represented 83 percent of the total number of customers in 2006 who switched services, but used just 20 percent of the electricity sold to switched customers.[58]

Each of the five retail service territories in ERCOT open to competition has REPs with varying numbers of electric service products available to residential customers.[59] Each REP may offer multiple products or service packages within any region, allowing customers to choose among different types of energy sources or pricing options. Consumers interested in promoting "green" renewable energy

Exhibit 27-13

REP Switching in the ERCOT Power Region, June 2007

	Customers in Competitive Areas	Percent	Customers Who Switched	Percent	Percent Who Switched
Residential	5,393,286	84.7%	2,103,828	84.0%	39.0%
Commercial	965,512	15.2%	398,826	15.9%	41.3%
Industrial	3,560	0.1%	2,537	0.1%	71.3%
Total	6,362,358	100.0%	2,505,191	100.0%	39.4%

Source: *The Electric Reliability Council of Texas.*

production, for instance, can choose an electric service package that uses renewable energy.

PUC and FERC continue to regulate IOUs in areas of Texas outside of ERCOT's power region. (More information on the Texas electricity market can be found in **Appendix 1.**)

Educated Consumer Choice

One of the biggest challenges for consumers in the new competitive market is how to choose the best or lowest-price REP for their needs. Surveys since 2002 have revealed that consumer knowledge of electricity pricing and costs is growing, but it will take time for all consumers to be ready to make informed choices.[60]

To aid consumers, PUC requires REPs to produce an Energy Facts Label, designed to standardize electricity information so that consumers in deregulated areas can compare competing REP prices. The label resembles the nutrition labels found on many food products, and provides information on electricity prices, contract terms, sources of generation and emissions levels (**Exhibit 27-14**).

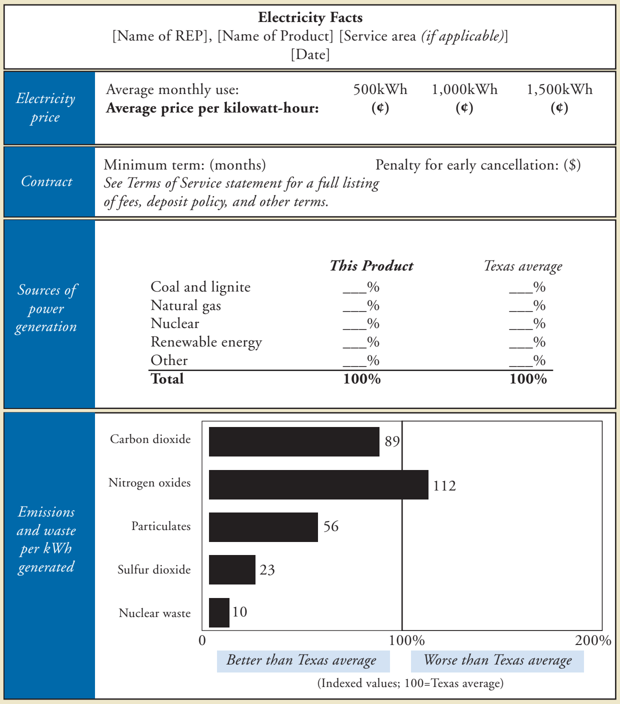
Has Deregulation Succeeded?

Texas' wholesale deregulation is widely viewed as successful, but the results of Texas' retail deregulation legislation are disputed. Supporters say deregulation has achieved what the legislation intended and that prices are comparable to where they were when deregulation began in January 2002, despite a 105 percent increase in the price of natural gas as of September 2007.[61] Critics say deregulation has raised prices for consumers and increased the profits of investor-owned competitive market participants.

Much of this difference in viewpoints, however, comes from differing understandings of what deregulation was intended to accomplish. According

Exhibit 27-14

Electricity Facts Label



Electricity Facts
[Name of REP], [Name of Product] [Service area *(if applicable)*]
[Date]

Electricity price

Average monthly use:	500kWh	1,000kWh	1,500kWh
Average price per kilowatt-hour:	**(¢)**	**(¢)**	**(¢)**

Contract

Minimum term: (months) Penalty for early cancellation: ($)
See Terms of Service statement for a full listing of fees, deposit policy, and other terms.

Sources of power generation

	This Product	*Texas average*
Coal and lignite	___%	___%
Natural gas	___%	___%
Nuclear	___%	___%
Renewable energy	___%	___%
Other	___%	___%
Total	**100%**	**100%**

Emissions and waste per kWh generated

Source: Public Utility Commission of Texas.

Retail electric providers' rates in deregulated areas of Texas may be particularly sensitive to changes in natural gas prices.

to the federal Electric Energy Market Competition Task Force:

> …prices are expected to guide consumption and investment decisions, leading to more economically efficient investments and lower prices than under traditional cost of service monopoly regulation.[62]

In its review of deregulated states, this task force concluded that it is difficult to draw conclusions about the effect of retail competition on prices, mostly because of the structure of the price caps in the newly deregulated market. It further stated: "there is no reason to believe, however, that retail competition in this market will not function as competition does in any market, by reducing quality-adjusted prices."[63]

Supporters of Texas deregulation say it provides more choices for customers and better service, and that rates ultimately will be fairest when set by the market rather than a regulator. They say the increase in rates since deregulation was caused not by the new competitive market, but rather by market forces such as the spiraling cost of natural gas, and events such as hurricanes Katrina and Rita, which would have forced rates up even under regulation. In fact, supporters believe consumer electric rates would have risen even more than they have since 2002 if the market had remained regulated.[64]

Critics say deregulation has severed all ties between price and cost, allowing the private sector to raise prices for consumers and profits for the deregulated, investor-owned power generation companies and REPs. Critics compare rates in deregulated areas to rates under regulated, municipally owned utilities and co-ops; on average they state, MOUs, co-ops, and IOUs within Texas still subject to rate regulation charge lower rates than deregulated IOUs.[65] **Exhibit 27-15** identifies residential rates in select areas of the state.

Natural gas prices have increased drastically worldwide since the start of deregulation in 2002, a major cause of electric price increases for those IOUs with predominately natural gas fuel mixes. Texas, which generates about half its electricity from natural gas, has seen electricity rates rise as gas prices have increased.[66]

REP rates in deregulated areas of Texas may be particularly sensitive to changes in natural gas prices, since a majority of Texas electricity is generated by natural gas. These providers must purchase electricity on the wholesale market and then sell it to commercial or residential customers. Prices on the wholesale market, therefore, tend to fluctuate along with natural gas prices.

MOUs and regulated vertically integrated utilities that can retain ownership of power plants base prices on their average costs, including capital investment, return, operations and maintenance expenses, and fuel costs. Deregulated REPs are more likely to charge their customers rates tied to the marginal cost of wholesale electricity prices, which in turn are correlated with natural gas prices. Marginal costs will exhibit greater variability than average costs and thus, some argue, rates in the deregulated areas of Texas have been higher in recent years largely because of increasing natural gas prices.[67]

Supporters of deregulation also argue that MOUs and co-ops have a higher percentage of coal generation, which is significantly cheaper than the predominantly natural gas fuel mix for IOUs. Critics point out that regulated MOUs and co-ops also avoid the costs of federal taxes and profits, thus allowing them to offer lower rates to consumers.[68]

PUC measures the success of the deregulated market by the number of REPs available in the market; the number of customers who choose to switch from an AREP to a CREP; and the number of customer complaints it receives. The good news, PUC says, is that there is an abundance of new REPs and service plans, some with prices below the formerly regulated rate.[69] Nearly 50 percent of all residential customers, however, have not selected a cheaper plan either with their affiliate REP or a new, competitive REP, even though they are available.

THE OUTLOOK FOR ELECTRICITY

The Texas state demographer projects that the state's population will rise to more than 33 million in 2025, and more than 36 million in 2030.[70] This growing population will create a rising demand for electricity in all sectors. Federal and state poli-

Exhibit 27-15

Residential Rate Comparisons in Texas, December 2007

City	Retail Electric Provider	Average Cost Per Kilowatt Hour (kWh)	Reliability Council	Deregulated
Amarillo	Xcel	$0.083 kWh	Southwest Power Pool (SPP)	No
Austin	Austin Energy (City of Austin)	$0.084 kWh	Electric Reliability Council of Texas (ERCOT)	No
Beaumont	Entergy Gulf States	$0.113 kWh	Southeastern Electric Reliability Council (SERC)	No
Brownsville	Brownsville Public Utility Board	$0.100 kWh	ERCOT	No
Dallas*	TXU Energy	$0.139 kWh	ERCOT	Yes
El Paso	El Paso Electric	$0.113 kWh	Western Electric Coordinating Council (WECC)	No
Houston*	Reliant Energy	$0.141 kWh	ERCOT	Yes
Laredo*	AEP Texas Central	$0.156 kWh	ERCOT	Yes
Lubbock	Lubbock Power and Light	$0.083 kWh	SPP	No
Odessa*	TXU Energy	$0.139 kWh	ERCOT	Yes
San Antonio	City Power Service (City of San Antonio)	$0.067 kWh	ERCOT	No

*The average kWh charge listed for these cities is based on the rates charged by the largest electric provider in the area for a 12 month electric rate program.
Source: Public Utility Commission of Texas.

cies and market forces will determine how this demand will be met.

Texas has access to energy resources sufficient to meet its projected electricity demands through 2030 and beyond. Generating capacity is likely to be a bigger concern for Texas in the future.

Projected Demand

By 2030, the federal Energy Information Administration (EIA) projects that U.S. commercial demand for electricity will rise by 63 percent, residential demand will rise by 39 percent, while the industrial sector will rise by 17 percent. The increase in demand will be due not only to population growth, but also to increased disposable income, which spurs increased purchases of products and homes with additional floor space needing electricity.[71]

Historically speaking, energy demand and consumption are correlated to three factors: the state's economy and demography, which affect mid- and long-term variations in energy demand, and the weather, which affects short-term variations.[72]

ERCOT expects energy demand in its power region to increase by 39.4 percent from 2007 through 2025, from about 313 million megawatt-hours (MWh) to more than 436 million MWh, while peak demand is expected to increase at about the same rate, rising by 40.9 percent, to 89,883 MW in 2025 (**Exhibit 27-16**).[73]

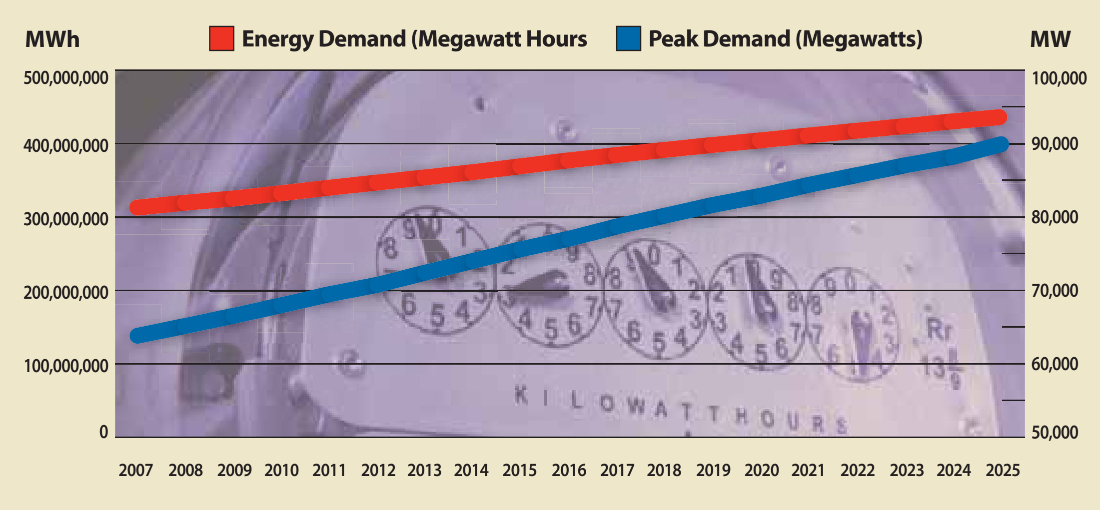
The average hourly load in the ERCOT power region increased by 22.5 percent from 1997 to 2006. The average hourly load is expected to rise by 22.9 percent over the next 9 years (**Exhibit 27-17**).[74]

ERCOT has set a target reserve margin of 12.5 percent for electricity generation capacity within its boundaries. The reserve margin is the amount by which capacity exceeds projected peak hourly load, which typically occurs on afternoons in July and August in the ERCOT region.[75] ERCOT projects that, given expected population and economic growth, the reserve margin will drop below the 12.5 percent target as early as 2008, though reserve margins will exceed 12.5 percent by 2009 if planned generation facilities come online.[76]

ERCOT expects energy demand in its power region to increase by 39.4 percent from 2007 through 2025.

Exhibit 27-16

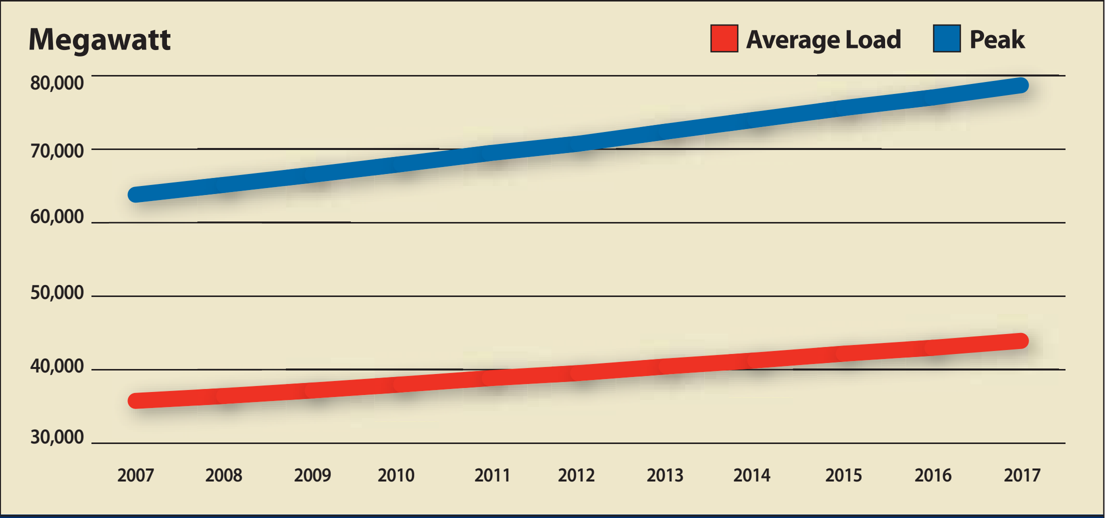
Annual Energy and Peak Demand Forecast 2007-2025, ERCOT Power Region



Source: Electric Reliability Council of Texas.

Exhibit 27-17

MWh Peak Demand and Average Hourly Load Forecast in ERCOT Power Region, 2007-2017



Source: Electric Reliability Council of Texas.

Meeting the growing demand for electricity in Texas will require new generation and transmission capacity. ERCOT projects $3.1 billion in spending on transmission lines from 2007 through 2011 and that another $3 billion will need to be invested from 2011 through 2016 in order to ensure adequate transmission capacity.[77] Substantial investments in new generating capacity also will be needed. In the longer term, increased energy efficiency and demand response may also act to limit consumption.

Meeting Projected Needs

According to EIA, coal-fired plants will continue to provide the nation's largest share of electricity for the foreseeable future, producing 57 percent of the nation's electricity by 2030, followed by natural gas (16 percent) and nuclear power (15 percent).[78]

The projected fuel mix for Texas is different, however, due to our greater use of natural gas and the difficulty in building new Texas coal plants due to environmental issues. In Texas in 2006, 49 percent of generation came from natural gas, compared with 37 percent for coal.[79]

Federal and state policy, along with technological breakthroughs, could lead to substantial deviations from these projections. Policies to limit carbon emissions currently being considered by Congress, for example, could erode coal's price advantages. If carbon emissions are taxed or capped in some manner, the price of using coal to generate electricity with current technology is sure to increase. Unless currently experimental technology to capture carbon emissions is proven to be effective and affordable, any restrictions on carbon emissions will force Texas and the U.S. to turn to new sources of energy to meet future electricity demands.

Texas has a competitive wholesale market structure and new power plant decisions are left up to private investors (or public power entities such as Austin Energy and San Antonio's City Public Services, or CPS). Under this system, all risks related to new power plants — construction cost overruns, fuel costs and compliance with future environmental regulations — are borne by the investors. **Exhibit 27-18** indicates the types of power plants that are being evaluated by developers within ERCOT.

The electric industry is in the midst of a significant period of change and the predominant type of power plants being evaluated have changed rapidly. A significant portion of the possible power plants (**Exhibit 27-19**) will not be completed for a wide variety of reasons. Any power project that does ultimately move to completion requires a signed interconnection agreement. During 2007, there were 19 interconnection agreements signed of which 17 were for wind power projects, representing 78.6 percent of the new MW capacity that have committed to connect to the ERCOT system.[80]

Since the collective output of numerous wind power plants is variable, large amounts of wind power create challenges in planning for capacity adequacy. During summer afternoons coincident with peak loads, ERCOT data suggests the output of Texas wind power plants typically *average* about 23 percent of their nameplate rating except along the South Texas coast, where sea breeze driven winds result in an average of about 50 percent.[81] There are instances, however, when wind generation can drop dramatically, well below the average nameplate rating. In February 2008, ERCOT had to shutoff power to some industrial users to prevent rolling blackouts partially due to a sudden drop in wind. To ensure reliability of the system, it is appropriate to view a new, variable output resource like wind power conservatively until such time as it is better understood how it will integrate within the system.

Meeting our growing demand for electricity will require large capital investments in generation and transmission capacity. Another factor that is expected to make future generating plants

Meeting the growing demand for electricity in Texas will require new generation and transmission capacity.

EXHIBIT 27-18

Generation Interconnection Requests by Fuel Type through 2007, MW

Fuel	Public	Not Public	Total
Coal	4,841	2,708	7,549
Natural Gas	3,708	26,367	30,075
Nuclear	5,986	6,400	12,386
Other	0	425	425
Wind	9,631	31,486	41,117
Total	24,166	67,386	91,552

Source: Electric Reliability Council of Texas.

EXHIBIT 27-19

Generation Interconnection Request Activity in 2007

Screening Studies Requested

Fuel	Number of Plants	MW
Coal	6	2,008
Natural Gas	40	23,613
Nuclear	2	6,400
Other	0	0
Wind	79	29,478
Total	127	61,499

Interconnection Studies Requested

Fuel	Number of Plants	MW
Coal	4	383
Natural Gas	17	5,292
Nuclear	3	9,100
Other	1	45
Wind	45	13,076
Total	70	27,896

Interconnection Agreements Signed

Fuel	Number of Plants	MW
Coal	1	581
Natural Gas	1	255
Nuclear	0	0
Other	0	0
Wind	17	3,064
Total	19	3,900

Source: The Electric Reliability Council of Texas.

significantly more expensive than existing plants is accelerating global demand for basic materials such as steel and copper and skilled personnel to build and operate power plants. These factors could coincide with new policies that increase the cost of burning fossil fuels. A restricted fuel supply resulting from resource depletion or new regulatory restrictions, combined with increased demand for electricity, will translate into higher electricity costs, unless new technologies reduce the cost or expand the supply of other sources of energy, or lead to efficiency gains that reduce energy demand. Higher electricity prices are also likely to affect demand for electricity as homeowners and businesses turn to more energy-efficient homes and commercial buildings and more efficient appliances.

The continuing growth of the Texas economy depends on the ability for residents and businesses to access affordable and reliable electricity. Texas must find ways to expand generating capacity, continue the trend toward improved efficiency and diversify our energy portfolio to meet the state's growing electricity demand.

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CHAPTER 28

Government Financial Subsidies

INTRODUCTION

Previous chapters examined fuel sources and efficiency measures that might help meet Texas' energy needs. This chapter will examine one aspect of government involvement in the energy industry: financial subsidies.

As noted in the Overview to this report (Chapter 2), and in the chapters discussing specific fuel sources, government action can affect the development of energy resources. This chapter discusses one form of government action – financial subsidies directed at specific fuel sources. In order to make comparisons across fuel sources, this chapter **estimates** financial subsidies for the most recent year for which complete data were available, 2006.

WHAT ARE GOVERNMENTAL FINANCIAL ENERGY SUBSIDIES?

In May 1999, the Office of Policy at the U.S. Department of Energy asked the Energy Information Administration (EIA) to prepare an update of its 1992 Service Report on federal energy subsidies, using a more specific definition of "subsidies" provided by the Office of Policy. In their letter requesting the study, the Office of Policy asked the EIA to examine programs through which government or a public body provided a "specific financial benefit" covering "primary energy only" (As opposed to efficiency standards or similar services not tied to specific fuel sources).[1]

For many years, federal, state and local governments have provided subsidies to energy producers and purchasers to encourage the development and production of various fuel sources. These subsidies provide financial support for specific industries in the form of tax incentives, direct spending, research and development funds and other support mechanisms.

The federal government has traditionally used financial subsidies to encourage the development of new energy sources, to improve the extraction or production of the energy source, or to encourage domestic production of the energy source.

As early as 1916, the federal government instituted income tax incentives to encourage individuals and corporations to drill for oil. During the 1930s, federally financed dams created hydroelectric power. From the 1950s onward, the federal government financed research into nuclear power. More recently, the federal government has provided research funding and other financing to expand the availability of renewable energy sources.[2] Virtually all U.S. energy resources have received or currently receive subsidies.

As a result of this complex web of subsidies, Texans as both energy consumers and federal, state and local taxpayers may pay more for some energy sources than is reflected in their electric bill or the posted price at the gas station. Finding the cost of energy produced by different fuels has implications for the choices made by individual Texans, Texas businesses and policymakers.

Texans as both energy consumers and federal, state and local taxpayers may pay more for some energy sources than is reflected in their electric bill or the posted price at the gas station.

PREVIOUS ENERGY SUBSIDY STUDIES

Relatively few studies examining federal energy subsidies for different types of fuels have been conducted, and some of those are more than five years old and thus do not include the results of major recent changes in federal law. Still other studies provide figures on total subsidies, but relatively little detail on which subsidies are included in their estimates.

Practical difficulties may explain why so few studies of federal subsidies have been completed. Detailed assessments of federal subsidies across multiple fuels require months of work and a wide scope of knowledge. The necessary data often are lacking and many incentives are difficult to quantify. Furthermore, subsidies for energy sources occur in many government programs across multiple agencies, and the U.S. government itself does not compile comparative information about them.

For these reasons, examinations of subsidies and costs applicable to different fuel sources tend to be infrequent and incomplete. Chapter 30 lists some additional subsidy studies.

COMPTROLLER'S ENERGY SUBSIDY STUDY

Due to the lack of up-to-date, documented data on federal fuel subsidies, the Texas Comptroller of Public Accounts has undertaken an independent **estimate**. In addition, the agency has documented Texas state and local government subsidies for different types of fuels, to examine their total cost for Texas taxpayers and consumers.

The Comptroller's estimates focus on federal, state and local government *financial* subsidies for different fuel sources. Financial subsidies provide the most direct governmental incentives for businesses to produce a particular type of fuel. While it is impossible to capture all government support for different energy sources, even partial evaluations can suggest the scale and comparative levels of support. This study does not include externalities such as environmental or health costs, because they often occur outside the scope of a single year and are difficult to quantify and tie to a single fuel source.

The Comptroller's office has completed an estimate of federal, state and local subsidies for fuels for 2006. Unless otherwise noted, federal subsidies are for the federal fiscal year (FFY), which runs from October 1, 2005 to September 31, 2006; Texas state subsidies are for the state fiscal year (FY), which runs from September 1, 2005 to August 31, 2006; and Texas property tax subsidies are for the 2006 calendar year.

This chapter focuses on identifying energy expenditures of different types of fuels through a relatively simple formula (**Exhibit 28-1**).

This analysis does not include subsidies for energy storage or conservation, since this study focuses on subsidies to fuel types. Subsidies are allocated to specific fuel sources unless information is not available. (See Appendix 2 for more information on the Comptroller's methodology and why some types of subsidies were included and excluded.)

EXHIBIT 28-1

A Simple Formula

***Taxpayer* Energy Subsidies**

+

***Consumer* Energy Spending**

=

Total Energy Spending

Source: Texas Comptroller of Public Accounts.

FEDERAL ENERGY SUBSIDIES

The federal government provides financial energy subsidies through tax incentives; direct spending for government services; the assumption of certain types of liability or risk by the federal government; government ownership of energy production; access to resources on federal lands and tariffs (**Exhibit 28-2**).

The federal government offers energy producers and purchasers tax incentives, such as credits, deductions, exemptions and allowances. For example, purchasers of clean-fuel burning vehicles may receive a federal income tax credit.

The federal government provides grants and loans to encourage the development and purchase of certain energy systems, such as the purchase of renewable energy systems. Grants and loans are two examples of direct federal spending. Direct spending (also called direct expenditure) is a term used by previous studies of energy subsidies to describe federal programs through which the federal government provides direct financial benefits to energy producers or consumers.[3]

Grants are counted at full face value since they are a direct financial benefit to the grantee. Loans are counted only to the extent that they lower the "price" of money to the loan recipients. Government loans may come with lower interest rates, so the differential between a commercial interest rate and the government rate is the only subsidy counted. Previous studies of energy subsidies count loans in this manner, and have concluded that providing loans is "widely recognized as an energy subsidy."[4]

The federal government appropriates funds for government services for the energy industry that are not covered by industry fees or trust funds. The most common direct spending appropriation is for research and development for a specific type of fuel, for example, research and development for solar energy. This study does not include federal spending for regulatory activities.

The federal government can assume part of the risk for the activities of energy producers, for example, assuming part of the risk and fiscal responsibility for the cost of nuclear power accidents. These are costs that would otherwise need to be paid under a private commercial insurance plan.

The federal government owns some energy production facilities, especially hydroelectric dams. The cost of operating these facilities may be subsidized, for example, when the federal government does not charge energy consumers the full amount of the costs to produce the energy. The facility receives direct appropriations from the federal government and, unlike a private company, does not have to make all of its revenues from ratepayers.

The federal government provides access to federally owned lands for energy producers. These lands may be leased for their natural resource production. Some subsidy studies point to reduced royalties for oil leases on government lands, where the federal government receives below-market value for oil royalties. Sales of timber from federal parks and forests may be similarly low-priced. The amount of the below-market pricing is the amount of the subsidy counted in this study.

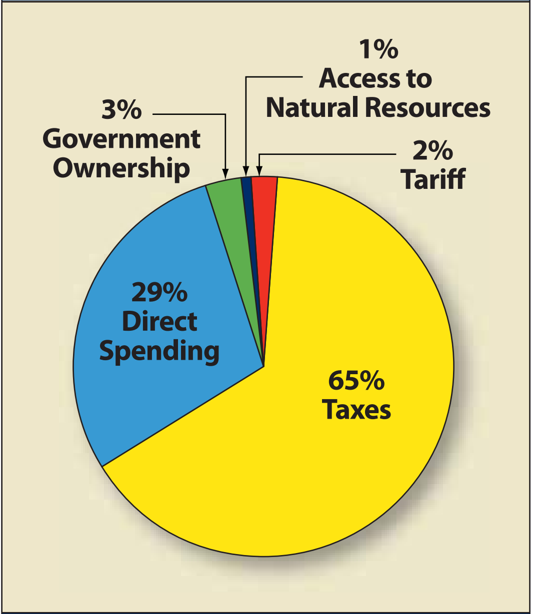
Finally, tariffs may restrict the importation of foreign fuel and favor domestic energy producers. The U.S. tariff on Brazilian ethanol is one example. It allows U.S. ethanol producers to sell their product at higher prices than they would be able to charge if they had to compete with cheaper, imported ethanol if there were no tariff. In this instance, the subsidy total is the amount of the tariff collected from ethanol importers.

Tariffs may restrict the importation of foreign fuel and favor domestic energy producers.

Exhibit 28-3 describes and provides examples of these subsidies.

EXHIBIT 28-2

Estimated Percent of Total Federal Subsidies by Type in 2006



Source: Texas Comptroller of Public Accounts.

TEXAS STATE AND LOCAL ENERGY SUBSIDIES

Like the federal government, Texas state and local governments also provide tax incentives (**Exhibit 28-4**). For example, Texas gives an exemption from the oil and gas severance tax to encourage producers to re-open wells that have not produced for the previous two years and property tax exemptions are available for energy producers as well. Additionally, Texas local utilities provide homeowner incentives, such as rebates for installing solar photovoltaic systems.

EXHIBIT 28-3

Types of Federal Financial Energy Subsidies

Types of Financial Subsidies	Descriptions	Examples
Taxes	Special tax credits, deductions, exemptions and allowances related to the federal tax code	• Income tax deduction of certain domestic oil and gas drilling costs • Income tax credit for purchase of clean-fuel burning vehicles
Direct Spending	Annual federal appropriations for government services, grants or loans, frequently for research and development (this does not include the costs of regulatory agencies or costs covered by industry fees or trust funds)	• US Department of Energy funding for research and development of renewable energy • U.S. Department of Agriculture spending for corn subsidies • U.S. Department of Agriculture funding for grants or loans to farmers for purchasing or upgrading renewable energy systems (loans subsidies include only the difference between government interest rates and commercial interest rates)
Liability/Risk Assumption	Assumption of liability or risk by the federal government for activities of energy producers	• Nuclear reactor liability (sole example in this study)
Government Ownership of Energy Production	Federal ownership of hydroelectric power and other power generating facilities	• U.S. Department of Energy ownership of hydroelectric power-producing dams that sell power below market price • Tennessee Valley Authority ability to issue debt to pay for construction and to sell power below the cost of recovering the full amount of debt owed
Access to Resources on Federal Lands	Government-owned resources which are leased or sold to energy producers at below-market pricing	• Oil royalties paid by energy producers at below-market pricing • Forest service timber sales at below-market pricing
Tariffs	Tariff restricting import of ethanol	• U.S. tariff on Brazilian ethanol (sole example in this study)

Source: Texas Comptroller of Public Accounts.

EXHIBIT 28-4

Types of State and Local Financial Energy Subsidies

Types of Financial Subsidies	Descriptions	Examples
Taxes	Special tax credits, deductions, exemptions, allowances and property tax incentives	• Tax exemption for oil and gas production for a wellbore certified as non-producing for previous two years • Chapter 312 property tax abatements and Chapter 313 property value limitations
Homeowner Incentives	Rebates, leasing/lease purchase programs	• Monetary rebate for customers who install solar photovoltaic systems • Program to lease or purchase solar water pumping systems directly from utility company
Direct Spending	Grants from matching general revenue funding	• Fuel Ethanol and Biodiesel Production Incentive Program (sole example in this study)

Source: Texas Comptroller of Public Accounts.

TOTAL FEDERAL SUBSIDIES BY FUEL SOURCE

The Comptroller's office estimates that the total amount of federal energy subsidies for 2006 was $13.6 billion. Ethanol had the largest share, at $4.7 billion, or 34.6 percent of total subsidies. The share of federal subsidies by fuel source is shown in **Exhibit 28-5**.

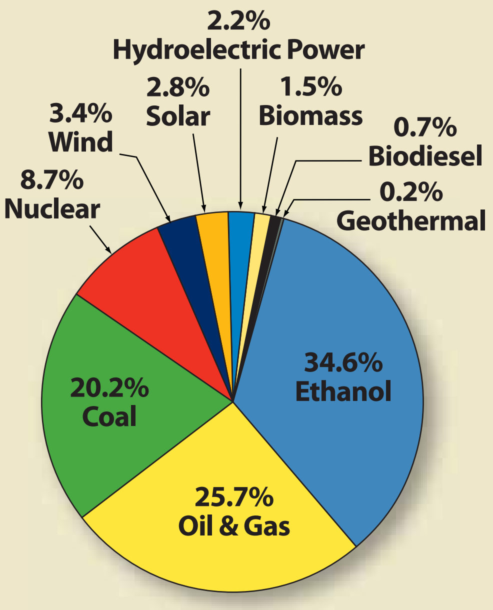
TOTAL CONSUMER SPENDING AT THE FEDERAL LEVEL

One way to evaluate the amount of governmental subsidies is to compare them to the national total of consumer spending for each source of fuel. **Exhibit 28-6** shows federal subsidies for 2006 as compared to national level spending for each fuel source.

EXHIBIT 28-5

Estimated Percent of Total Federal Subsidies in 2006, Allocated by Fuel Source

Total Federal Subsidies: $13.6 billion



Source: Texas Comptroller of Public Accounts.

TEXAS STATE AND LOCAL ENERGY SUBSIDIES

The Comptroller's Office also compiled an estimate of state and local energy subsidies for 2006. In Texas, state and local subsidies totaled $1.4 billion in 2006. Oil and gas garnered most of the subsidies with an estimated 99.6 percent. However, the oil and gas subsidies constituted only 1.5 percent of all Texas spending on oil and gas since the estimated total spending on the oil and gas industry was $94.7 billion in 2006.

TEXAS CONSUMER SPENDING AT STATE AND LOCAL LEVELS

Exhibit 28-7 shows Texas state and local subsidies for 2006 as compared to state spending on each fuel source.

FEDERAL, STATE AND LOCAL SUBSIDIES AS A PERCENT OF CONSUMER SPENDING

In Texas, state and local subsidies totaled $1.4 billion in 2006.

The Comptroller estimates that in 2006 the federal government subsidized 26.5 percent of the cost of ethanol consumer purchases, while no state or local subsidies were granted for ethanol in 2006. The federal government subsidized 9.9 percent of consumer purchases for biodiesel, and Texas state and local governments subsidized 3.1 percent. **Exhibit 28-8** shows subsidies and consumer spending as a percentage of total expenditures in 2006, by fuel source.

Chapter 313 Property Value Limitations

It is important to note that **Exhibit 28-8** does not reflect changes in federal, state and local subsidies that occurred after 2006. One notable change is the rising trend in Texas property tax value subsidies, such as Chapter 313 property value limitations, which have a significant impact on the Texas budget.

Under Chapter 313 of the Texas Tax Code, school districts may provide *Property Value Limitations* to businesses by offering a tax credit and an eight-year limitation on the appraised value of a property, for the maintenance and operations portion of the school district property tax. In exchange for the value limitation and tax credit, the property owner must enter into an agreement with the school district to create a specific number of jobs and build or install specified types of real and personal property worth a

EXHIBIT 28-6

Estimated Federal Government Taxpayer Subsidies as a Share of Total U.S. Consumer Spending in 2006*

Energy Source	Federal Taxpayer Subsidies	Total Energy U.S. Consumer Spending	Total Spending on Energy Source	Federal Taxpayer Subsidies as a Percent of Total Spending
Oil and Gas**	$3,502,732,143	$772,404,554,400	$775,907,286,543	0.5%
Coal	2,754,908,000	37,228,867,200	39,983,775,200	6.9
Nuclear	1,187,426,000	4,506,192,000	5,693,618,000	20.9
Subtotal Nonrenewable	**$7,445,066,143**	**$814,139,613,600**	**$821,584,679,743**	**0.9%**
Ethanol	4,708,277,549	13,082,400,000	17,790,677,549	26.5
Biodiesel	92,315,835	840,350,000	932,665,835	9.9
Wind	457,924,289	3,502,105,629	3,960,029,918	11.6
Solar	382,756,318	2,731,644,481	3,114,400,799	12.3
Hydroelectric power	295,234,608	56,123,748,494	56,418,983,102	0.5
Biomass	209,641,875	50,421,528,417	50,631,170,292	0.4
Geothermal	29,158,534	5,825,057,818	5,854,216,352	0.5
Subtotal Renewables	**$6,175,309,008**	**$132,526,834,839**	**$138,702,143,847**	**4.5%**
Total Subsidies	**$13,620,375,151**	**$946,666,448,439**	**$960,286,823,590**	**1.4%**

*Federal fiscal years run from October 1 to September 30.

**'Oil and gas' includes natural gas production, crude oil production and natural gas plant liquids production.

Sources: Energy Information Agency and Texas Comptroller of Public Accounts.

EXHIBIT 28-7

Estimated Texas State and Local Taxpayer Subsidies as a Share of Total Texas Energy Consumer Spending in 2006

Energy Source	Texas State and Local Subsidies	Total Texas State and Local Consumer Spending	Total Spending on Energy Source	Texas State and Local Subsidies as a Percent of Total Texas Spending on Energy
Oil and Gas	$1,417,434,337	$93,326,324,400	$94,743,758,737	1.5%
Coal	n/a	2,207,721,600	2,207,721,600	0.0
Nuclear	n/a	197,251,200	197,251,200	0.0
Subtotal Nonrewables	**$1,417,434,337**	**$95,731,297,200**	**$97,148,731,537**	**1.5%**
Ethanol	n/a	93,539,160	93,539,160	0.0
Biodiesel	2,107,420	65,967,475	68,074,895	3.1
Wind	1,508,800	833,501,140	835,009,940	0.2
Solar	2,574,101*	25,458,927	28,033,028	9.2
Hydroelectric power	n/a	276,128,843	276,128,843	0.0
Biomass	n/a	1,401,718,490	1,401,718,490	0.0
Geothermal	45,400	18,698,436	18,743,836	0.2
Subtotal Renewables	**$6,235,721**	**$2,715,012,471**	**$2,721,248,192**	**0.2%**
Total	**$1,423,670,058**	**$98,446,309,671**	**$99,869,979,729**	**1.4%**

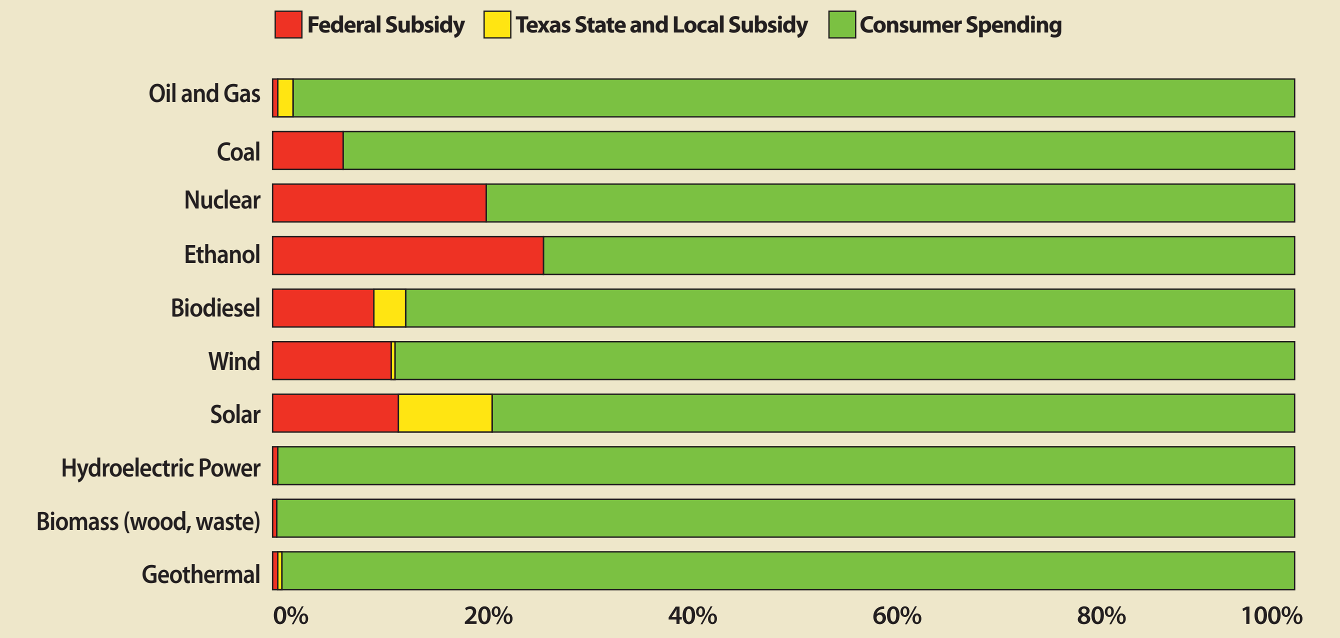
n/a: not applicable

*$2,074,101 of this total comes from Austin Energy utility company.

Sources: U.S. Energy Information Administration and Texas Comptroller of Public Accounts.

Exhibit 28-8

Estimated Subsidies and Consumer Spending as a Percentage of Total Expenditures in 2006



Source: Texas Comptroller of Public Accounts.

certain amount.[5] The 2007 Legislature required the Comptroller to provide a report before the beginning of each regular legislative session assessing the progress of each agreement made under Chapter 313.[6] **Exhibit 28-9** illustrates the projected increase in the Chapter 313 incentive. Based on data collected for the legislatively mandated study, these estimates may be revised later in 2008.

SPENDING ON NONRENEWABLE ENERGY

The Comptroller estimates that the U.S. consumers spent approximately $814.1 billion to generate energy from nonrenewable sources in 2006. This estimate is taken at the time a consumer – either a homeowner or utility company – decides to purchase a type of fuel. Total 2006 spending on nonrenewables, including subsidies, is estimated at $821.6 billion. Nonrenewable subsidies comprised about $7.4 billion of that amount, or less than one percent.

DETAIL: OIL AND GAS SUBSIDIES

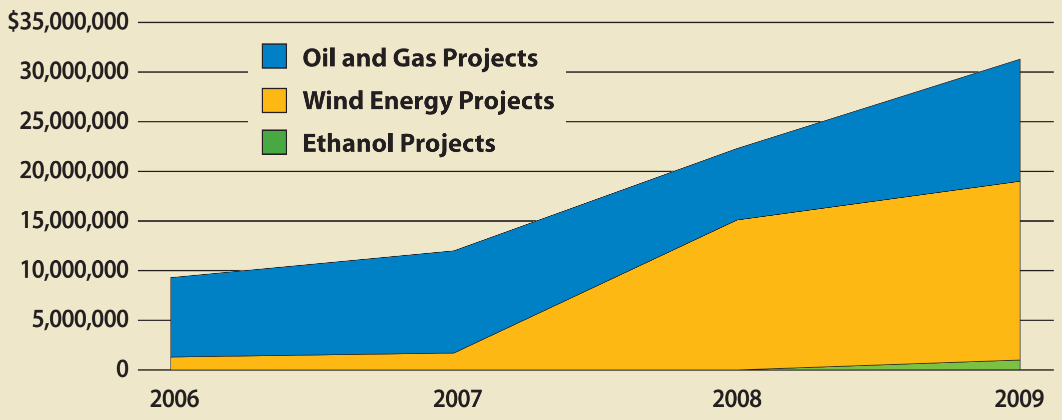
Federal Oil and Gas Tax Subsidies

Federal oil and gas subsidies come in the form of tax incentives for producers and investors; reduced royalties paid by producers for oil leases on federal lands; very small, targeted appropriations to pay for oil and gas research and development; and appropriations for pipeline safety programs and the nation's Strategic Petroleum Reserve.

In 2006, federal tax subsidies for the oil and gas industry amounted to an estimated $3.5 billion, based on tax data from the U.S. Office of Management and Budget (OMB) and additional analysis by the Comptroller. The largest oil and gas tax subsidies are the Expensing of Exploration and Development Costs Credit, the Percentage Depletion Allowance and the Alternative Fuel Production Credit. All are intended to increase the production of domestic oil and gas.

Exhibit 28-9

Estimated State Impact* of Energy-Related Chapter 313 Agreements



* The state impact is the result of tax loss and tax credit costs incurred each year under Tax Code, Chapter 313. Tax Year 2006 amounts were reported to the Comptroller by appraisal districts for the Tax Year 2006 Property Value Study. Amounts for Tax Years 2007 through 2009 were taken from the latest application documents available to the Comptroller for each project, and were used to prepare the Comptroller's estimate of the Chapter 313 cost for the 2007 Tax Exemptions and Tax Incidence report.

Source: Texas Comptroller of Public Accounts.

The *Expensing of Exploration and Development Costs Credit* allows investors in oil or gas exploration and development to "expense" (to deduct from their corporate or individual income tax) intangible drilling costs (IDCs). IDCs include wages, the costs of using machinery for grading and drilling and the cost of unsalvageable materials in constructing wells. These costs are "intangible" in comparison to costs for salvageable expenditures (such as pipes or casings) or costs related to acquiring property for drilling. The credit enables oil and gas producers to immediately write off as an expense these costs from income taxes rather than amortize them (spread the deductions out) over the productive life of the property.

This tax credit, intended to encourage domestic oil and gas exploration, was originally implemented through federal regulations in 1916; it became law in 1954. The Congressional Research Service has estimated that the Expensing of Exploration and Development Costs tax credit was worth $1.1 billion to the oil and gas industry in 2006.[7]

The *Percentage Depletion Allowance* permits independent fuel mineral producers and royalty owners (including oil, gas, coal, geothermal and uranium) to deduct a fixed percentage of gross income for large upfront expenditures from their corporate and personal income tax.

The tax deduction was first implemented in 1926, primarily to encourage oil and gas exploration. It allows eligible oil and gas producers and royalty owners to deduct some expenses associated with acquiring mineral rights and exploring for possible mineral deposits; development costs such as drilling; and costs for capital equipment such as pumps.

The allowance is available only to independent producers who produce fewer than 1,000 barrels per day and any related royalty owners; the deduction is 15 percent of gross income for oil, gas and oil shale. The amount deducted is limited to 100 percent of net income for oil and gas. Under this method, total deductions can exceed the capital invested to acquire and produce an oil or gas reserve.[8] The Congressional Research Service estimates that the oil and gas industry's share of this exemption was $1 billion in 2006.[9] In addition, the Energy Policy Act of 1992 also allows independent oil and gas producers to take larger deductions against the alternative minimum tax for percentage depletion and intangible drilling costs, reducing the amount paid on income taxes by an unknown amount.[10]

The *Alternative Fuel Production Credit*, implemented in 1980, applies to oil produced from shale and tar sands and natural gas produced from geopressured brine, Devonian shale, coal seams or biomass. In 2005, the Energy Production Act added some facilities that produce coke and coke gas to the production credit. In 2006, the credit was worth about $7.05 per barrel of oil-equivalent fuels. The credit has helped promote unconventional gas production and, after 2005, synthetic fuels produced from chemically altered coal.[11] Prior to the Energy Production Act, OMB estimated that the oil and gas industry would receive $890 million from this tax credit in 2006.[12]

The *Exemption from Passive Loss Limitation for Working Interest on Oil and Gas Property Credit* exempts investors from federal passive loss limitation rules that limit the amounts that investors not actively involved in an enterprise in other industries are able to deduct. This benefit was worth $30 million in 2006.[13]

Several smaller tax incentives also are dedicated to oil and gas, including: *Natural Gas Distribution Pipelines Treated as 15-Year Property; Temporary 50 Percent Expensing for Equipment Used in the Refining of Liquid Fuels;* and *Amortization of All Geological and Geophysical Expenditures Over Two Years.*

Many federal subsidies related to discovering or drilling for oil also subsidize natural gas, since a well may produce oil or gas or both. One tax subsidy specific to natural gas, however, is *Natural Gas Distribution Pipelines Treated as 15-Year Property.* This change in the Energy Policy Act of 2005 shortens the depreciation period to 15 years for any gas distribution lines first used after April 11, 2004 and before January 1, 2011. OMB estimated that this saved corporations $20 million in 2006.[14]

Under the *Temporary 50 Percent Expensing for Equipment Used in the Refining of Liquid Fuels* tax deduction, producers of oil from shale and tar sands may expense 50 percent of the cost of refinery investments placed in service before January 1, 2012. These investments must increase the capacity of an existing refinery by at least 5 percent, or increase the volume of qualified fuels by at least 25 percent. OMB estimated that this deduction was worth $10 million in 2006.[15]

The *Amortization of All Geological and Geophysical Expenditures Over Two Years* allows geological and geophysical expenditures incurred in connection with oil and gas exploration in the U.S. to be amortized over two years for independent oil companies and five years for certain major, integrated oil companies, a faster rate than expenses in other industries. OMB estimated the benefit to the oil and gas industry to be $10 million in 2006.[16]

Federal Business Tax Subsidies Available to the Oil and Gas Industry

In addition to tax credits exclusive to the oil and gas industry, the federal government offers general tax incentives to business that some studies contend are particularly beneficial to oil and gas producers. These include the *Accelerated Depreciation Allowance* and the *Foreign Tax Provisions Credit.*

The *Accelerated Depreciation Allowance* greatly benefits the oil and gas industry because of its high capital costs. This tax provision allows business owners to take bigger deductions from corporate income tax in the first years after buying a business asset than would be available under general accounting principles.[17] OMB estimates that the subsidy provided by the accelerated depreciation of buildings (other than rental housing) and machinery and equipment totaled $35.5 billion in fiscal 2006 for all industries.[18]

OMB has not separately estimated the effect of this provision on the oil and gas industry. A private study released in 1996, however, examined corporate tax records as well as statistical data and concluded that the petroleum industry accounted for almost 13 percent of this subsidy. However, since more recent and more detailed information is not available to confirm this relationship, the potential subsidy cannot be estimated, but is simply noted because of its large potential size.

The federal government taxes U.S. companies on their worldwide income. These companies receive a *Foreign Tax Provisions Credit* for taxes paid to other governments, to prevent double taxation. Income earned through controlled foreign corporations is not taxed in the U.S. until it returns home as dividends. In 1996, one IRS study found that in 1992, an average of 13 percent of large companies with foreign tax liabilities were associated with oil and gas.[19] For reasons similar to those stated above for the Accelerated Depreciation Allowance, this potential subsidy cannot be estimated but is simply noted due to its potential size.

Federal Royalty Subsidies

In 2005, federal and Native American lands supplied about 35 percent of the oil and 26 percent of the natural gas produced in the U.S.

Oil and gas companies pay the federal government royalties to drill on federal lands. In 2005, federal and Native American lands supplied about 35 percent of the oil and 26 percent of the natural gas produced in the U.S. Oil and gas companies that lease these lands pay the U.S. Department of Interior's Minerals Management Service (MMS) royalties based on a percentage of the cash value of the oil and natural gas produced and sold. In lieu of royalty payments, MMS may choose to accept crude oil, which is then either sold or placed in the nation's Strategic Petroleum Reserve.[20]

In 1995, Congress passed the Outer Continental Shelf Deep Water Royalty Relief Act of 1995, which authorized MMS to provide royalty relief on oil and gas produced in the deep waters of the Gulf of Mexico from leases issued from 1996 through 2000, a time when oil and gas prices were relatively low. MMS established that this royalty relief would be available only if oil and gas prices fell below certain levels for leases granted in 1996, 1997 and 2000. They did not, however, include this limitation for leases issued in 1998 and 1999.

MMS estimates that the federal government has lost $1 billion on leases granted in 1998 and 1999 for the seven-year period from 2000 to the end of 2006, or an estimated loss of about $143 million a year.[21]

Federal Research and Development Spending

In 2006, Congress appropriated $64 million for *Oil and Gas Research and Development by the Department of Energy (DOE).*[22] Historically, most of this federal funding has gone to joint projects funded with federal, university and independent company funds intended to develop new reserves and extend the life of old ones.[23] Congress also appropriated $6.9 million for *Oil Spill Research in the Department of Interior's Minerals Management Service* in 2006.[24]

Federal Petroleum Reserve Subsidies

The federal government maintains three petroleum reserves, the *Strategic Petroleum Reserve, Naval Petroleum and Oil Shale Reserves* and the *Northeast Home Heating Oil Reserve*. These reserves are intended to provide the nation with emergency supplies of oil in the case of disruptions to commercial oil supplies.[25]

The U.S. *Strategic Petroleum Reserve*, established after the 1973-74 oil embargo and currently managed by the U.S. Department of the Interior, consists of several storage sites created in deep underground salt caverns along the Texas and Louisiana Gulf Coast. The Energy Policy Act of 2005 directed the U.S. Secretary of Energy to fill the reserve to its authorized 1 billion-barrel capacity. Congress appropriated $207 million in 2006 to maintain these reserves.[26]

The U.S. Department of Energy received $21 million in appropriations from Congress in 2006 to manage the *Naval Petroleum and Oil Shale Reserves* program. The Naval Petroleum Reserve is the Teapot Dome field in Casper, Wyoming, which is now a largely exhausted "stripper" field that serves as an oilfield technology-testing center. The U.S. Department of Energy is the lead office coordinating the creation and implementation of a commercial strategic fuel (oil shale and tar sands) development program for oil shale lands in Colorado, Utah and Wyoming. These oil shale lands are federal lands under the administration of the U.S. Department of Interior's Bureau of Land Management.[27]

The *Northeast Home Heating Oil Reserve* is a supply of emergency fuel oil for homes and businesses in the northeast U.S. that was established in 2000. Congress did not appropriate additional funds

Exhibit 28-10

Estimated Federal Oil and Gas Subsidies in 2006

Federal Oil and Gas Tax Subsidies

Subsidy	Type	Amount
Expensing of Exploration and Development Costs Credit	taxes	$1,100,000,000
Percentage Depletion Allowance	taxes	1,000,000,000
Alternative Fuel Production Credit	taxes	890,000,000
Exemption from Passive Loss Limitation for Working Interests in Oil and Gas Properties	taxes	30,000,000
Natural Gas Distribution Pipelines Treated as 15-Year Property	taxes	20,000,000
Temporary 50 percent Expensing for Equipment Used in the Refining of Liquid Fuels	taxes	10,000,000
Amortize all geological and geophysical expenditures over two years	taxes	10,000,000
Subtotal		**$3,060,000,000**

Oil and Gas Industry Share of Federal Business Tax Subsidies

Subsidy	Type	Amount
Accelerated Depreciation Allowance	taxes	cbe*
Foreign Tax Provisions Credit	taxes	cbe

Federal Oil and Gas Royalty Subsidies

Subsidy	Type	Amount
U.S. Department of Interior, Oil and Gas Royalty Losses on 1998 and 1999 Gulf Oil and Gas Leases	access to natural resources	$142,857,143

Federal Oil and Gas Research and Development

Subsidy	Type	Amount
U.S. Department of Energy, Oil and Gas Research and Development	direct spending	$64,350,000
U.S. Department of Interior, Minerals Management Service Oil Spill Research	direct spending	6,900,000
Subtotal		**$71,250,000**

Federal Oil and Gas Petroleum Reserve Subsidies

Subsidy	Type	Amount
U.S. Department of Energy, Strategic Petroleum Reserve	direct spending	$207,340,000
U.S. Department of Energy, Naval Petroleum and Oil Shale Reserves	direct spending	21,285,000
Subtotal		**$228,625,000**
Total		**$3,502,732,143**

*Cannot be estimated.

Percent of Federal Oil and Gas Subsidies in 2006, by Type

Taxes	87.4%	**Government Ownership of Energy Production**	0.0%
Direct Spending	8.6%	**Access to Resources on Federal Lands**	4.1%
Liability/Risk Assumption	0.0%	**Tariffs**	0.0%

Note: Numbers may not total due to rounding.
Source: Texas Comptroller of Public Accounts.

for this program in 2006.[28] Sales from the reserve financed the program in 2006. Current storage contracts are for two million barrels.[29]

The total amount for all three petroleum reserve programs was over $228 million in 2006.

Various taxes represented approximately 87.4 percent of federal government subsidies for oil and gas in 2006 (**Exhibit 28-10**).

Texas State and Local Government Oil and Gas Subsidies

Texas state and local governments offered exemptions for the oil and gas industry and its consumers that totaled an estimated $1.4 billion in state fiscal 2006. The largest of these subsidies came in the form of incentives built into the state's crude oil and natural gas severance taxes.

Texas Crude Oil Severance Tax Incentives

This tax is imposed at a rate of 4.6 percent of the market value of crude oil produced in Texas.[30] Texas producers received a benefit from four incentives from this tax in 2006. The incentives – *Two-Year Inactive Wells, Three-Year Inactive Wells, Enhanced Oil Recovery Projects* and *Co-production* – produced a total of almost $94.5 million in subsidies in 2006 (**Exhibit 28-11**).

The *Two-Year Inactive Wells* program provides a 10-year incentive for oil and gas severance taxes from a well that the Texas Railroad Commission has certified as not producing oil for two years preceding the date of the application for certification; in other words, the incentive applies to dormant wells brought back into production. Wells qualifying for this incentive garnered over $46 million in exemptions in 2006.[31] A comparable *Three-Year Inactive Wells* program gave producers $997,875 in exemptions in 2006.

The *Enhanced Oil Recovery Project* provides a partial 10-year tax incentive from the date of certification by the Railroad Commission as an eligible oil field. Producers pay half the crude oil tax rate or 2.3 percent. This incentive saved producers $45.6 million in 2006.[32]

The *Co-production* exemption provided a 10-year, 50 percent tax incentive for fields designated by the Railroad Commission as being enhanced oil recovery projects that permanently remove water from an oil or gas reservoir to obtain oil that could not otherwise be extracted. In fiscal 2006, the Co-production incentive provided over $1.7 million in subsidies. The incentive ended in fiscal 2007.[33]

Texas Natural Gas Severance Tax Incentives

Texas' natural gas severance tax is imposed at a rate of 7.5 percent of the market value of gas produced and kept within the state. Texas allowed producers four incentives from this tax in 2006: *High-Cost Gas, Two-Year Inactive Wells, Three-Year Inactive Wells* and *Flared/Released Gas*. These gave producers a total of more than $1 billion in subsidies in 2006 (**Exhibit 28-12**).

Exhibit 28-11

Estimated Texas Crude Oil Severance Tax Incentives in 2006

Subsidies	Amount
Two-Year Inactive Wells	$46,135,868
Three-Year Inactive Wells	997,875
Enhanced Oil Recovery projects	45,647,759
Co-production	1,718,444
Total	**$94,499,946**

Source: Texas Comptroller of Public Accounts.

Exhibit 28-12

Estimated Texas Natural Gas Severance Tax Incentives in 2006

Exemption	Amount
High-Cost Gas	$1,108,694,781
Two-Year Inactive Wells	55,829,144
Three-Year Inactive Wells	2,876,612
Flared/Released Gas	36,229
Total 2006	**$1,167,436,766**

Source: Texas Comptroller of Public Accounts.

The *High-Cost Gas* program provides a tax incentive for high-cost gas wells based on the ratio of each well's drilling and completion costs to twice the median cost for all high-cost Texas gas wells submitted in the prior fiscal year. This exemption generated more than $1.1 billion in subsidies in 2006.[34]

The *Two-Year and Three-Year Inactive Wells* programs for natural gas are similar to those for crude oil described in the section above. These provided producers with $58.7 million in incentives in 2006 from the natural gas tax.

The *Flared/Released Gas* program provides a lifetime incentive for gas produced from an oil well and brought to market gas that previously had been released into the air for 12 months or more. It generated just $36,229 in subsidies in 2006.[35]

Texas Motor Fuels Tax

Texas motor fuels tax includes tax exemptions, refunds and credits for both gasoline and diesel fuel. (Tax subsidies for biodiesel and ethanol are discussed in a later section.)

The gasoline tax is charged on each gallon of gasoline sold in Texas used to propel vehicles on Texas public roads. Exemptions include sales to exempt purchasers, such as the federal government, Texas public school districts and nonprofit electric and telephone cooperatives organized under the Texas Utilities Code. They also include exemptions for uses other than propelling a vehicle on Texas public roads, such as aviation, marine, agricultural, construction, industry and commercial and transit-company uses. Texas offered just over $80 million in these exemptions in 2006 (**Exhibit 28-13**).[36]

Texas Diesel Subsidies

Texas' *Diesel Fuel Tax Exemptions* are similar to those for gasoline, except that the state provides additional exemptions for railway engine use, scheduled intra-city bus routes and diesel fuel blends such as biodiesel and ethanol. The value of these exemptions cannot be estimated.

Franchise Tax Exemptions

In 2006, the Texas franchise tax provided tax credits worth an estimated $40 million to the oil and gas industry. The tax credits were primarily for investment, research and development and for job creation. The 79th Legislature, however, changed the franchise tax from a tax based on the greater of net earned surplus (federal taxable income with modifications) or net taxable capital (net worth) to a tax on taxable margins (total revenue minus either the cost of goods sold; the amount of compensation; or 30 percent of total revenue).[37]

This change became effective for tax reports due after January 1, 2008, and will benefit oil and gas companies that subtract the cost of goods sold. In the oil and gas industry's case, the cost of goods sold includes depreciation, depletion and amortization necessary for the production of goods. It also includes intangible drilling and "dry hole" costs (the cost of drilling wells that do not produce sellable oil or gas) as well as geological and geophysical costs incurred to identify and locate property with the potential to produce minerals. The change to this tax was not in effect in 2006 and therefore is not reflected in the estimate.

Under certain conditions, oil and gas producers now will be allowed to exclude certain oil and gas

Exhibit 28-13

Estimated Gasoline Tax Exemptions in 2006

Exemptions*	Amount
Federal government	$10,900,000
Public schools	4,400,000
Sales between license holders	cbe**
Sales for export	cbe
Aviation use	5,600,000
Fuel arriving in the tank of a motor vehicle (non-interstate trucker)	cbe
Fuel lost by fire theft or accident	3,500,000
Marine use	11,600,000
Agricultural use	9,800,000
Construction use	9,500,000
Industry and commercial use	24,400,000
Transit company use	negligible
Electric & telephone cooperative use	500,000
Total	**$80,200,000**

*Exemptions do not include discounts related to tax collection by permit holders.
**Cannot be estimated.
Source: Texas Comptroller of Public Accounts.

revenues from total revenue when they calculate their taxable margin. Those conditions are that the average monthly price of oil falls below $40 per barrel or the average closing price of gas is below $5 per 1 million Btus. The revenue excluded would be that derived from an oil well producing less than 10 barrels a day over a 90-day period or a gas well producing an average of less than 250,000 cubic feet (250 mcf) a day over a 90-day period.

Texas Local Property Tax Exemptions

Local governments may provide property tax incentives for the oil and gas industries. In 2006, Texas school districts reported the oil and gas industries' property taxes were reduced by over $9.3 million in tax benefits as a result of Chapter 313 property value limitation agreements.

Under Chapter 312 of the Texas Tax Code, cities, counties and other taxing districts (except school districts) may provide *Property Tax Abatements*, which are agreements between a taxpayer and a taxing unit that exempt all or part of the increase in value of real property and/or tangible personal property from taxation for a period not to exceed ten years.[38] The Comptroller estimates that in 2006, the oil and gas industries claimed over $22.9 million in Chapter 312 property tax abatements.

In addition to these incentives, the Economic Development property tax refund provides state sales and use tax and franchise tax refunds to some Texas property owners for paying local school property taxes, subject to specific requirements, as defined in Sections 111.301 through 111.304 of the Texas Tax Code. If the total amount of all refunds claimed by property owners in any year exceeds $10 million, the Comptroller must reduce each claimant's refund proportionally so that all property owners share in the $10 million.[39] Oil and gas industries were refunded over $3 million in 2006 through this incentive.

Exhibit 28-14 summarizes subsidies Texas state and local governments provided to the oil and gas industries in 2006, which totaled over $1.4 billion, and were comprised 100 percent of various taxes.

DETAIL: COAL SUBSIDIES

Federal Coal Subsidies

The biggest tax subsidy for coal in 2006 was its share of the A*lternative Fuel Production Credit*,

In 2006, Texas school districts reported the oil and gas industries' property taxes were reduced by over $9.3 million in tax benefits as a result of Chapter 313 property value limitation agreements.

EXHIBIT 28-14

Estimated Texas State and Local Oil and Gas Subsidies in 2006

Subsidy	Type	Amount
State Natural Gas Severance Tax Exemptions	taxes	$1,167,436,766
State Crude Oil Severance Tax Exemptions	taxes	94,499,946
State Gasoline Tax Exemptions	taxes	80,200,000
State Franchise Tax Exemptions	taxes	40,000,000
Chapter 312 Property Tax Abatements (city, county and other property taxing districts)	taxes	22,903,646
Chapter 313 Property Value Limitations (school districts)	taxes	9,304,108
Economic Development Property Tax Refund	taxes	3,089,871
State Diesel Fuel Tax Exemptions	taxes	cbe*
Total		**$1,417,434,337**

*Cannot be estimated

Percent of Texas State and Local Oil and Gas Subsidies in 2006, by Type

Taxes	100.0%	**Homeowner Incentives**	0.0%
Direct Spending	0.0%		

Source: Texas Comptroller of Public Accounts.

followed by its share of the *Percentage Depletion Allowance* and the *Expensing of Exploration and Development Costs*. (These taxes are described above in the section on oil and gas subsidies.) Other tax subsidies are specific to the coal industry, such as the *Capital Gains Treatment for Coal Royalties* and the *Exemption of Government Payments to Disabled Coal Workers*.

In 2005, Congress expanded the *Alternative Fuel Production Credit* to include a subsidy for firms that create synthetic fuel from chemically altered coal.[40] The synthetic fuel subsidy is nearly $3 per the equivalent of a barrel of oil for facilities that produce coke or coke gas.[41] After the 2005 legislation, OMB's estimate of the value of this tax credit increased from $890 million to almost $3 billion in 2008.[42] This is the basis of the Comptroller's estimate of coal's share of this tax credit of $2.1 billion.

OMB valued *Capital Gains Treatment for Coal Royalties* at $160 million in 2006.[43] Owners of coal mining rights who lease their property usually receive royalties (payments from the companies mining the land). If the owners are individuals, they may be eligible to pay taxes on the royalties at a lower capital gains tax rate rather than at the higher individual income tax rate.[44]

Coal producers can apply the *Expensing of Exploration and Development Costs* to the costs of surface mining and the construction of shafts and tunnels.[45] The Comptroller estimates coal's share of this tax incentive to be $37 million in 2006.

The Comptroller estimates coal's share of the *Percentage Depletion Allowance* to be $29.7 million in 2006. As described in the section on oil and gas subsidies above, the Percentage Depletion Allowance allows mineral producers and royalty owners to deduct 10 percent of their gross income up to a total equivalent to 50 percent of their net income to cover such capital costs as mine excavation.[46]

Based on an estimate by the U.S. Joint Committee on Taxation, the Comptroller estimates that coal's share of the *Special Rules for Mining Reclamation Reserve* cost the U.S. Treasury an estimated $12 million in 2006. This provision allows mining operators to deduct the cost of reclamation and closing.[47]

The *Exemption of Government Payments to Disabled Coal Workers* from individual income taxes provides an additional tax incentive for certain members of the coal industry and cost the U.S. Treasury $50 million in 2006, according to OMB. Former coal miners who receive disability payments from the Black Lung Trust Fund do not have to pay income tax on them.[48]

The coal subsidies do not include the federal Black Lung Disability Program or the U.S. Department of Labor's Special Benefits to Disabled Coal Miners.

Finally, the USDA's *Rural Utilities Service* provides loans to utilities; their 2006 budget provides $2.5 billion for such loans. In addition, Congress provided an additional $1 billion for rural electric utilities in recent Appropriation Acts. It is unknown how many of those loans were for coal-fired plants in 2006.[49] Thus, this subsidy cannot be estimated.

In 2007, conservation groups filed a lawsuit against a proposed coal-fired project, the Highwood Generating Station in Montana, to prevent the Rural Utilities Service from lending the project more than $600 million.[50]

Various tax incentives represented the majority of coal subsidies in 2006 (**Exhibit 28-15**).

Texas State and Local Government Coal Subsidies

Texas state government does not offer subsidies to the coal industry. Furthermore, while local governments may provide property tax exemptions for coal companies and school districts may provide property value limitations, neither were in effect in 2006 for any coal plants in Texas.

DETAIL: NUCLEAR SUBSIDIES

Federal Nuclear Subsidies

In 2006, the U.S. nuclear industry received an estimated $1.2 billion in federal subsidies.

The U.S. Department of Energy administers a *Non-Defense Environmental Cleanup* program. This program provides for the cleanup and risk reduction of sites used for civilian energy research. Congress appropriated $349.7 million for this program in 2006.[51]

In 2006, the U.S. nuclear industry received an estimated $1.2 billion in federal subsidies.

Exhibit 28-15

Estimated Federal Coal Subsidies in 2006

Subsidy	Type	Amount
Alternative Fuel Production Credit (coal's share)	taxes	$2,090,000,000
U.S. Department of Energy, Coal Research and Development	direct spending	376,198,000
Capital Gains Treatment for Coal Royalties	taxes	160,000,000
Exemption of Payments to Disabled Coal Workers	taxes	50,000,000
Expensing of Exploration and Development Costs (coal's share)	taxes	37,010,000
Percentage Depletion Allowance (coal's share)	taxes	29,700,000
Special Rules for Mining Reclamation Reserves (coal's share)	taxes	12,000,000
U.S. Department of Agriculture, Rural Utilities Service Loans for Coal-Fired Plants	direct spending	cbe*
Total		**$2,754,908,000**

*Cannot be estimated

Percent of Federal Coal Subsidies in 2006, by Type

Taxes	86.3%	**Government Ownership of Energy Production**	0.0%
Direct Spending	13.7%	**Access to Resources on Federal Lands**	0.0%
Liability/Risk Assumption	0.0%	**Tariffs**	0.0%

Source: Texas Comptroller of Public Accounts.

The U.S. Department of Energy also has several nuclear energy research and development programs, including the *Fusion Energy Research program*, the *Advanced Fuel Cycle Initiative*, the *Nuclear Power 2010 program*, the *Generation IV Nuclear Energy Systems program* and the *Nuclear Hydrogen Initiative*.

The *Fusion Energy Research* program funds efforts at universities, private sector institutions and federal laboratories to develop fusion power. (Fusion is the energy source that powers the sun in which atoms of hydrogen fuse together to form helium in a very hot and highly charged gas or plasma.) Congress appropriated $280.7 million for this program in 2006.[52]

The *Advanced Fuel Cycle Initiative* focuses on developing technologies that may reduce the amount and long-term toxicity of high-level waste from spent nuclear fuel. Congress appropriated $78.4 million for this program in 2006.[53]

The *Nuclear Power 2010* program focuses on ending technical, institutional and regulatory barriers to the deployment of new nuclear power plants. Congress appropriated $65.3 million for this program in 2006.[54]

The *Generation IV Nuclear Energy Systems Initiative* is intended to develop the next-generation nuclear reactors and fuel cycles to make hydrogen possible. Congress appropriated $53.3 million for this program in 2006.[55]

The *Nuclear Hydrogen Initiative* goal is to develop new technologies to generate hydrogen on a commercial scale in an environmentally safe manner. Congress appropriated $24.1 million for this program in 2006.[56]

In addition to these initiatives, the *Infrastructure Facilities Management* program maintains and enhances national research facilities, including a series of national nuclear technology laboratories. Congress appropriated $149.2 million for this program in 2006.[57]

The Tennessee Valley Authority is a federal corporation that sells power to utilities, industries and federal agencies at a cost below what most utilities would charge.[58] TVA can issue bonds and notes to generate capital expenditure funds, and can carry up to $30 billion in outstanding debt at any time.[59] In fact, TVA is one of only two federal agencies that can issue new debt, and held $26 billion in outstanding debt at the end of 2006.[60]

A number of studies by the U.S. General Accounting Office have found that this high level of debt and debt service could place TVA at a competitive disadvantage if it were forced to compete on the open market with other utilities.[61] A substantial portion of this debt was generated when TVA built three nuclear plants. Construction delays, cost overruns and shutdowns of the nuclear plants meant that the plants could not produce electricity for sale, and TVA excluded the costs of the plants from its electricity rates for a long period.[62] Its current electricity rates are not sufficient to pay off the costs of these nuclear plants.[63] This study allocates a portion of this debt to nuclear subsidies to account for the debt attributed to nuclear power plants, amounting to a total of $186.3 billion in 2006.

The Comptroller estimates uranium's share of the *Percentage Depletion Allowance* to be $0.5 million in 2006. As described in the section on oil and gas subsidies above, the Percentage Depletion Allowance allows uranium producers and royalty owners to deduct up to 22 percent of their gross income from mining, up to a total amount of 50 percent of net income.[64]

The federal *Price-Anderson Act of 1957* limits the liability of nuclear plant operators in the event of accidents, and establishes insurance requirements for them. Some sources say this represents an implied subsidy to commercial nuclear plant investors in the form of reduced insurance premiums, which lower their operating costs.[65] A recent GAO study, however, noted that no credible quantification of the Price-Anderson Act is available.[66] Thus this study does not estimate the amount of the subsidy.

Finally, the federal Energy Policy Act of 2005 provided the nuclear industry with financial incentives to build new nuclear power plants. The act provided, among other incentives, a production tax credit of 1.8 cents per kilowatt-hour for up to 6,000 megawatts of capacity from new, qualified advanced nuclear power facilities for eight years.[67] None of these credits were claimed in 2006 because no nuclear plants came on line that year. The first application for a new reactor eligible for this incentive was submitted in September 2007, to expand the South Texas Project.

In all, direct spending represented the majority of federal government subsidies for nuclear energy in 2006 (**Exhibit 28-16**).

Texas State and Local Nuclear Subsidies

Texas state government does not offer subsidies to nuclear energy companies. While local governments may provide property tax exemptions for nuclear companies and school districts may provide property value limitations, neither were in effect in 2006 for any nuclear energy companies in Texas. The South Texas Project has, however, submitted an application for a Chapter 313 property value limitation to Palacios Independent School District for their nuclear energy project. If approved and implemented, their first year of the proposed qualifying time period would be 2012.

SPENDING ON RENEWABLE ENERGY

The Comptroller estimates that the U.S. spent over $132.5 billion to generate energy from renewable sources in 2006. As in the nonrenewable section, this estimate is taken at the time a consumer – either a homeowner or utility company – decides to purchase a type of fuel. Total spending on renewables *including* subsidies is estimated at $138.7 billion in 2006. Renewable subsidies comprised approximately $6.2 billion of that total.

DETAIL: ETHANOL SUBSIDIES

Federal Ethanol Subsidies

Federal ethanol subsidies are primarily federal tax credits. The largest credit, the V*olumetric Ethanol*

Total spending on renewables including subsidies is estimated at $138.7 billion in 2006. Renewable subsidies comprised approximately $6.2 billion of that total.

EXHIBIT 28-16

Estimated Federal Nuclear Subsidies in 2006

Subsidy	Type	Amount
U.S. Department of Energy, Non-Defense Environmental Cleanup	direct spending	$349,687,000
U.S. Department of Energy, Research and Development:		
– Fusion Energy Research	direct spending	$280,683,000
– Advanced Fuel Cycle Initiative	direct spending	$78,408,000
– Nuclear Power 2010	direct spending	$65,340,000
– Generation IV Nuclear Energy Systems	direct spending	$53,263,000
– Nuclear Hydrogen Initiative	direct spending	$24,057,000
TVA Pricing Below What is Needed for Debt Service (nuclear-related)	government ownership	$186,300,000
U.S. Department of Energy Infrastructure Facilities Management	direct spending	$149,188,000
Percentage Depletion Allowance (uranium share)	taxes	500,000
Price-Anderson Act of 1957	risk/liability	cbe*
Total		**$1,187,426,000**

*Cannot be estimated

Percent of Federal Nuclear Subsidies in 2006, by Type

Taxes	0.04%	**Government Ownership of Energy Production**	15.69%
Direct Spending	84.27%	**Access to Resources on Federal Lands**	0.00%
Liability/Risk Assumption	cbe	**Tariffs**	0.00%

*Cannot be estimated
Source: Texas Comptroller of Public Accounts.

Excise Tax Credit (VEETC), accounted for 54.6 percent of federal ethanol subsidies in 2006, or $2.6 billion. The VEETC represented 41.6 percent of 2006 federal subsidies for all renewables.

The American Jobs Creation Act of 2004 established the VEETC, which provides ethanol blenders or retailers with 51 cents per gallon of ethanol blended with gasoline, or (to phrase it in another way) $.0051 per percentage point of ethanol blended (i.e., E10 is eligible for $.051 per gallon; E85 is eligible for $.4335 per gallon).[68]

The VEETC may be taken instead of the *Alcohol Fuel Income Tax Credit*, which also provides a 51 cent-per-gallon tax credit. The credit actually consists of the *Alcohol Mixture Credit*, the *Alcohol Credit* and the *Small Producer Credit*.[69] A producer of alcohol mixed with gasoline or other special fuel that either uses the fuel or sells it to others is eligible for the Alcohol Mixture Credit. Sellers or users of alcohol that is used as a fuel in a business or sold as fuel at retail qualify for the Alcohol Credit. Small ethanol producers — those that have a production capacity of 60 million gallons or less — that sell no more than 15 million gallons in the current year qualify for the Small Producer Credit.[70] The *Alcohol Fuel Income Tax Credit* totaled $50 million in 2006.[71]

Second in importance is USDA's *Subsidies for Growing Corn*. In 2006, 20 percent of the corn harvest went to ethanol production, and total agricultural subsidies through the Commodity Credit Corporation for corn in that year totaled $8.8 billion.[72] Thus, an estimated $1.8 billion went to subsidize corn destined for ethanol production.

The U.S. uses all of the ethanol it produces and imports some from other countries. Other countries that produce ethanol and import it into the U.S. may be subject to import tariffs or duties, depending on federal law or trade agreements. A general ad valorem tax of 2.5 percent is assessed on imports.

Two other trade policies affect imports. Some countries can import ethanol without a tariff as long as they import less than the amount set by the United States International Trade Commission – a quota that is set each year. In addition, a tax of 14.27 cents per liter, or 54 cents per gallon, is assessed on imports that are not exempt from the tariff or that exceed the limits allowed by other countries. Brazil, a large producer and exporter of ethanol, is subject to the tariff, thus the tariff is frequently called the *Brazilian ethanol tariff.*[73] The U.S. International Trade Commission has estimated that these assessments amounted to approximately $252.7 million in 2006.[74]

However, some imported ethanol from Caribbean Basin Initiative (CBI) countries can enter the U.S. without paying duties, even if the ethanol was actually produced in a non-CBI country. Ethanol can be dehydrated in a CBI country, and then shipped to the U.S. to avoid the duty.[75] In addition, current law allows duties that are paid when ethanol is imported to be refunded if a related product, jet fuel, is exported.[76] This is called "duty drawback." There are no data regarding the amounts subject to this drawback,[77] but there are tax proposals at the federal level to repeal the exemption for ethanol-related export refunds. To obtain the estimate for tariffs, this study used the U.S. International Trade Commission's calculations minus the estimated tax saving of repealing the duty drawback for ethanol, for a total of $246.7 million.[78]

The U.S. Department of Energy funds research to develop domestic biomass resources as energy sources. Biomass and biorefinery systems research focus on technological improvements to use biomass resources for fuels and power. The research effort funds ways to reduce the cost of harvesting and preparing biomass feedstocks, the chemical processes used to transform the feedstocks into various fuels or energy, and testing of biorefinery technologies to evaluate their performance.[79] Approximately 90 percent of the $89.8 million 2006 budget, or $80.8 million, is allocated to ethanol production.[80]

Various taxes comprised the majority of federal subsidies for ethanol in 2006 (**Exhibit 28-17**).

Exhibit 28-17

Estimated Federal Ethanol Subsidies in 2006

Subsidy	Type	Amount
Volumetric Ethanol Excise Tax Credit	taxes	$2,570,000,000
U.S. Department of Agriculture, Agricultural Commodity Subsidies (corn)	direct spending	1,760,800,000
Tariff on Imports of Brazilian ethanol	tariff	246,679,149
U.S. Department of Energy, Biomass and Biorefinery Research and Development (ethanol-related)	direct spending	80,798,400
Alcohol Fuel Tax Credit	taxes	50,000,000
Total		**$4,708,277,549**

Percent of Federal Ethanol Subsidies in 2006, by Type

Taxes	55.6%	**Government Ownership of Energy Production**	0.0%
Direct Spending	39.1%	**Access to Resources on Federal Lands**	0.0%
Liability/Risk Assumption	0.0%	**Tariffs**	5.2%

Note: Numbers may not total due to rounding.
Source: Texas Comptroller of Public Accounts.

Texas State and Local Ethanol Subsidies

Chapter 23 of the Texas Tax Code provides for a special property tax value for land used for agricultural purpose as well as land used for timber production.[81] This provides a subsidy to the extent that the land would be used to grow biomass that is used as fuel, such as in the production of ethanol or in firing biomass to produce electricity. However, exact data on land usage for fuel production is not collected, and thus this subsidy cannot be estimated.

DETAIL: BIODIESEL SUBSIDIES

Federal Biodiesel Subsidies

Most federal subsidies for biodiesel take the form of federal personal and corporate income or excise tax credits. Biodiesel benefits primarily from *Biodiesel Tax Credits*. These include the *Biodiesel Credit*, the *Renewable Diesel Credit*, the *Biodiesel (or Agri-Biodiesel) Mixture Credit*, the *Renewable (or Agri-Biodiesel) Diesel Mixture Credit* and the *Small Agri-Biodiesel Producer Tax Credit*.[82]

Most federal subsidies for biodiesel take the form of federal personal and corporate income or excise tax credits.

These credits are based on the number of gallons used or produced. Each gallon of biodiesel, or biodiesel used in a mixture, can qualify for an income tax credit of 50 cents per gallon. Biodiesel from "virgin" raw plant materials (agri-biodiesel) qualifies for a higher credit, $1 per gallon, as does non-virgin renewable diesel. Small agri-biodiesel producers — those that have a production capacity of 60 million gallons or less — that do not exceed 15 million gallons of production in a year qualify for a 10-cent per gallon income tax credit.[83] Biodiesel and small agri-biodiesel producers qualified for $90 million in tax credits for this purpose in 2006.[84]

Section 1344 of the Energy Policy Act of 2005 extended the *VEETC Excise Tax Credit for Biodiesel* producers through 2008 (see the ethanol section for full discussion of VEETC). For biodiesel, the credits are $1 per gallon of agri-biodiesel and 50 cents per gallon for waste-grease biodiesel. If the fuel is used in a mixture, the credit amounts to one cent per percentage point of agri-biodiesel used or a half-cent per percentage point of waste-grease biodiesel.[85]

The 2006 value of the VEETC for biodiesel is included in the amounts for biodiesel producer tax credits.[86]

The federal U.S. Department of Agriculture's *Renewable Energy Systems and Energy Efficiency Improvements Program* provides grants, loans and loan guarantees to farmers, ranchers or rural small businesses so that they can buy renewable energy systems and make energy efficiency upgrades.[87] These funds enable farmer and rural producers to expand the use of innovative renewable energy technologies in producing farm products. The 2006 awards helped to establish biodiesel plants in eight states.[88] For 2006, this study counted only the amount of direct grants as a subsidy, or $2.3 million for biodiesel. The amount of the interest rate between the government interest rate and the commercial rate would also count as a subsidy, but information was not available to calculate this difference.

The majority of federal subsidies for biodiesel were comprised of various taxes (**Exhibit 28-18**).

Texas State and Local Biodiesel Subsidies

The Texas Department of Agriculture administers the *Fuel Ethanol and Biodiesel Production Incentive Program*. Registered producers are charged a fee of 3.2 cents per gallon of fuel produced. The funds collected and matching general revenue funding may be appropriated for grants to producers as incentives to develop ethanol and biodiesel industries in Texas.[89] For 2006, nearly $2.1 million was distributed in incentive payments to biodiesel producers, while no funding was distributed to ethanol producers. This estimate counts only matching general revenue funding as the subsidy and omits fees charged to the industry. The last payments for the program were distributed in November 2007, and no appropriations were made by the 80th Legislature for the program to continue.[90]

In 2006, the biodiesel industry claimed $10,943 in *Chapter 312 Property Tax Abatements*. Furthermore, although Chapter 313 property value limitations are available to the biodiesel industry, none were in effect in 2006.

Direct Spending represented the majority of state and local biodiesel subsidies in 2006 (**Exhibit 28-19**).

Exhibit 28-18

Estimated Federal Biodiesel Subsidies in 2006

Subsidy	Type	Amount
Biodiesel and Small Agri-biodiesel Producer Credit	taxes	$90,000,000
U.S. Department of Agriculture, Renewable Energy Systems and Energy Efficiency (biodiesel-related)	direct spending	2,315,835
Total		**$92,315,835**

Percent of Federal Biodiesel Subsidies in 2006, by Type

Taxes	97.5%	**Government Ownership of Energy Production**	0.0%
Direct Spending	2.5%	**Access to Resources on Federal Lands**	0.0%
Liability/Risk Assumption	0.0%	**Tariffs**	0.0%

Source: Texas Comptroller of Public Accounts.

DETAIL: WIND SUBSIDIES

Federal Wind Subsidies

The more significant of the two main federal subsidies for wind energy is the *New Technology Energy Tax Credit* which applies to corporate and individual income taxes. This is a tax credit for producing and selling electricity produced from certain energy sources, including wind. Wind energy benefits most from this subsidy, compared to other energy sources due to the fact that much more electricity is generated from wind than by other resources eligible for the credit. In 2006, the credit was worth 1.9 cents per kilowatt-hour (kWh) of energy produced. A number of other renewable and some non-renewable energies also benefit from this tax credit.[91] Tax expenditure numbers from the U.S. Treasury combine two different sources of tax credits in the New Technology Tax Credit. The investment tax credit for solar and geothermal energy and the production tax credit for wind, biomass, small irrigation power, landfill gas, trash combustion and hydropower are counted in one tax expenditure number.[92] This study allocates tax credits to the different energy sources based on recommendations from U.S. Treasury staff and the percentages that each renewable energy source contributed to total production in 2006.

Exhibit 28-19

Estimated Texas State and Local Biodiesel Subsidies in 2006

Subsidy	Type	Amount
Texas Department of Agriculture, Fuel Ethanol and Biodiesel Production Incentive Program	direct spending	$2,096,477
Chapter 312 Property Tax Abatements (city, county and other property taxing districts)	taxes	10,943
Total		**$2,107,420**

Percent of Texas State and Local Biodiesel Subsidies in 2006, by Type

Taxes	0.5%	**Homeowner Incentives**	0.0%
Direct Spending	99.5%		

Source: Texas Comptroller of Public Accounts.

Research and development funding at the U.S. Department of Energy contributed over $38.3 million to wind subsidies in 2006. The *U.S. Department of Agriculture's Renewable Energy Systems and Energy Efficiency* programs accounted for approximately $5.1 million in federal subsidies to wind in 2006. For a full discussion of this program, see the listing under Biodiesel.

Governments and cooperative electrical companies can issue *Clean Renewable Energy Bonds* to help finance renewable energy projects. Since governmental or consumer-owned utilities do not benefit from income tax credits, tax credit bonds make financing for renewable energy projects affordable. Holders of the bonds receive a tax credit, instead of paying interest to the issuer. This makes financing available to the issuers, and the bond holders benefit at tax time.[93] In 2006, holders of bonds for wind energy benefited by an estimated $3.7 million in reduced taxes due to the tax credit for holding bonds.

In addition, the *U.S. Department of Energy's Renewable Energy Production Incentive* program pays governmental and nonprofit electrical cooperatives for producing power using renewable energies, including wind. Facilities are paid per kilowatt hour, up to the amount allocated by federal appropriations.[94] Wind energy received an estimated $2.8 million from this program in 2006. A total of $4.8 million was distributed across all renewable energies in 2006.[95]

Tax subsidies accounted for nearly 90 percent of federal wind subsidies in 2006 (**Exhibit 28-20**).

Texas State and Local Wind Subsidies

The Texas Tax Code provides a *Solar and Wind-Powered Energy Devices Exemption* on the amount of appraised property value arising from the installation or construction of a wind-powered or solar energy device. The device must produce energy for on-site use. Due to limitations with data collection, the amount of the subsidy for wind only cannot be estimated.

In 2006, the wind industry claimed approximately $1.3 million in tax benefits from *Chapter 313 Property Value Limitations* and more than $215,000 in *Chapter 312 Property Tax Abatements*.

EXHIBIT 28-20

Estimated Federal Wind Subsidies in 2006

Subsidy	Type	Amount
New Technology Energy Tax Credit (wind-related)	taxes	$408,000,000
U.S. Department of Energy, Research and Development, Wind Energy	direct spending	$38,333,000
U.S. Department of Agriculture, Renewable Energy Systems and Energy Efficiency (wind-related)	direct spending	$5,103,037
Clean Renewable Energy Bonds (wind-related)	taxes	$3,672,131
U.S. Department of Energy, Renewable Energy Production Incentive (wind-related)	direct spending	$2,816,121
Total		**$457,924,289**

Percent of Federal Wind Subsidies in 2006, by Type

Taxes	89.9%	**Government Ownership of Energy Production**	0.0%
Direct Spending	10.1%	**Access to Resources on Federal Lands**	0.0%
Liability/Risk Assumption	0.0%	**Tariffs**	0.0%

Source: Texas Comptroller of Public Accounts.

Various taxes represented 100 percent of state and local subsidies for wind in 2006 (**Exhibit 28-21**).

DETAIL: SOLAR SUBSIDIES

Federal Solar Subsidies

Research, Development, Test and Evaluation, Defense-Wide expenditures are the largest federal subsidies for solar energy. The U.S. Department of Defense (DOD) is the largest single funding source for the research and development of solar power. DOD has funded research on solar cells, solar thermal energy conversion, solar collection, solar thermal propulsion, high-efficiency solar photovoltaics, solar-powered ocean monitoring devices, novel solar cell configurations for battlefield deployment and high-altitude and long-endurance unmanned aircraft powered by solar energy.[96] DOD's Defense Advanced Research Projects Agency funded approximately $274.8 million of research projects including solar energy in 2006.[97]

DOE, Solar Energy Research and Development also contributed funding of $81.8 million to solar subsidies in 2006.[98]

Three tax credits account for the remaining subsidies. The *Residential Solar and Fuel Cell Tax Credit* authorizes a 30 percent credit on personal income taxes for the purchase of solar electric, photovoltaic and solar water heating property. The credit includes the cost of installation up to $2,000 for solar electric or solar water heating property. [99] In 2006, this tax credit amounted to $10 million.[100]

The *New Technology Energy Tax Credit* was worth 1.9 cents per kWh of energy produced by solar power in 2006, for a total of $1.2 million.[101] See the section on wind subsidies for a full discussion of the *New Technology Energy Tax Credit*.

Clean Renewable Energy Tax Credit Bonds account for the remaining federal solar subsidies. See the section on Clean Renewable Energy Bonds under wind power for a full description of this subsidy. For 2006, the tax credit bonds saved taxpayers an estimated $14.2 million for solar energy projects.

The U.S. Department of Agriculture's *Renewable Energy Systems and Energy Efficiency* program accounted for $0.7 million in federal subsidies to solar energy in 2006. For a full discussion of the program, see the listing under biodiesel subsidies.

Some mortgage programs regulated or supported by the U.S. government offer loans for efficiency upgrades including solar energy. For example, Fannie Mae (a congressionally chartered, shareholder-owned company and the nation's largest source of home mortgage funds) offers an energy loan up to $15,000 for energy efficiency upgrades including solar water and space heating systems and photovoltaic systems.[102] FreddieMac (a congressionally chartered,

EXHIBIT 28-21

Estimated Texas State and Local Wind Subsidies in 2006

Subsidy	Type	Amount
Chapter 313 Property Value Limitations (school districts)	taxes	$1,293,600
Chapter 312 Property Tax Abatements (city, county and other property taxing districts)	taxes	215,200
Solar and Wind-Powered Energy Devices School Property Tax Exemption (wind's share)	taxes	cbe*
Total		**$1,508,800**

*Cannot be estimated

Percent of Texas State and Local Wind Subsidies in 2006, by Type

Taxes	100.0%	**Homeowner Incentives**	0.0%
Direct Spending	0.0%		

Source: Texas Comptroller of Public Accounts.

shareholder-owned company that purchases mortgages from lenders) has similar energy efficiency programs.[103] The U.S. Department of Agriculture offers FarmerMac, a mortgage service for farmers similar to FreddieMac, through the Rural Housing Service. To the extent that government loans' interest rates are below interest rates that may be obtained in the commercial market, this would constitute a subsidy. However, no information comparing government loan rates to commercial rates is available, therefore this subsidy cannot be estimated.

The U.S. Department of Agriculture Rural Development Electric Program makes several types of direct loans and loan guarantees to utilities serving rural customers. The purpose of the financing is to upgrade and expand the rural electric infrastructure.

Renewable energy programs may be financed through direct loans or guaranteed loans. In addition, a program for assistance to rural communities with extremely high energy costs distributes loans and grants for utility improvements in areas where the average residential energy cost is at least 275 percent of the national average.[104]

Energy produced by hydroelectric power receives its main federal subsidies through government ownership.

For 2006, the total amount of loans and loan guarantees was $4.5 billion.[105] However, only the cost of the loans (interest rate) that is below what would be available commercially may be counted as a subsidy. Because the loans are made across multiple years, with differing interest rates, the exact cost of the subsidy for 2006 cannot be estimated. However, the General Accountability Office estimated the 2007 cost of the subsidy was $2.4 million.[106] In addition, because the loans are not specific to fuel source, the cost of the subsidy to renewable or nonrenewable fuels cannot be estimated.

The *Renewable Energy Production Incentive* program, described under federal subsidies to wind, contributed a relatively minor subsidy to solar energy, totaling just more than $22,000 in 2006.[107]

Direct spending comprised over 93.4 percent of federal subsidies for solar energy in 2006 (**Exhibit 28-22**).

Texas State and Local Solar Subsidies

Texas law established a *Franchise Tax Exemption for Solar Manufacturers and Deduction for Purchasers* in 2006. This provision exempted businesses that engage exclusively in the business of manufacturing, selling or installing solar energy devices from the franchise tax. In addition, business taxpayers were able to deduct 10 percent of the amortized cost of solar energy equipment or equipment used in a clean coal project from the base of the franchise tax or, alternatively, to deduct the cost of the system from the company's taxable capital. As noted above, in 2006 the franchise tax base was earned surplus or capital.[108]

Beginning with reports due after January 1, 2008, the franchise tax base will be the taxable margin on total revenue minus either cost of goods sold or compensation. The exemption for solar equipment producers will continue under the new tax base. Purchasers will continue to be able to deduct 10 percent of the cost. The Comptroller estimates the value of both exemptions at about $500,000 per year.

Texas provides a *Solar and Wind-Powered Energy Devices School Property Tax Exemption*, previously described in the section on wind subsidies; however, due to limitations with data collection, the amount of the subsidy for solar only cannot be estimated.

A few Texas utilities offer subsidies for the purchase or lease of solar energy devices. Austin Energy offers a rebate program for the purchase and installation of photovoltaics.[109] In 2006, Austin Energy rebated nearly $2.1 million back to its residential customers through this program.[110] The *Austin Energy Utility Rebate for Solar Water Heating Program* provides a similar rebate for solar water heaters, although no rebates were granted to customers in 2006. [111]

Such subsidies are not limited to urban areas. Big Country Electric Coop in Roby, Texas offers solar water pumping systems to its members. These systems deliver livestock water where electrical power is unavailable or uneconomical. The systems sell for about $2,750, or can be leased for $50 per month over a 60-month term. Each standard system uses two 75-watt DC solar panels. Thus far, co-op members have obtained about 50 of these systems.[112] Big Country does not keep data on the cost of this program, however, so its dollar value cannot be estimated.[113]

Most rebates offered by Texas utilities are for energy efficiency programs and are not fuel-specific. These are discussed in the chapter on energy efficiency.

Homeowner incentives accounted for over 80 percent of state and local subsidies for solar in 2006 (**Exhibit 28-23**).

DETAIL: HYDROELECTRIC POWER SUBSIDIES

Federal Hydroelectric Power Subsidies

Energy produced by hydroelectric power receives its main federal subsidies through government ownership. The federal government owns and operates entities such as the Tennessee Valley Authority (TVA) and four power marketing administrations that produce electricity for sale to consumers, industries and businesses.[114] Government ownership allows electricity to be sold below market price or to omit cost elements such as debt service.

Three power marketing administrations, the Western Area Power Administration, the Southwestern Power Administration and the Southeastern Power Administration, sell power to consumers below the rates that commercial utilities would charge.[115] They can charge lower rates because they do not have to pay high costs for fuel; the cost of producing electricity from hydroelectric power is low. In addition, their original construction financing interest rates were favorable, since they were generally set at 1930s and 1940s rates. Even for new construction projects, these administrations have been allowed to pay interest at below-market rates, even though the U.S. Treasury, which financed the projects, has to pay long-term interest rates above the administrations' rate payments. This amounts to a subsidy to the production of hydroelectric power.[116] For 2006, this subsidy amounted to $160 million.[117]

TVA, the federal corporation that sells power to utilities, industries and federal agencies, can issue debt to fund operations and capital expenditures (see the nuclear section for a full discussion of this

EXHIBIT 28-22

Estimated Federal Solar Subsidies in 2006

Subsidy	Type	Amount
U.S. Department of Defense, Research, Development, Test and Evaluation, Defense-Wide	direct spending	$274,773,000
U.S. Department of Energy, Solar Energy Research and Development	direct spending	81,791,000
Clean Renewable Energy Bonds (solar-related)	taxes	14,229,508
Residential Solar and Fuel Cell Tax Credit	taxes	10,000,000
New Technology Energy Tax Credit (solar-related)	taxes	1,222,274
U.S. Department of Agriculture, Renewable Energy Systems & Energy Efficiency (solar-related)	direct spending	718,396
U.S. Department of Energy, Renewable Energy Production Incentive (solar-related)	direct spending	22,140
U.S. FreddieMac, FannieMae, FarmerMac (mortgage energy loan programs)	direct spending	cbe*
Total		**$382,756,318**

*Cannot be estimated

Percent of Federal Solar Subsidies in 2006, by Type

Taxes	6.6%	**Government Ownership of Energy Production**	0.0%
Direct Spending	93.4%	**Access to Resources on Federal Lands**	0.0%
Liability/Risk Assumption	0.0%	**Tariffs**	0.0%

Source: Texas Comptroller of Public Accounts.

EXHIBIT 28-23

Estimated Texas State and Local Solar Subsidies in 2006

Subsidy	Type	Amount
Austin Energy Utility Rebate for Solar Photovoltaic Program	homeowner incentives	$2,074,101
State Franchise Tax Exemption for Solar Manufacturers and Deduction for Purchasers	taxes	500,000
Austin Energy Utility Rebate for Solar Water Heating Program	homeowner incentives	0*
Solar and Wind-Powered Energy Devices School Property Tax Exemption (solar's share)	taxes	cbe**
Big Country Electric Coop Photovoltaic Water Pump Sales & Lease Program	homeowner incentives	cbe
Total		**$2,574,101**

*No program participants in 2006
**Cannot be estimated

Percent of Texas State and Local Solar Subsidies in 2006, by Type

Taxes	19.4%	**Homeowner Incentives**	80.6%
Direct Spending	0.0%		

Source: Texas Comptroller of Public Accounts.

subsidy). This study allocates a portion of this debt to nuclear subsidies to account for the debt attributed to nuclear power plants, leaving $83.7 million attributed to hydroelectric power subsidies in 2006.

Hydroelectric power also benefits from the *New Technology Energy Tax Credit* which supplies a federal income tax credit for incremental amounts of electricity produced from improved energy efficiency or increases in capacity to existing hydroelectric power plants. For hydroelectric power, the credit is one half of the specified rate, or about 9 cents per kWh of electricity generated. Plants can claim the credit for ten years, beginning on the date upon which the improvement was placed into service.[118] For 2006, hydroelectric power benefited from an estimated $50.6 million in federal subsidies from the *New Technology Energy Tax Credit*.

Research and development funding at DOE was a relatively minor contributor to hydroelectric power subsidies in 2006, amounting to less than $0.5 million.

Bond holders of Clean Energy Renewable Bonds benefited by an estimated $0.5 million in 2006 tax credits (see Wind for a full discussion).

Government ownership represented over 82 percent of federal subsidies for hydroelectric power in 2006 (See **Exhibit 28-24**).

Texas State and Local Hydroelectric Power Subsidies

No state or local subsidies for hydroelectric power were claimed in Texas in 2006.

DETAIL: BIOMASS SUBSIDIES

Federal Biomass Subsidies

Biomass encompasses a broad array of different energy sources. The most economically significant of these, which also accounts for the largest federal subsidies, is wood. Wood-derived biomass energy accounts for an estimated 93.2 percent or about $195.4 million of all federal subsidies for biomass (**Exhibit 28-25**).

Current tax rules allow timber producers to deduct most of the costs of maintaining timber at the time those costs are incurred. These costs include property taxes, interest, insurance and labor and materials devoted to removing unwanted trees and controlling fire, disease and insects. Other industries must apply capitalization rules that prohibit production costs from being deducted until goods or services are actually sold. The net effect of *Expensing of Multi-Period Timber-Growing Costs* lowers the effective tax rate on timber.[119] For 2006, the portion of timber that was used as fuel earned a subsidy of $52.2 million.

When landowners sell lumber, proceeds of the sale can be counted as capital gains for income tax purposes, under certain circumstances. If the landowner does not apply capital gains rules, the proceeds are taxed at regular income rates of up to 35 percent. In addition, the landowner would have to pay an additional 15.3 percent self-employment tax because this category of income is considered self-employment. By using capital gains treatment for this income, landowners can limit taxable liability to the profit or gain from the sale, minus any selling costs and the basis of the timber costs. To take *Capital Gains Tax Treatment of Lumber Income*, the landowner must have owned the property for more than a year.[120] For 2006, the portion of timber that was used as fuel earned a subsidy of $28.8 million.

The *Reforestation Amortization and Tax Credit* allows landowners to deduct most of their reforestation expenses from their taxable income over an eight-year period (amortization) and to receive a direct tax credit of 10 percent of their reforestation expenses.[121] For 2006, the portion of timber that was used as fuel earned a subsidy of $54 million.

The U. S. Forest Service sells timber from national forests. In recent years, the U.S. Forest Service has spent more on timber programs than it has collected from the sales of timber. The difference between the expenditures and sales revenues amounts to a subsidy of the cost of timber. Only the percent of timber estimated to be used as fuel is counted in *Forest Service Losses and Timber Sales*. For 2006, this amounted to $23.4 million in federal subsidies.

Exhibit 28-24

Estimated Federal Hydroelectric Power Subsidies in 2006

Subsidy	Type	Amount
U.S. Department of Energy, Power Marketing Administration Below Market Pricing of Power	government ownership	$160,000,000
TVA Pricing Below What is Needed for Debt Service (hydroelectric power-related)	government ownership	83,700,000
New Technology Energy Tax Credit (hydroelectric power-related)	taxes	50,580,592
U.S. Department of Energy, Hydroelectric Power Research and Development	direct spending	495,000
Clean Renewable Energy Bonds (hydroelectric power-related)	taxes	459,016
Total		**$295,234,608**

Percent of Federal Hydroelectric Power Subsidies in 2006, by Type

Taxes	17.3%	**Government Ownership of Energy Production**	82.5%
Direct Spending	0.2%	**Access to Resources on Federal Lands**	0.0%
Liability/Risk Assumption	0.0%	**Tariffs**	0.0%

Source: Texas Comptroller of Public Accounts.

Wood-derived biomass energy accounts for an estimated 93.2 percent or about $195.4 million of all federal subsidies for biomass.

Direct spending for biomass comes from the U.S. Department of Agriculture's *Renewable Energy Systems and Energy Efficiency* program (described in biodiesel) and in the Renewable Energy Production Incentive program, described under federal subsidies to wind. Together, both sources contributed approximately $5.5 million in subsidies to biomass energy in 2006.[122]

Various taxes accounted for the majority of federal subsidies for biomass in 2006 (**Exhibit 28-25**).

Texas State and Local Biomass Subsidies

Chapter 312 and Chapter 313 incentives (as previously described) are available to companies in the biomass industry, but none were claimed in 2006.

DETAIL: GEOTHERMAL SUBSIDIES

Federal Geothermal Subsidies

Geothermal energy benefits from the *Geothermal Technologies Research and Development* program at the U. S. Department of Energy. The program funds activities to develop geothermal resources, develop technologies to enhance the productivity and lifespan of engineered geothermal reservoirs, conduct research on drilling and to enhance the deployment of technologies from research to active use.[123] In 2007, the U.S. Department of Energy received $22.8 million for the program.[124] The *New Technology Energy Tax Credit* accounted for $6.1 million and direct spending to farmers and rural businesses under the *Renewable Energy Systems and Energy Efficiency program* amounted to just over $285,000.

Exhibit 28-25

Estimated Federal Biomass Subsidies in 2006

Subsidy	Type	Amount
Amortization and Expensing of Reforestation Expenditures*	taxes	$54,000,000
Expensing Multi-Period Timber Growing Costs*	taxes	$52,200,000
New Technology Energy Tax Credit (biomass-related)	taxes	$44,085,760
Capital Gains Treatment of Certain Lumber Income*	taxes	$28,800,000
U.S. Department of Agriculture, Forest Service Losses, Timber Sales, and Fuel Wood Fraction*	access to natural resources	$23,400,000
U.S. Department of Agriculture, Renewable Energy Systems and Energy Efficiency (biomass-related)	direct spending	$3,589,232
U.S. Department of Energy, Renewable Energy Production Incentive (biomass-related)	direct spending	$1,960,325
Clean Renewable Energy Bonds (biomass-related)	taxes	$1,606,558
Total		**$209,641,875**

* Portion of biomass used as fuel

Percent of Federal Biomass Subsidies in 2006, by Type

Taxes	86.2%	**Government Ownership of Energy Production**	0.0%
Direct Spending	2.6%	**Access to Resources on Federal Lands**	11.2%
Liability/Risk Assumption	0.0%	**Tariffs**	0.0%

Source: Texas Comptroller of Public Accounts.

Direct spending represented the majority of federal subsidies for geothermal energy in 2006 (**Exhibit 28-26**).

Texas State and Local Geothermal Subsidies

The following Texas utilities provide rebate subsidies for geothermal heat pumps: CenterPoint Energy, College Station Utilities, Denton Municipal Electric, Farmers Electric Cooperative and United Cooperative Services. The rebate offered may be a fixed amount, an amount based on the efficiency rating of the heat pump, an amount given per ton of the heat pump or an amount based on the demand and energy savings at a specified rate. In 2006, these utilities returned $45,400 in rebates to their residential customers (**Exhibit 28-27**).[125]

Homeowner incentives accounted for 100 percent of state and local subsidies for geothermal energy in 2006 (**Exhibit 28-27**).

CONCLUSION

This chapter estimates the federal, state and local energy governmental subsidies that Texans supported in 2006. It provides a snapshot of the relative percent of subsidies for each type of fuel and a description of the different types of subsidies for each fuel.

Financial subsidies to the energy sector have been used to support the development or extraction of energy resources, in some cases helping to create new businesses or whole industries. Favorable tax treatment, direct government spending including research and development, government ownership, access to natural resources, and favorable tariff policies all played important roles in 2006.

These subsidies are being directed to renewable energy-producing resources in addition to more traditional oil, gas and coal industries. Ethanol production, for example, benefited from tax credits, agricultural subsidies, trade policies and direct spending in 2006. One-fifth of the nation's corn crop in 2006 was directed to ethanol production – no doubt the entire price of corn, including subsidies, affected farmers' planting decisions. In Texas and other states, the growth of the wind industry has been spurred by federal tax credits, direct federal spending and local property tax subsidies. Non-financial factors, as discussed in each energy source, also can play important roles in developing energy resources such as Texas' natural opportunity for wind

Financial subsidies to the energy sector have been used to support the development or extraction of energy resources, in some cases helping to create new businesses or whole industries.

EXHIBIT 28-26

Estimated Federal Geothermal Subsidies in 2006

Subsidy	Type	Amount
U.S. Department of Energy, Research and Development (geothermal-related)	direct spending	$22,762,000
New Technology Energy Tax Credit (geothermal-related)	taxes	6,111,372
U.S. Department of Agriculture, Renewable Energy Systems and Energy Efficiency (geothermal-related)	direct spending	285,162
Total		**$29,158,534**

Percent of Federal Geothermal Subsidies in 2006, by Type

Taxes	21.0%	**Government Ownership of Energy Production**	0.0%
Direct Spending	79.0%	**Access to Resources on Federal Lands**	0.0%
Liability/Risk Assumption	0.0%	**Tariffs**	0.0%

Source: Texas Comptroller of Public Accounts.

resources as well as a policy of building transmission capacity.

Each financial subsidy entails costs to Texas consumers, who are also taxpayers. As policy makers consider energy policy in the coming years, this chapter is intended to help them identify federal, state and local government financial subsidies. This, combined with the fuel source analyses of earlier chapters in this report, can aid decision makers in weighing potential consequences of governmental policies.

Exhibit 28-27

Estimated Texas State and Local Geothermal Subsidies in 2006

Subsidy	Type	Amount
Farmers Electric Cooperative Residential/Agricultural Energy Efficiency Rebate Program (geothermal heat pumps)	homeowner incentives	$24,900
Denton Municipal Electric EnergySave Rebate Program (geothermal heat pumps)	homeowner incentives	17,500
United Cooperative Services Residential Energy Efficiency Rebate Program (geothermal heat pumps)	homeowner incentives	3,000
CenterPoint Energy Commercial and Industrial Standard Offer Program (geothermal heat pumps)	homeowner incentives	0
College Station Utilities Residential Energy Back II Rebate Program (geothermal heat pumps)	homeowner incentives	0
Total		**$45,400**

Percent of Texas State and Local Geothermal Subsidies in 2006, by Type

Taxes	0.0%	**Homeowner Incentives**	100.0%
Direct Spending	0.0%		

Source: Texas Comptroller of Public Accounts.

State Energy Conservation Office

The State Energy Conservation Office (SECO) within the Texas Comptroller's Office funds energy efficiency and renewable energy programs. Federal funding to SECO comes from the U.S. Department of Energy's *State Energy Program*.

The federal State Energy Program is financed by direct federal appropriations and Petroleum Violation Escrow funds, more commonly known as "oil overcharge" funds. This funding for states originated in 1983 when oil companies repaid the federal government for overcharging consumers for oil and petroleum products. The overcharges stemmed from violations of the oil price controls that were in place from 1973 to 1981.[126]

Oil overcharge funds would not be considered subsidies because they originated from the oil companies. Direct federal appropriations can be considered subsidies, but State Energy Program funding from direct appropriations cannot be distinguished from oil overcharge funds. Therefore, this study does not estimate the amount of subsidies to energy sources from the State Energy Program.

ENDNOTES

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CHAPTER 29

Conclusion

This report is intended to help policy makers sort through the many issues associated with energy policies. This report can be used as a tool to understand the current energy environment and as a starting point to assess the potential impact of the numerous policy proposals presented to them. In putting together this report, Comptroller staff interviewed scores of experts in energy and related fields and reviewed thousands of research reports, articles and other documents.

This report makes it clear that Texas will need a broad mix of energy resources, technological advances and efficiency improvements to meet growing energy needs. Texas' economic health is dependent on reliable energy and this report should help lawmakers evaluate the potential economic impact of proposed policies.

Texas, in contrast to many other states, has a wide variety of existing and potential resources to meet its energy demands in the coming decades, though the fuel mix of the future could be quite different than today's. As should be clear from this report, the days of near-total reliance on cheap and abundant fossil fuels may be drawing to a close. Instead, we will rely on a mix of fuels and improved efficiency.

Still, it is important to remember that traditional fossil fuels will continue to be our primary sources of energy for many years. Gasoline and diesel will continue to provide the vast majority of our transportation fuel. Natural gas and coal will not be displaced anytime soon as our primary sources of electricity. In fact, worldwide demand for fossil fuels is increasing rapidly, and China in particular is investing heavily in fossil fuels, opening coal-fired power plants at an average rate of one per week.

This demand, however — and the shrinking reserves being tapped to meet it — make it vitally important that we learn how to use these fuels more efficiently.

As this report has documented, any source of energy has its own benefits and limitations. The fuels we have relied on for decades generally are still the least expensive for most uses. But they can carry costs that are not necessarily reflected in the prices consumers pay. The costs of pollution, for instance, may be borne by all.

U.S. policymakers, however, are increasingly likely to quantify and impose some of these costs on producers and consumers. In particular, greenhouse gas emissions seem likely to be restricted in some manner.

The expectation of such policies, along with rising fossil fuel prices, has directed a great deal of attention toward renewable energy sources and nuclear power. Investment in the technologies needed to tap these resources is rising rapidly, driven in part by government subsidies.

Policy makers will have a number of decisions to make regarding energy policy in the coming years. And just as choices made by energy producers and consumers carry costs and benefits, so do choices made by governments. Furthermore, much as decisions made by private businesses can have spillover effects, the costs of which are paid by society, government policies intended to encourage the development of a chosen resource can have unintended consequences. For example, federal policy now mandates that a portion of the U.S. transportation fuel supply come from ethanol and other biofuels. Critics have noted that the subsequent rapid rise in demand for corn has driven corn prices higher, encouraged farmers to replace existing crops with corn and has thus contributed to rising prices for a wide array of other food products.

The unintended consequences of new government action can be exacerbated by establishing policies that favor given resources – "picking winners" – instead of setting policy goals and establishing broad guidelines that will allow the market to meet those

Texas will need a broad mix of energy resources, technological advances and efficiency improvements to meet growing energy needs.

goals in the most efficient means possible, no matter the fuel source or technology employed.

Government has played a large role in the development of alternative energy sources. The development of wind energy, biofuels and nuclear power has been assisted by the application of government subsidies to make new energy technology affordable. Yet such assistance must be applied carefully. Public policies that attempt to pick winners in the race for new energy technologies are an inefficient way to achieve policy goals, running the risk not only of wasting taxpayer money, but also of directing private investment away from promising uses.

Fortunately, Texas is in a position to lead on national energy policy, due to its unique experience in conventional energy technology, its vibrant research community and its vast reserves of energy resources. Breakthroughs made in Texas can have an enormous economic impact on the state — and the world.

CHAPTER 30

For Further Information

GENERAL U.S. GOVERNMENT ENERGY WEB SITES

Energy Information Administration (EIA)
http://www.eia.doe.gov/

EIA collects, analyzes and forecasts statistical data on energy. Each year, EIA updates the *Annual Energy Outlook*, a projection and analysis of U.S. energy supply, demand and prices through 2030. The projections are based on results from their National Energy Modeling System.

EIA also publishes individual "State Energy Profiles" that list general details on each state's usage, generating capacity and fuel mix. These state profiles provide historical information from 1990 through 2005 and compare state totals with U.S. data for analysis and forecasting purposes.

National Renewable Energy Laboratory (NREL)
http://www.nrel.gov

NREL is the premier federal laboratory for the research and development of renewable energy sources and improved energy efficiency.

U.S. Department of Energy (DOE)
http://www.energy.gov/

DOE is responsible for implementing U.S. energy policy to ensure national, economic and energy security and for promoting scientific and technological innovation.

U.S. Environmental Protection Agency (EPA)
http://www.epa.gov/

EPA leads the nation's environmental science, research, education and assessment efforts. It develops and enforces regulations, issues permits and distributes grants and financial assistance for research and education projects.

CRUDE OIL

EIA. "Basic Petroleum Statistics." July 2007.
http://www.eia.doe.gov/neic/quickfacts/quickoil.html

EIA. "Refinery Capacity Report." June 2007.
http://www.eia.doe.gov/oil_gas/petroleum/data_publications/refinery_capacity_data/refcapacity.html

EIA publishes annual reports on the nation's oil consumption, production and usage. These reports rank states based on their share of national production and consumption.

EIA also publishes annual reports on U.S. and Texas crude oil refining capacity and any proposed additions to that capacity.

Michigan State University. "EnviroTools."
http://www.envirotools.org/

This site defines common terms and processes in petroleum refining and provides a background on the industry and a technical explanation of how crude oil is refined. It also explains the environmental hazards associated with the industry and the market and environmental forces affecting it.

Ramos, Mary G. "Oil and Texas: A Cultural History." ***Texas Almanac, 2000-2001***. Dallas, Texas: Dallas Morning News, 2008.
http://www.texasalmanac.com/history/highlights/oil/

This article provides a brief history of the oil business in Texas, including a timeline of events, major oil finds, industry pioneers and the transformation of the Texas economy from a rural, agricultural base to a booming industrial power.

Texas State Historical Association. "East Texas Oilfield." *The Handbook of Texas Online*, Austin, Texas, January 2008. http://www.tshaonline.org/handbook/online/articles/EE/doe1.html

This article provides a brief history of the legendary East Texas Oilfield, located in and around the cities of Kilgore, Longview and Tyler.

Yergin, Daniel. *The Prize: The Epic Quest for Oil, Money & Power.* New York: Touchstone, 1991.

This book records the history, pioneers, financiers, tycoons and economic and political actions that shaped the development of the oil industry.

LIQUEFIED PETROLEUM GAS (LPG)

DOE. *Just the Basics: Liquefied Petroleum Gas.* Washington, D.C., August 2003. http://www1.eere.energy.gov/vehicleandfuels/pdfs/basics/jtb_1pg.pdf

This brochure explains the basics of LPG as a transportation fuel. It includes details on emissions and safety issues, LPG production, production sources and fleet sizes.

Energy and Environmental Analysis, Inc. *Study of the Propane Industry's Impact on U.S. and State Economics.* Arlington, Virginia, November 2004. http://www.npga.org/files/public/Economic_Study_Propane_Value_Final.pdf

This report provides a detailed analysis of the effects of the propane industry in each state. It examines both direct and indirect contributions to the economy such as production, imports and the effect of growth in other sectors. The report also details the number of jobs associated with the propane industry.

National Propane Gas Association (NPGA) http://www.npga.org/i4a/pages/index.cfm?pageid=1

This site lists a number of publications concerning propane and identifies federal and state legislative issues important to the industry.

Propane Education and Research Council (PERC) http://www.propanecouncil.org/

This site is a resource for data and reports pertaining to propane.

Railroad Commission of Texas (RRC), Alternative Fuels Research & Education Division. "Propane." http://www.propane.tx.gov/

This site offers information for the home and commercial use of propane, services for marketers of propane and a propane outlet directory.

NATURAL GAS

EIA. "Natural Gas." http://www.eia.doe.gov/oil_gas/natural_gas/info_glance/natural_gas.html

This site gives the basics on how natural gas is captured and used, and how it produces energy, as well as an introduction to the liquefied natural gas industry.

RRC. "Monthly Oil and Gas Production by Year, January 2002—February 2008." http://www.rrc.state.tx.us/divisions/og/statistics/production/ogismcon.pdf

This table summarizes Texas natural gas and oil production by month from January 2002 to February 2008.

Texas Comptroller of Public Accounts. "Natural Gas Production Tax." http://www.window.state.tx.us/taxinfo/nat_gas/

This page shows the types and amounts of state taxes collected on natural gas production and consumption.

COAL

DOE, Office of Fossil Energy http://www.fe.doe.gov/

This office provides strategic information on all forms of fossil energy.

Freese, Barbara. *Coal: A Human History.* New York: Penguin Books, 2003.

This book describes how coal has shaped the daily life of mankind for centuries.

FutureGenAlliance
http://www.futuregenalliance.org

FutureGen was a multibillion-dollar federal project to construct and operate a state of the art, non-polluting coal-fired electricity generation plant. Carbon sequestration was a major component of the project. DOE decided in January 2008 not to fund the FutureGen project. See Chapter 7 for more information.

Massachusetts Institute of Technology (MIT). *The Future of Coal: An Interdisciplinary MIT Study.* Cambridge, 2007.
http://web.mit.edu/coal/

This report provides valuable information on the current uses of coal and its impact on the world's economy and environment. The report was the subject of Congressional hearings in spring 2007.

RRC
http://www.rrc.state.tx.us/

RRC enforces Texas' mine reclamation laws.

Texas Commission on Environmental Quality (TCEQ)
http://www.tceq.state.tx.us/

TCEQ enforces state and federal environmental laws that affect all Texas energy producers and consumers.

World Coal Institute. *The Coal Resource: A Comprehensive Overview of Coal.* London, 2005.
http://www.worldcoal.org/assets_CM/files/pdf/thecoalresource.pdf

This report provides information on the past, present and future uses of coal. It explains new technologies for coal and its global demand and supply.

NUCLEAR ENERGY

Federation of American Scientists (FAS)
http://www.fas.org/index.html

FAS was formed in 1945 by atomic scientists from the Manhattan Project who felt it was their ethical obligation to use their expertise to guarantee the safe and responsible application of nuclear energy. The FAS site contains a detailed explanation and diagram of the nuclear fuel cycle.

Nuclear Energy Institute (NEI)
http://www.nei.org/

NEI is the policy arm of the nuclear energy and technologies industry. It participates in both national and global policy-making. NEI's objective is to promote beneficial uses of nuclear energy and technologies in the U.S. and internationally.

Pew Center on Global Climate Change
http://www.pewclimate.org/

This site provides one explanation of global climate change and its causes and effects.

Union of Concerned Scientists (UCS)
http://www.ucsusa.org/

UCS is a nonprofit partnership of scientists and citizens whose mission is to ensure that all people have clean air, energy and transportation. UCS promotes solutions to global climate change and nuclear safety.

University of Wisconsin at Madison, College of Engineering. "University of Wisconsin Nuclear Reactor Tour."
http://reactor.engr.wisc.edu/tour/reactor.htm

This site explains how the University of Wisconsin nuclear reactor derives energy from splitting uranium atoms and how nuclear reactors produce electricity.

U.S. Nuclear Regulatory Commission (NRC)
http://www.nrc.gov/

NRC licenses and regulates commercial nuclear power plants, radioactive waste and other uses of nuclear materials, including nuclear medicine.

World Nuclear Association
http://www.world-nuclear.org/index.html

The World Nuclear Association is a private international organization that promotes the worldwide use of nuclear power as a sustainable energy resource.

SOLAR ENERGY

American Solar Energy Society. *Tackling Climate Change in the U.S.: Potential Carbon Emissions Reductions from Energy Efficiency and Renewable Energy by 2030*, by Charles F. Kutscher, ed. Boulder, Colorado, January 2007.
http://ases.org/climatechange/climate_change.pdf

This report compiles papers on six renewable energy technologies presented at the National Solar Energy Conference (SOLAR 2006). Experts in the fields of solar, wind, biomass, biofuels and geothermal were asked to calculate the potential for accelerating the deployment of renewable energy technologies.

Bradford, Travis. *Solar Revolution: The Economic Transformation of the Global Energy Industry.* Cambridge, Massachusetts: MIT Press, 2006.

This book discusses the future of energy and the role that renewable energy will play, focusing on solar energy.

NREL. *Power Technologies Energy Data Book,* by Jorn Aabakken, ed. 4th ed. Golden, Colorado, August 2006.
http://www.nrel.gov/analysis/power_databook/

This report profiles the various renewable energy technologies. It includes maps that overlay natural resources of biomass, geothermal, solar and wind energy with the national transmission grid and major electricity load centers. Another map shows current installed capacity, while a chart provides historic trends for generating capacity by state.

President's Council of Advisors on Science and Technology. *The Energy Imperative: Technology and the Role of Emerging Companies.* Washington, D.C., November 2006.
http://www.ostp.gov/pdf/pcast_energyimperative_final.pdf

This report makes recommendations for federal energy policy. It includes a discussion of global and national energy trends, the potential benefits of various technologies and federal government initiatives.

Renewable Energy Policy Project. "Federal Energy Subsidies: Not All Technologies are Created Equal," by Marshall Goldberg. *REPP: Renewable Energy Policy Project Research Report.* Washington, D.C., July 2000.
http://www.crest.org/repp_pubs/pdf/subsidies.pdf

This article provides information on federal subsidies for nuclear, wind, photovoltaic and solar thermal electricity-generating technologies. It includes subsidy estimates for select technologies.

The University of Texas at Austin, IC^2 Institute. *Opportunity on the Horizon: Photovoltaics in Texas*, by Bruce Kellison, Eliza Evans, Katharine Houlihan, Michael Hoffman, Michael Kuhn, Joel Serface, and Tuan Pham. Austin, Texas, June 2007.
http://www.utexas.edu/ati/cei/documents/TexasSolarOpportunity2007.pdf

This position paper details the solar industry in Texas. It provides information on the economic, public policy and technological benefits of growing the PV industry.

WIND ENERGY

DOE. *Annual Report on U.S. Wind Power Installation, Cost, and Performance Trends: 2006,* by Ryan Wiser and Mark Bolinger. Washington, D.C., May 2007.

http://www1.eere.energy.gov/windandhydro/pdfs/41435.pdf

> This report provides an overview of key wind development trends in the United States. The report includes information on wind capacity growth, dominant wind turbine manufacturers, turbine size, wind power prices, and project performance and capital costs.

Greenpeace International and Global Wind Energy Council. ***Global Wind Energy Outlook 2006.*** Amsterdam, Netherlands, September 2006.
http://www.gwec.net/fileadmin/documents/Publications/GWEC_A4_0609_English.pdf

> This report provides information on the status of wind power worldwide, discussing policy issues, environmental impacts, wind resources and the outlook for wind power.

Lawrence Berkeley National Laboratory. ***Using the Federal Production Tax Credit to Build a Durable Market for Wind Power in the United States,*** by Ryan Wiser, Mark Bolinger and Galen Barbose. Berkeley, California, November 2007.
http://eetd.lbl.gov/EA/emp/reports/63583.pdf

> This report discusses the importance of the federal production tax credit (PTC) on wind power development in the United States. It includes information on the legislative history and design of the PTC. The report also provides information on the impact that frequent expiration/extension cycles of the PTC have on the wind industry.

NREL. ***Wind Energy Update***, by Larry Flowers. Golden, Colorado, February 2008.
http://www.eere.energy.gov/windandhydro/windpoweringamerica/pdfs/wpa/wpa_update.pdf

> This PowerPoint presentation provides an update on wind energy. It includes graphics, maps and illustrations on a wide variety of topics including capacity and cost trends, wind resource map, evolution of wind technology, wind as a percent of electricity consumption, comparative generation costs and a list of the drivers of wind power.

Resources for the Future. ***The Economic and Policy Setting of Renewable Energy: Where Do Things Stand?*** by Joel Darmstadter. Washington, D.C., December 2003.
http://www.rff.org/documents/RFF-DP-03-64.pdf

> This report discusses the status and prospects for renewable energy. It provides detailed information and illustrations on wind power.

ETHANOL

DOE. ***Breaking the Biological Barriers to Cellulosic Ethanol: A Joint Research Agenda: A Research Roadmap Resulting from the Biomass to Biofuels Workshop, December 7-9, 2005, Rockville, Maryland.*** Washington, D.C., June 2006.
http://genomicsgtl.energy.gov/biofuels/2005workshop/b2blowres63006.pdf

> This comprehensive study contains information on the benefits and feasibility of biofuels, and discusses the use of systems biology to overcome barriers to cellulosic ethanol production. It also provides a wealth of detail on the biological processes involved in producing cellulosic ethanol.

DOE. "Genomics: GTL—Systems Biology for Energy and Environment."
http://genomicsgtl.energy.gov/biofuels/index.shtml

> This site provides a number of links to information on the use of biofuels for transportation, the ethanol production process and the benefits and challenges of cellulosic ethanol.

DOE. Oak Ridge National Laboratory (ORNL) and U.S. Department of Agriculture. ***Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply,*** by Robert Perlack, Lynn Wright, Anthony Turhollow, Robin Graham, Bryce Stokes, and Donald Erbach. Oak Ridge, Tennessee, April 2005.
http://www1.eere.energy.gov/biomass/pdfs/final_billionton_vision_report2.pdf

This publication estimates the amount of biomass resources likely to be available for energy production and other needs by the middle of the 21st century.

DTN. "DTN Ethanol Center."
http://www.dtnethanolcenter.com/

This site offers the latest ethanol news, an ethanol blog and locations for ethanol production plants. It also provides information on various related industries including the corn, soybean and sugar markets.

Lawrence Livermore National Laboratory. *Health and Environmental Assessment of the Use of Ethanol as a Fuel Oxygenate: Report to the California Environmental Policy Council in Response to Executive Order D-5-99.* Livermore, California, December 1999.
http://www-erd.llnl.gov/ethanol/etohdoc/index.html

This report addresses the effects of using ethanol as a fuel oxygenate. Topics covered include impacts on human health, air quality, groundwater and surface water.

National Corn Growers Association. *2008 World of Corn.* Chesterfield, Missouri, 2008.
http://www.ncga.com/WorldOfCorn/main/WOC%202008.pdf

This report provides statistics on the amount of corn planted, harvested and consumed in the U.S., and facts about corn-based ethanol production.

Renewable Fuels Association
http://www.ethanolrfa.org/

This site reviews public policies related to renewable fuels and provides information on the ethanol industry as well as data on ethanol production. It also covers topics such as renewable fuels standards and available subsidies.

Texas State Energy Conservation Office (SECO)
http://www.seco.cpa.state.tx.us/

This site provides information on nearly every aspect of ethanol, including subsidies, availability in Texas, cellulosic ethanol, Texas ethanol plants and issues affecting the ethanol industry.

BIODIESEL

Castor Oil.in. "Bio-diesel WWW Encyclopedia."
http://www.castoroil.in/reference/plant_oils/uses/fuel/bio_fuels.html

This site provides a collection of resource links about biodiesel featuring information on all aspects of the product, from production to consumption.

EIA. *Biodiesel Performance, Costs, and Use*, by Anthony Radich. Washington, D.C., June 2004.
http://www.eia.doe.gov/oiaf/analysispaper/biodiesel/index.html

This paper explains the procedures EIA uses to calculate the cost of biodiesel to consumers and producers.

EPA. "Biodiesel: Fat to Fuel."
http://www.epa.gov/region09/waste/biodiesel/index.html

This site details the benefits of biodiesel, highlights funding opportunities and provides definitions and resources about this fuel source. Some regional information is available.

National Biodiesel Board. *"Biodiesel: The Official Site of the National Biodiesel Board."*
http://www.biodiesel.org

The National Biodiesel Board is the national trade association of the U.S. biodiesel industry. The site provides fact sheets and other information on biodiesel and the industry. This site reports on the market for biodiesel and its environmental impact.

WOOD

Federal Energy Management Program (FEMP). "Biomass Cofiring in Coal-Fired Boilers." *Federal Technology Alert.* Washington, D.C., May 2004.
http://www1.eere.energy.gov/femp/pdfs/fta_biomass_cofiring.pdf

This report examines the cofiring of fossil fuels with wood waste as a method for reducing operating costs, reducing pollution and expanding the use of renewable energy. It includes a case study and discusses implementation barriers for cofiring operations.

FEMP. *Biomass Energy—Focus on Wood Waste.* Washington, D.C., July 2004.
http://www1.eere.energy.gov/femp/pdfs/bamf_woodwaste.pdf

This publication examines wood-fired biomass and the benefits of wood-waste fuels, explaining their potential and providing examples of successful energy projects using wood waste.

Nacogdoches Power, LLC. "Project Info."
http://www.nacogdochespower.com/ProjectInfo.html

Nacogdoches Power is a joint venture between Bay Corp Holdings and Energy Management, two companies that own a variety of electricity generation facilities throughout the northeastern U.S. Nacogdoches Power is building a 100 megawatt wood-fired biomass facility in Sacul, Texas. This site provides a brief description of the project.

NREL. *The Value of the Benefits of U.S. Biomass Power.* Golden, Colorado, November 1999.

This report discusses the positive and negative aspects of the use of wood-fired biomass for electricity generation.

ORNL. *Processing Cost Analysis for Biomass Feedstocks*, by Phillip Badger. Oak Ridge, Tennessee, October 2002.
http://bioenergy.ornl.gov/pdfs/ornltm-2002199.pdf

This report focuses on the various processes involved in generating electricity from forest and mill residues and urban waste including fuel handling, storing and processing. It also discusses various combustion systems used and environmental factors affecting the industry.

Texas Forest Service (TFS). *Biomass from Logging Residue and Mill Residue in East Texas, 2005,* by Weihuan Xu and Burl Carraway. College Station, Texas, May 2007.
http://txforestservice.tamu.edu/uploadedFiles/Sustainable/econdev/TXloggingmillresidue2005.pdf

TFS is a division of the Texas A&M University System, charged with directing all forest interests in Texas. This publication discusses the availability of wood residues in a 43-county area of East Texas and provides estimates of the amount of logging and mill residue available.

Texas Forestry Association (TFA)
http://www.texasforestry.org/

TFA is a nonprofit trade group of more than 3,200 Texas foresters that promotes the industry in Texas.

FEEDLOT BIOMASS

American Society of Agricultural and Biological Engineers. "Feedlot Manure as Reburn Fuel for NO_X Reduction in Coal Fired Plants," by K. Annamali, B. Thien, J. Sweeten, K. Heflin and L.W. Greene. *Proceedings of the Third International Conference on Air Pollution from Agricultural Operations*, Research Triangle Park, N.C, October 12-15, 2003. St. Joseph, Michigan, 2003.

This publication, written by a group of Texas A&M System researchers, discusses the use of manure as a reburn fuel.

EPA. *AgSTAR Handbook*, 2nd ed. Washington, D.C., January 2008.
http://www.epa.gov/agstar/resources/handbook.html

This publication discusses methane generation from manure, to help farmers evaluate the prospects for using anaerobic generation.

NREL. *Methane Recovery from Animal Manures: The Current Opportunities Casebook,* by P. Lusk. Washington, D.C., September 1998.
http://www.nrel.gov/docs/fy99osti/25145.pdf

This publication focuses on methane generation from manure, emphasizing anaerobic digestion.

LANDFILL GAS

EPA. *An Overview of Landfill Gas Energy in the United States.* Washington, D.C., May 2007. http://epa.gov/lmop/docs/overview.pdf

This site describes the federal Landfill Methane Outreach Program, which promotes the development of landfill gas energy, and provides an overview of how landfill gas is converted to energy and why the process is beneficial to the environment.

EPA. "Trash to Treasure: Landfills as an Energy Resource," by Rachel Goldstein. *District Energy*, Third Quarter 2006. http://www.epa.gov/landfill/docs/3q06landfill.pdf

This reprinted article provides a brief but comprehensive overview of the use of landfill gas for energy.

NREL. *Managing America's Solid Waste*, by J.A. Phillips. Golden, Colorado, September 1998. http://www.nrel.gov/docs/legosti/fy98/25035.pdf

This report is a comprehensive study on all aspects of waste disposal, including its history and interviews with key personnel.

TCEQ. *Municipal Solid Waste in Texas: A Year in Review: FY 2005 Data Summary and Analysis.* Austin, Texas, June 2006. http://www.tceq.state.tx.us/assets/public/comm_exec/pubs/as/187_06.pdf

This report on Texas solid waste disposal provides facts and figures about solid waste generation, disposal and prevention of damage.

MUNICIPAL WASTE COMBUSTION

EPA. "Municipal Solid Waste in the United States: 2006 Facts and Figures." Washington, D.C., January 2008. http://www.epa.gov/epaoswer/non-hw/muncpl/msw99.htm

This site provides facts and figures about U.S. solid waste generation and disposal.

Integrated Waste Services Association. *The 2007 IWSA Directory of Waste-to-Energy Plants*, by Ted Michaels. Washington, D.C., October 2007. http://www.wte.org/docs/IWSA_2007_Directory.pdf

This is a comprehensive survey of waste-to-energy facilities in the U.S., with useful maps and charts about the field. Information on each plant includes trash capacity, energy capacity, startup date, use of technology, owner, operator, continuous emissions monitors and air pollution control systems.

Lehman College. "Introduction to Municipal Solid Waste Incineration," by Marjorie J. Clarke. Paper presented at the Air and Waste Management Association Annual Meeting, Baltimore, Maryland, June 23-27, 2002. New York City. http://www.geo.hunter.cuny.edu/~mclarke/IntroMSWincineration.htm

This paper on the science of municipal solid waste incineration contains illustrations and an extensive list of references.

Waste-to-Energy Research and Technology Council. "The ABC of Integrated Waste Management (IWM)." New York City. http://www.seas.columbia.edu/earth/wtert/faq.html

This site provides a list of frequently asked questions about IWM, answered by the group representing the waste-to-energy industry. The site explains the costs, benefits and processes of IWM.

HYDROELECTRICITY

American Society of Civil Engineers. "Report Card for America's Infrastructure: Dams." http://www.asce.org/reportcard/2005/page.cfm?id=23

This article looks at dam safety and the present condition of the nation's dams, and provides recommendations for action.

Banks, Jimmy and John E. Babcock. ***Corralling the Colorado: The First Fifty Years of the Lower***

Colorado River Authority. Austin, Texas: Eakin Press, 1988.

This book is a comprehensive history of the development of the Highland Lakes and the quasi-governmental agency that controls them.

EPA. eGRID, Version 2.1. Washington, D.C., April 2007.
http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html

The Emissions & Generation Resource Integrated Database (eGRID) is a comprehensive inventory of the environmental effects of U.S. electric power systems, including air emissions data. eGRID2006 Version 2.1 contains the complete release of year 2004 data, organized to reflect the owner, operator and electric grid configuration as of October 1, 2006.

Foundation for Water and Energy Education. "Education."
http://fwee.org/education.html

The foundation's Web site provides educational resources about hydropower, hydroelectric generation, environmental impacts and current issues.

Franklin and Eleanor Roosevelt Institute. *TVA: Electricity for All.* Hyde Park, New York, 2003.
http://newdeal.feri.org/tva/index.htm

This site provides information about the Tennessee Valley Authority and its hydroelectric dams, built as a result of the New Deal and the rural electrification program of the 1930s.

International Rivers Network. *Fizzy Science: Loosening the Hydro Industry's Grip on Reservoir Greenhouse Gas Emissions Research,* by Patrick McCully. Berkeley, California, November 2006.
http://internationalrivers.org/files/FizzyScience2006.pdf

This paper examines the controversy in the scientific community over greenhouse gas emissions from reservoirs. It discusses this technical and often-misunderstood issue in a clear and straightforward manner.

Texas Water Development Board (TWDB). *2007 State Water Plan.* Austin, Texas, November 2006.
http://www.twdb.state.tx.us/publications/reports/State_Water_Plan/2007/2007StateWaterPlan/2007StateWaterPlan.htm

Texas water law requires the TWDB to produce a state water plan to provide for the development, management and conservation of Texas' water resources. The plan also must provide responses for drought conditions. The state water plan incorporates regional water plans from the state's 16 water planning regions.

OCEAN POWER

Center for Energy and the Global Environment. "Southern New England Wave Energy Resource Potential," by George Hagerman. Paper presented at *Building Energy 2001*, Tufts University, Boston, Massachusetts, March 23, 2001.
http://ctinnovations.com/pdfs/S_New_Engl_Wave_Energy_Resource_Potential.pdf

This technical paper contains information about the wave energy potential of a specific U.S. location, discusses differences in the power of New England and British waves and reviews areas in Japan doing wave research.

Electric Power Research Institute. *Final Summary Report: Project Definition Study—Offshore Wave Power Feasibility Demonstration Project*, by Roger Bedard, George Hagerman, Mirko Previsic, Omar Siddiqui, Robert Thresher, and Bonnie Ram. Palo Alto, California, September 2005.
http://www.epri.com/oceanenergy/attachments/wave/reports/009_Final_Report_RB_Rev_2_092205.pdf

This report discusses the wave power potential of five U.S. sites as well as possible devices and plant designs.

European Commission. "Energy Research: Introduction to Ocean Energy Systems."

http://ec.europa.eu/research/energy/nn/nn_rt/nn_rt_oes/article_1128_en.htm

This European Union site on the subject of ocean energy describes some of the research and development projects the European Commission is supporting.

Ocean Renewable Energy Coalition. *Ocean Energy Report for 2005,* by Carolyn Elefant and Sean O'Neill. Peterborough, New Hampshire: RenewableEnergyWorld.com, January 9, 2006. http://www.renewableenergyworld.com/rea/news/infocus/story?id=41396

This article provides a thorough summary of events in the ocean power arena in 2005. It is a useful resource on a relatively new technology.

Research Institute for Sustainable Energy (RISE). "Information Portal – Wave." Perth, Australia: Murdoch University, August 5, 2006. http://www.rise.org.au/info/Tech/wave/index.html

This Australian site provides a primer on wave energy devices, with photos, explanatory diagrams and links to further information.

Scottish Enterprise. *Marine Renewable (Wave and Tidal) Opportunity Review: Introduction to the Marine Renewable Sector.* Glasgow, Scotland, December 2005. http://oceanrenewable.com/wp-content/uploads/2007/03/oregreport.pdf

This paper provides an extensive introduction to the Scottish ocean energy sector, covering subjects such as project life-cycles and supply chains. It also reviews ocean energy elsewhere in the world.

State of Hawaii. "Ocean Thermal Energy." Honolulu, Hawaii: March 20, 2007. http://hawaii.gov/dbedt/info/energy/renewable/otec

This site offers information and history about ocean thermal energy conversion (OTEC). All U.S. OTEC activity to date has taken place in Hawaii.

Weiss, Peter. "Oceans of Electricity: New Technologies Convert the Motion of Waves into Watts." *Science News,* April 14, 2001. http://www.sciencenews.org/articles/20010414/bob12.asp

This article provides a history and other information about the potential of wave energy.

GEOTHERMAL ENERGY

American Solar Energy Society. *Tackling Climate Change in the U.S.: Potential Carbon Emissions Reductions from Geothermal Power by 2030,* by Martin Vorum and Jefferson Tester. Boulder, Colorado. http://www.ases.org/climatechange/toc/09_geothermal.pdf

This report summarizes various reports on the potential for geothermal energy in the U.S. It includes a good discussion of the obstacles and benefits involved in the development of geothermal resources.

Carrier Corporation, United Technologies Research Center and Chena Hot Springs Resort. "Power Production from a Moderate -Temperature Geothermal Resource," by Joost J. Brasz, Bruce P. Biederman, and Gwen Holdmann. Paper presented at the GRC Annual Meeting, Reno, Nevada, September 25-28, 2005. http://www.yourownpower.com/Power/grc%20paper.pdf

This technical paper explains Organic Rankine Cycle technology, which can produce electricity from non-traditional heat sources such as lower-temperature geothermal resources and waste heat from other processes. The authors are associated with the companies that created the Chena Hot Springs system in Alaska.

DOE. *Federal Geothermal Research Program Update: Fiscal Year 2002.* Washington, D.C., September 2003. http://www1.eere.energy.gov/geothermal/pdfs/fy02_program_review.pdf

This report provides background into the goals for geothermal energy development in the U.S.

DOE. "Geothermal Technologies Program." Washington, D.C., March 19, 2008. http://www1.eere.energy.gov/geothermal/

This is the main portal for geothermal information of all kinds, including information on how geothermal power plants and EGS systems work.

Louisiana State University, Basin Research Institute. *Gulf Coast Geopressured-Geothermal Program Summary Report Compilation*, by Chacko J. John, Gina Maciasz and Brian J. Harder. Washington, D.C.: DOE, June 1998. http://www.osti.gov/bridge/servlets/purl/661414-sdGF56/webviewable/661414.PDF

This report describes a geothermal power plant in Brazoria County that produced electricity for several months in 1989 and 1990.

MIT. *The Future of Geothermal Energy: Impact of Enhanced Geothermal Systems (EGS) on the United States in the 21st Century—An Assessment by an MIT-led Interdisciplinary Panel.* Cambridge, Massachusetts, 2006. http://geothermal.inel.gov/publications/future_of_geothermal_energy.pdf

This in-depth report covers the subject of Enhanced (or Engineered) Geothermal Systems (EGS) and their potential in the U.S. The report suggests that a modest investment in R&D could produce 100,000 megawatts of electrical generation capacity within 50 years.

NREL. *Geothermal—The Energy Under Our Feet: Geothermal Resource Estimates for the United States*, by Bruce D. Green and R. Gerald Nix. Golden, Colorado, November 2006. http://www.nrel.gov/docs/fy07osti/40665.pdf

This report details a workshop for geothermal experts conducted by the National Renewable Energy Laboratory. It provides estimates of domestic geothermal resources as well as more general information about geothermal energy.

SECO. "Texas Geothermal Energy." http://www.seco.cpa.state.tx.us/re_geothermal.htm

This site on geothermal energy contains information about geothermal resources in the U.S. and Texas, as well as various ways to use geothermal energy.

University of Texas of the Permian Basin. *Geopowering Texas: A Report to the Texas State Energy Conservation Office on Developing the Geothermal Energy Resource of Texas*, by Richard Erdlac, Jr. Austin, Texas: SECO, January 2007. http://www.seco.cpa.state.tx.us/zzz_re/re_geopowering2007.pdf

This report compiles information about the development of geothermal energy in Texas. It explores the possibilities of using oil and gas well data to develop geothermal resources, with an emphasis on West Texas.

HYDROGEN

SECO. *Accelerating the Commercialization of Fuel Cells in Texas.* Austin, Texas, 2002. http://www.seco.cpa.state.tx.us/zzz_feulcell-initiative/fciac_finalreport.pdf

This plan, prepared in response to a legislative mandate, provides both background and recommendations for accelerating the commercialization of fuel cells.

State of California. "California Hydrogen Highway." http://www.hydrogenhighway.ca.gov/

This site provides information about California's progress towards developing hydrogen-based transportation in the state.

Texas Department of Transportation (TxDOT). *TxDOT Strategic Plan for Hydrogen Vehicles and Fueling Stations.* Austin, Texas, August 2006. http://www.utexas.edu/research/ctr/pdf_reports/0_5590_1.pdf

This plan, prepared in response to a legislative mandate, defines a path for TxDOT to follow in encouraging the introduction of hydrogen as a fuel in Texas.

EFFICIENCY AND CONSERVATION

American Council for an Energy-Efficient Economy (ACEEE). ***Potential for Energy Efficiency, Demand Response, and Onsite Renewable Energy to Meet Texas's Growing Electricity Needs***, by Neal Elliott, Maggie Eldridge, Anna Shipley, John 'Skip' Laitner, Steven Nadel, Alison Silverstein, Bruce Hedman and Mike Sloan. Washington, D.C., March 2007.
http://www.aceee.org/pubs/e073.htm

This report examines Texas' efficiency resources. It explains levels of energy efficiency, how to make use of them and the resulting costs and benefits.

ACEEE. ***The Economic Benefits of an Energy Efficiency and Onsite Renewable Energy Strategy to Meet Growing Electricity Needs in Texas,*** by John 'Skip' Laitner, R. Neal Elliott and Maggie Eldridge. Washington, D.C., September 2007.
http://www.aceee.org/pubs/e076.htm

This follow-up report forecasts the macroeconomic effects of the policy recommendations outlined in the previous report, concluding that they are cost-effective and would provide an economic stimulus while reducing air emissions significantly.

DOE. "Energy Efficiency and Renewable Energy."
http://www.eere.energy.gov/

This site provides good information available about conserving and using energy efficiently, as well as links to other renewable energy sites.

DOE. "Energy Savers: Tips on Saving Energy & Money at Home."
http://www1.eere.energy.gov/consumer/tips/save_energy.html

This site provides energy and money-saving tips.

DOE and EPA. ***National Action Plan for Energy Efficiency: A Plan Developed by More than 50 Leading Organizations in Pursuit of Energy Savings and Environmental Benefits through Electric and Natural Gas Energy Efficiency.*** Washington, D.C., July 2006.
http://www.epa.gov/cleanenergy/documents/napee/napee_report.pdf

DOE and EPA released this National Action Plan to encourage a sustainable, aggressive national commitment to energy efficiency. The plan enumerates the barriers to increased energy efficiency. It was developed by more than 50 participants representing state utility commissions, power companies, large retailers, state energy offices (including SECO) and consumer advocates.

Frontier Associates. "Texas Energy Efficiency." Austin, Texas.
http://www.texasefficiency.com/

This site, supported by investor-owned utilities, provides information on the utility efficiency programs required by the 1999 Texas Legislature.

McKinsey Global Institute. ***Curbing Global Energy Demand Growth: The Energy Productivity Opportunity*** by Florian Bressand, Diana Farrell, Pedro Haas, Fabrice Morin, Scott Nyquist, Jaana Remes, Sebastian Roemer, Matt Rogers, Jaeson Rosenfeld, and Jonathan Woetzel. San Francisco, California, May 2007.
http://www.mckinsey.com/mgi/reports/pdfs/Curbing_Global_Energy/MGI_Curbing_Global_Energy_full_report.pdf

This is an in-depth sector case study covering buildings, transportation, and industries. It highlights how policies and investments in existing technologies that yield an internal rate of return of 10 percent or higher can contribute to a reduction in global energy demand growth.

Western Governors' Association (WGA). ***Clean Energy, a Strong Economy and a Healthy Environment: Report of the Clean and Diversified Energy Advisory Committee to the Western***

Governors. Denver, Colorado, June 2006.
http://www.westgov.org/wga/meetings/am2006/CDEAC06.pdf

This report presents the findings and recommendations of a task force that examined existing energy efficiency programs and the potential for additional savings within the 18 states of the WGA region. It also describes the benefits of the adoption of a set of "Best Energy Practices" for the WGA states, as well as market failures and barriers that restrict greater investment in energy efficiency.

DIRECT USE

EIA. "Official Energy Statistics from the U.S. Government."
http://www.eia.doe.gov/

EIA publishes individual State Energy Profiles that list details on usage, generating capacity, fuel mix, etc. The profiles provide historical information from 1990 through 2005, and report the state information as a percentage of U.S. totals for analysis and forecasting purposes.

TRANSPORTATION

Aspen Institute. *Energy Markets and Global Politics: 2006 Forum on Global Energy, Economy and Security,* by Leonard L. Coburn. Washington D.C., 2006.
http://www.aspeninstitute.org/atf/cf/{DEB6F227-659B-4EC8-8F84-8DF23CA704F5}/EE_ENERGY_MARKETS_AND_GLOBAL_POLITICS_I.PDF
(Part I); and

http://www.aspeninstitute.org/atf/cf/{DEB6F227-659B-4EC8-8F84-8DF23CA704F5}/EE_ENERGY_MARKETS_AND_GLOBAL_POLITICS_II.PDF
(Part II)

This publication discusses the effect of global politics and burgeoning global energy markets on the U.S. transportation industry.

Auto Alliance. "Resources and Tools: Alternative Fuel Autos are Everywhere."
http://www.discoveralternatives.org/Resources_and_Tools_AFAs_Everywhere.php

This site lists the number of alternative fuel vehicles operating in the nation and in each state.

EIA. "Table S7. Transportation Sector Energy Consumption Estimates, 2005."
http://www.eia.doe.gov/emeu/states/sep_sum/html/sum_btu_tra.html

This site details transportation usage in the U.S., including the types of fuel used by each state and sector as well as the types of fuel produced.

National Museum of American History. "America on the Move."
http://americanhistory.si.edu/ONTHEMOVE/themes/story_48_1.html

This site provides several videos about the history of the transportation industry and its effect on the U.S. economy and lifestyle.

ORNL. *Transportation Energy Data Book,* 26th ed., by Stacy C. Davis and Susan W. Diegel. Oak Ridge, Tennessee, 2007.
http://cta.ornl.gov/data/download26.shtml

This 26th edition is a statistical compendium prepared and published by the Oak Ridge National Laboratory. It is designed as a desktop reference with statistics and information on transportation activity as well as factors that influence transportation energy use.

U.S. Government Accountability Office (GAO). *Crude Oil: Uncertainty about Future Oil Supply Makes It Important to Develop a Strategy for Addressing a Peak and Decline in Oil Production.* Washington, D.C., February 2007.
http://www.gao.gov/new.items/d07283.pdf

This publication considers when worldwide oil production could peak and assesses the potential for transportation technologies to mitigate the consequences of a decline in oil production. It also examines federal efforts to reduce uncertainty about peak oil production and how to lessen the consequences of a decline.

ELECTRICITY

EIA. "Electricity Generating Capacity." http://www.eia.doe.gov/cneaf/electricity/page/capacity/capacity.html

EIA publishes annual reports on electricity generating capacity that include data on existing electric generating units listed by state. This site details electric generating unit additions by state for 2005 and 2006, and lists proposed generation units by state, company and plant for 2008. It includes counts of plant generators by energy source.

Houston Advanced Research Center and Institute for Energy, Law and Enterprise, University of Houston Law Center. *Guide to Electric Power in Texas,* 3rd ed. Houston, Texas, January 2003. http://www.beg.utexas.edu/energyecon/documents/guide_electric_power_texas_2003.pdf

This guide was prepared to provide a comprehensive and balanced educational resource for a wide range of retail customer groups.

Public Utility Commission of Texas (PUC). *2007 Report to the 80th Texas Legislature: Scope of Competition in Electric Markets in Texas.* Austin, Texas, January 2007. http://www.puc.state.tx.us/electric/reports/scope/index.cfm

PUC publishes information every two years on the status of deregulation in the Texas electricity market.

PUC. *The State of Texas Official Guide to Electric Choice: Everything You Need to Know About Choosing an Electric Company that's Right for You.* Austin, Texas, June 2007. http://www.powertochoose.org/_files/_pdf/Consumerguide_eng.pdf

This brochure is intended to help consumers understand recent changes in Texas' electric market. To learn more, call the Texas Electric Choice Answer Center toll-free at (866) PWR-4-TEX [(866)797-4839]; TTY users should dial 7-1-1 in Texas.

SUBSIDIES ACROSS FUEL SOURCES

Bezdek, Robert and Robert Wending. **"A Half Century of U.S. Federal Government Energy Incentives: Value, Distribution, and Policy Implications" *International Journal of Global Energy Issues,*** 2007.

This article estimates federal government energy subsidies for the last 50 years. It also advocates for expanded federal support for renewable energy.

EIA. *Federal Financial Interventions and Subsidies in Energy Markets 1999: Primary Energy.* Washington, D.C., September 1999. http://www.eia.doe.gov/oiaf/servicerpt/subsidy/pdf/sroiaf(99)03.pdf

This report examines direct federal payments to producers or consumers of primary energy sources and discusses federal assistance for research and development of primary energy sources.

GAO. *Federal Electricity Subsidies: Information on Research Funding, Tax Expenditures, and Other Activities that Support Electricity Production.* Washington, D.C., October 2007. http://www.gao.gov/new.items/d08102.pdf

This report provides information on DOE federal funding for electricity-related research and development, including funding by type of fuel. It also reviews the tax expenditures the federal government provides to subsidize electricity production, again citing expenditures by type of fuel. The report details ways the government subsidizes electricity through federal power entities, the Department of Agriculture and the Price-Anderson Act.

Koplow, Douglas. ***Federal Energy Subsidies: Energy, Environmental, and Fiscal Impacts.*** Washington, D.C.: Alliance to Save Energy, April 1993. http://www.earthtrack.net/earthtrack/library/Fed%20Subsidies_1993%20Main%20Report.pdf

This report on 1989 federal subsidies to the energy sector explains their scope and their role in the promotion of U.S. energy policy. It recommends a subsidy pattern for renewable, nonpolluting energy and energy efficiency to meet our environmental, fiscal, economic and national security goals.

Koplow, Douglas. **"Memorandum to Jason Grumet and Drew Kodjak, National Commission on Energy Policy. Federal Subsidies to Energy in 2003 – A First Look,"** Cambridge, Massachusetts: Earth Track, July 30, 2004. http://www.earthtrack.net/earthtrack/library/FedSubs2003.pdf

This memorandum evaluates more than 75 federal subsidies to energy. It explains how the federal government subsidizes this sector of the economy and how much these programs are worth to the private sector.

SUBSIDIES RELATED TO OIL AND GAS

Congressional Research Service. ***Oil and Gas Tax Subsidies: Current Status and Analysis***, by Salvatore Lazzari. Washington, D.C., February 27, 2007. http://www.ncseonline.org/NLE/CRSreports/07March/RL33763.pdf

This report reviews oil and gas tax subsidies including those targeted for repeal by the CLEAN Energy Act of 2007.

GAO. ***GAO Briefing on Oil and Gas Royalties.*** Washington, D.C., March 27, 2006. http://www.nytimes.com/packages/pdf/business/29lease.pdf

This report examines the impact of various factors on oil and gas royalty revenues from 2001 to 2005 and the financial impact of royalty relief in the Gulf of Mexico.

SUBSIDIES RELATED TO RENEWABLES

EIA. ***Incentives, Mandates, and Government Programs for Promoting Renewable Energy,*** by Mark Gielecki, Fred Mayes and Lawrence Prete. Washington, D.C., February 2001. http://www.eia.doe.gov/cneaf/solar.renewables/rea_issues/incent.html

This report weighs the effectiveness of federal and state subsidies, mandates and support programs, including research and development, in furthering growth in electric generation and capacity. It states that some renewable facilities have failed because cost reductions have not kept pace with cost declines occurring in natural gas-fired generation.

MIT. ***Federal Tax Policy towards Energy,*** by Gilbert Metcalf. Cambridge, Massachusetts, January 2007. http://web.mit.edu/globalchange/www/MITJPSPGC_Rpt142.pdf

This report surveys the impact of tax subsidies derived from the Energy Policy Act of 2005. It argues that tax subsidies for domestic oil production on world oil supply and prices have little global impact. The report also states that nuclear power and renewable electricity sources benefit from depreciation and that tax credits make clean coal technologies cost-competitive with pulverized coal. It contends that tax credits for wind and biomass are cost-competitive with those for natural gas.

CHAPTER 31

Glossary of Energy Terms

Acid rain: Acid rain describes acidic compounds that fall out of the atmosphere, causing a variety of ground-level environmental effects. Acid rain can harm forests and soils, fish and wildlife and human health. Acid rain is caused primarily by emissions of sulfur dioxide and nitrogen oxides.

Air pollution control systems (APCS): APCS are used to eliminate or reduce airborne pollutants such as smoke, ash, dust, fly, sulfur, nitrogen oxides, carbon monoxide, odors and hydrocarbons. Some APCS include nitrogen oxide control devices, flue-gas particulate collectors and desulfurization units.

Alternative fuels: For transportation purposes, these include methanol, denatured ethanol and other alcohols, and fuels made with propane, hydrogen, coal-derived liquids and biological materials such as soy diesel. Alternative fuels also include energy derived from wind and solar power and any other fuels that are not substantially petroleum-based.

Ampere: The basic unit of electric current adopted under the Systeme International d'Unites. Commonly known as an "Amp." See also *Joule* and *Watt*.

Anaerobic: Meaning "in the absence of oxygen." In such environments, microscopic organisms can break down organic material such as manure.

Attainment area: A geographic region where the concentration of a specific air pollutant does not exceed federal standards.

Average megawatt (MWa or aMW): One megawatt of capacity produced continuously over a period of one year. 1 aMW = 1 MW x 8760 hours/year = 8,760 MWh = 8,760,000 kWh.

Bcf: Billion cubic feet.

Biodegradable: Capable of decomposing rapidly under natural conditions.

Biodiesel: A biofuel produced through transesterification, a process in which organically derived oils are combined with alcohol (ethanol or methanol) in the presence of a catalyst to form ethyl or methyl ester. Biomass-derived ethyl or methyl esters can be blended with conventional diesel fuel or used on their own (100 percent biodiesel). Biodiesel can be made from soybean or rapeseed oils, animal fats, waste vegetable oils or microalgae oils. See also *Renewable energy*.

Biofuel: Gas or liquid fuels made from plant materials rather than petroleum products. Ethanol, biodiesel and methanol are biofuels. See also *Ethanol*, *Grain alcohol* and *Renewalbe energy*.

Biogas: A combustible gas derived from decomposing biological waste. Biogas normally consists of 50 to 60 percent methane.

Biomass fuel: Liquid, solid or gaseous fuel produced by the conversion of biomass. See also *Liquefaction*.

Biomass: Renewable organic matter such as agricultural crops and residue, wood and wood waste, animal waste, aquatic plants and the organic components of municipal and industrial wastes.

Boiler: A device for generating hot water or steam for power or heating purposes. Heat from a combustion source is transmitted to a fluid contained within tubes in the shell of the boiler. This heated fluid is delivered to an end use at a desired quality, temperature and pressure.

British thermal unit (Btu): A unit of heat energy equal to the heat needed to raise the temperature of one pound of water one degree Fahrenheit at one atmosphere pressure (sea level). See also *Kilowatt hour (kWh).*

Butane: A gas derived from natural gas or crude oil. Butane is a common component of gasoline and liquefied petroleum gas.

Capacity factor: The ratio of the energy produced by a generating unit in a given period of time to the energy that would have been produced at continuous full power operation during the same period.

Capacity: The maximum power that a machine or system can produce or carry safely. Capacity is the maximum instantaneous output of a resource under specified conditions. The capacity of generating equipment generally is expressed in kilowatts or megawatts.

Carbon dioxide (CO_2): An atmospheric gas formed by the burning of carbon-based materials. CO_2 is also produced by the respiratory systems of most of the world's life forms. Humans and animals exhale it; plants use it for photosynthesis. CO_2 is the world's most common greenhouse gas.

Carbon monoxide (CO): A colorless, odorless, poisonous gas produced when the carbon in fossil fuels is not entirely burned during combustion.

Carbon sink: A biosystem, such as a forest or an ocean, which absorbs carbon dioxide.

Carbon sequestration: The absorption and storage of carbon dioxide from the atmosphere. Carbon sequestration occurs naturally in plants.

Casinghead gas: Natural gas co-produced with crude oil from an underground formation.

Cellulosic ethanol: Conventional ethanol is derived from soft starches such as corn, while cellulosic ethanol is made from a wide variety of cellulose plant fiber, including stalks, grain straw, switchgrass, trees, and even municipal waste.

Clean Air Act (CAA): Federal law establishing ambient air quality emission standards for implementation by participating states. Originally enacted in 1963, the CAA was last amended in 1990. The CAA includes vehicle emission standards regulating the emission of criteria pollutants (lead, ozone, carbon monoxide, sulfur dioxide, nitrogen oxides and particulate matter). The 1990 amendments added reformulated gasoline requirements and oxygenated gasoline provisions.

CLEAN Energy Act of 2007 or the Energy Independence and Security Act of 2007: This act is intended to move the U.S. toward greater energy independence and security; increase the production of clean renewable fuels; protect consumers; increase the energy efficiency of products, buildings and vehicles; promote research on and the deployment of greenhouse gas capture and storage options; and improve the energy performance of the federal government.

Climate change: A term used for all forms of weather variances brought about by natural causes such as volcanic eruptions or human causes such as industrial pollution. See also *global warming.*

Coal: A fossil fuel composed mostly of carbon with traces of other elements. Coal is found in seams that can be extracted either by surface or underground mining.

Cofiring: The combustion or cogasification of coal and biomass, or the combustion of coal with biomass-derived fuel gas.

Cogeneration: See *Combined heat and power (CHP).*

Combined heat and power (CHP): The simultaneous production of electricity and heat from a single fuel source, such as natural gas, biomass, biogas, coal, waste heat or oil. Also known as cogeneration.

Combustion gases: Gases released by burning.

Combustion: Burning. The transformation of biomass fuel into heat, chemicals and gases through a chemical combination of hydrogen and carbon in fuel with oxygen in the air.

Compressed natural gas (CNG): Natural gas that has been compressed under high pressure (typically 2,000 to 3,600 pounds per square inch). See also *natural gas*.

Competitive Renewable Energy Zones (CR-EZs): Areas of the state identified as having the best renewable energy resources and requiring transmission infrastructure to deliver that energy to customers.

Concentrating Solar Power (CSP): Generally refers to large-scale solar thermal technology systems that use mirrors or reflectors to focus sunlight to heat a fluid and make steam, which then is used to generate electricity. See also *solar energy and parabolic trough*.

Conservation: Efficiency of energy use, production, transmission or distribution that results in a decrease of energy consumption while providing the same level of service.

Corporate Average Fuel Economy (CAFE): Federal standards enacted in 1975 for fuel economy in motor vehicles. The average of city and highway fuel economy test results weighted by a manufacturer for its car or truck fleet.

Crude oil: A mixture of liquid or gaseous hydrocarbons found in natural underground reservoirs. (Crude oil may exist in gaseous phase underground but become liquid at normal atmospheric pressure after being recovered from oil well or casinghead gas in lease separators.) Crude oil also may be recovered as a liquid from natural gas wells or as liquid products from tar sands, oil sands gilsonite and oil shale or as drip gases, which are a natural form of gasoline. Crude oil can be refined to produce heating oils, gasoline, diesel, jet fuels, lubricants, asphalt, ethane, propane, butane and many other products.

Decommissioning: Refers to the dismantling and removal of wind turbines at the end of their useful lives. See also *wind turbines and wind farms.*

Dekatherm: A metric unit of heat measurement equal to 1 million *BTUs*.

Deregulation: In the context of energy, the congressional or legislative repeal of laws requiring federal or state approval of retail rates charged by natural gas pipelines or electricity providers. Because these rates also included the costs of facilities built by these providers, deregulation means that the costs and financial risks of new facilities are borne by the investor, not the customer. *FERC* and *PUC* are two agencies that once regulated industries and now oversee industry retail markets to ensure fair competition.

Diesel: A petroleum-based fuel used in engines ignited by compression rather than spark. Diesel fuels are heavier and produce higher emissions than conventional gasoline. They also provide more power per unit of volume.

Diesel engine: A compression-ignition piston engine in which fuel is ignited by injecting it into air that has been heated (unlike a spark-ignition engine).

Digester: An airtight vessel or enclosure in which bacteria decomposes biomass in water to produce biogas.

Distillates: Light fuels or oil produced by boiling crude oil. Diesel and heating oil are common distillates.

Distributed power: Energy that can be generated on site, reducing or eliminating costs associated with fuel transportation and electricity transmission and distribution.

Dry ton: 2,000 pounds of material dried to a constant weight.

E85: A blend of 15 percent gasoline and 85 percent denatured ethanol by volume.

eGRID: The Emissions & Generation Resource Integrated Database (eGRID) provides air emissions data for the electric power sector. It is based on available plant-specific data for all U.S. electricity plants that provide power to the electric grid and report data to the U.S. government. eGRID contains air emissions data for nitrogen oxides, sulfur dioxide, carbon dioxide and mercury.

Electric Reliability Council of Texas (ERCOT): A nonprofit corporation under the supervision of the Public Utility Commission of Texas (*PUC*), ERCOT manages the state's largest electric power grid and marketplace by ensuring grid reliability, accommodation of scheduled energy transfers and the oversight of retail transactions. ERCOT is the only electricity grid in the nation contained entirely within a single state. See also *Public Utility Commission of Texas (PUC)*

Electricity: Electric current used as a power source.

Emissions: Waste substances released into the air or water.

Energy: The capacity of a physical system to do work.

Energy crops: Crops grown specifically for their fuel value. These include food crops such as corn and sugarcane and nonfood crops such as poplar trees and switchgrass. Currently, energy crops under development in the U.S. include short-rotation woody crops, which are fast-growing hardwood trees harvested in five to eight years, and herbaceous energy crops, such as perennial grasses that can be harvested annually after reaching full productivity in two to three years.

Energy Policy Act of 2005: This federal legislation established an energy research and development program covering energy efficiency; renewable energy; oil and gas; coal; American Indian energy; nuclear matters and security; vehicles and motor fuels, including ethanol; hydrogen; electricity; energy tax incentives; hydropower and geothermal energy; and climate change technology.

Enhanced Geothermal System (EGS): The recovery of subsurface heat to produce energy through technologies including engineered reservoirs (made by creating cracks in heated rock for water to circulate); geopressured-geothermal (using high-pressured brine to free hydrocarbons trapped in sedimentary layers, especially under the Gulf Coast); co-produced fluids (water mixed with fossil fuels in oil and gas fields); and low-quality, or low-temperature, conventional hydrothermal methods (as yet non-productive resources).

Enhanced Oil Recovery (EOR): The production of oil and gas by means other than natural pressure. EOR generally involves injecting water (or other fluids) or carbon dioxide underground near the target oil or gas reservoir. The pressure of the fluids or gases drives the hydrocarbon substances toward a conventional well, where they can be brought to the surface.

Ethanol: An alcohol compound with the chemical formula C_2H_5OH formed during sugar fermentation by yeast. Also known as grain alcohol. See also *biofuel* and *renewable energy*.

Fat: A water-soluble substance that is solid at room temperature. Fat belongs to a group of chemicals that are the main constituents of food derived from animal tissue, nuts and seeds. Fats are esters of glycerol and fatty acids.

Federal Energy Regulatory Commission (FERC): An independent federal agency that regulates the interstate transmission of natural gas, oil, and electricity. FERC also regulates the construction of natural gas and hydropower projects.

Federal Water Pollution Control Act: A federal regulatory law administered by the states. The act created the National Pollution Discharge Elimination System (NPDES), which guides the means and methods of constructing pipelines or other facilities in or across water bodies.

Feedstock: One product used as an ingredient for another. For example, a refinery produces many fuels, oil and gases that are feedstocks in chemical or plastic manufacturing.

Fossil fuel: Solid, liquid or gaseous fuels formed in the ground after hundreds of millions of years by chemical and physical changes in plant and animal residues under high temperature and pressure. Oil, natural gas and coal are fossil fuels. They are also hydrocarbons.

Fuel cell: A device that converts the chemical energy of a fuel directly to electricity and heat, without combustion.

Fuel cycle: The series of steps required to produce electricity. The fuel cycle includes mining or otherwise acquiring the raw fuel source, processing and cleaning the fuel, transportation, electricity generation, waste management and plant decommissioning.

Fuel: Any material that can be converted to energy.

Furnace: An enclosed chamber or container used to burn fuel or biomass in a controlled manner to produce heat for space or process heating.

Futures: A contract to buy a specific commodity at a future date and a guaranteed "strike" price. In the U.S., oil and gas futures contracts are traded on the New York Mercantile Exchange (NYMEX) and quoted extensively in daily financial news. Oil futures contracts are generally for West Texas Intermediate (WTI) grade crude delivered at an oil pipeline nexus near Cushing, Oklahoma. Natural gas futures contracts are delivered at any number of pipeline interconnections, the largest of which is the Henry Hub near Erath, Louisiana.

FutureGen Alliance: A multibillion-dollar public-private partnership organized to construct and operate a state of the art, non-polluting coal-fired electricity generation plant. In January 2008, DOE decided to withdraw funding for the FutureGen project. See Chapter 7 for more information.

Gas engine: A piston engine that uses gaseous fuel rather than gasoline. Fuel and air are mixed before they enter cylinders; ignition occurs with a spark.

Gas turbine (combustion turbine): A turbine that converts the energy of hot compressed gases (produced by burning fuel in compressed air) into mechanical power. Gas turbines are often fired by natural gas or fuel oil.

Gasification: A chemical or heat process to convert a solid fuel to a gaseous form.

Gasoline: A fuel refined from oil that is used in internal combustion engines.

Generator: A machine used for converting rotating mechanical energy to electrical energy.

Generator nameplate capacity: The maximum rated output of a generator under specific conditions designated by the manufacturer. Generator nameplate capacity is usually indicated in units of kilovolt-amperes (kVA) and in kilowatts (kW) on a nameplate physically attached to the generator.

Geopressured: Substances such as methane or water within the earth's crust that are forced upward by geologic pressures.

Geothermal energy: Energy derived from the natural heat of the Earth contained in hot rocks, hot water, hot brines or steam.

Global warming: A gradual increase in the earth's average surface temperature over time. The popular definition is warming caused by human activity such as exhaust from cars and power plants. The carbon dioxide in these exhausts traps the sun's heat. See also *climate change*.

Grain alcohol: See *ethanol* and *biofuel*.

Greenhouse gases: Gases that trap the heat of the sun in the Earth's atmosphere, producing a greenhouse effect. The two major greenhouse gases are water vapor and carbon dioxide. Other greenhouse gases include methane, ozone, chlorofluorocarbons and nitrous oxide.

Gross National Product (GNP): The value of all the goods and services produced in a national economy, plus the value of the goods and services imported, less the goods and services exported.

Gross State Product (GSP): The total value added in production in a state's economy in a year. Broadly, it equals the total value of goods and services produced less the cost of goods and services used in the production process.

Groundwater: Water found underground in soil or permeable rock, often feeding springs and wells.

Horsepower (electrical horsepower; hp): A unit for measuring the rate of mechanical energy output. The term is usually applied to engines or electric motors to describe maximum output. 1 hp = 745.7 Watts = 0.746 kW = 2,545 Btu/hr.

Hydrocarbon: Any chemical compound containing only hydrogen and carbon.

Hydrogen: A highly reactive colorless gas represented by the symbol H. Hydrogen is the lightest element and the most abundant in the universe. Water and most organic compounds contain hydrogen.

Incineration: Waste destruction by controlled burning at high temperatures.

Independent power producer: A power production facility that is not part of a regulated utility.

Integrated Waste Management (IWM): A method employing multiple waste control and disposal methods such as source reduction, recycling, reuse, incineration, and land filling, to minimize the environmental effect of waste. See also *Municipal Solid Waste*.

Internal combustion engine: An engine that has one or more cylinders in which the process of combustion occurs, converting energy released from the rapid burning of a fuel-air mixture into mechanical energy.

In situ leach mining (ISL mining): The recovery, by chemical leaching, of the valuable components of a mineral deposit without physical extraction of the mineralized rock from the ground. Also referred to as solution mining. See also *solution mining*.

Insolation: A term referring to the amount of solar radiation that strikes the planet's surface over some period of time.

Investor-owned utility (IOU): A private power company owned by and responsible to its shareholders.

Jatropha: A plant that originated in South America that grows in tropical and subtropical regions on non-arable, marginal and waste land. It can be crushed to produce oil that is used to make biodiesel.

Joule: One joule is equal to one watt of power radiated or dissipated for one second. See also *Ampere* and *Watt*.

Kilowatt-Ampere (kVa): A unit of power equal to 1,000 volt-amperes. It is the mathematical product of the volts and amperes in an electrical circuit.

Kilowatt hour (kWh): A measure of energy equivalent to the expenditure of one kilowatt for one hour. For example, 1 kWh will light a 100-watt light bulb for 10 hours. One kWh = 3,413 Btu. See also *British thermal unit*.

Kilowatt (kW): A measure of electrical power equal to 1,000 watts. 1 kW = 3,413 Btu/hr = 1.341 horsepower.

Landfill gas: Gas generated by decomposition of organic material at landfill disposal sites. Landfill gas is approximately 50 percent methane.

Liquefaction: The process of converting biomass from a solid to a liquid. The conversion process is a chemical change that takes place at elevated temperatures and pressures. See also *biomass fuel*.

Liquefied natural gas (LNG): Natural gas that has been pressurized and cooled to liquefy it for more efficient shipping and storage.

Liquefied petroleum gas (LPG): A product of petroleum gases; principally propane and butane, stored under pressure to keep it in a liquid state.

Logging residue: Materials left on the ground after logging, thinning, or other forest operations, such as treetops, broken branches, uprooted stumps, defective logs and bark.

Long ton (shipping ton): 2,240 pounds. Commonly used in Great Britain. See also *short ton, metric ton* and *ton (or tonne)*.

Megawatt (MW): The electrical unit of power that equals 1 million Watts (1,000 kW).

Mercury: A toxic heavy metal emitted during the combustion of fossil fuels, especially coal.

Methane: The simplest hydrocarbon—a gas with a chemical formula of CH_4. A naturally occurring light gas that, in its natural state, is odorless, colorless and lighter than air. Methane most commonly is produced from underground reservoirs, but also can be produced by the aerobic decomposition of any organic material. Methane is the largest component of the natural gas used as an energy source in residences, businesses and factories.

Metric ton (or tonne): 1000 kilograms. 1 metric ton = 2,204.6 lb = 1.023 short tons. See also *ton*, *long ton (shipping ton)* and *short ton*.

Mill residues: Wood materials and bark generated at manufacturing plants when harvested wood products are processed into primary wood products, including slabs, edgings, trimmings, sawdust, veneer clippings and cores and pulp screenings.

MMBtu: One million British thermal units (Btu).

MMCf: One million cubic feet.

Municipal Solid Waste (MSW): Trash or garbage. See also *Integrated Waste Management (IWM)*.

National Energy Modeling System (NEMS): NEMS is a computer-based modeling system of U.S. energy markets through 2025, designed and implemented by EIA. NEMS projects energy, economic, environmental and security impacts on the U.S. of energy policies and energy markets.

Natural gas: A mixture of gaseous hydrocarbons, primarily methane, occurring naturally in the earth and used as fuel. See also *compressed natural gas (CNG)*.

Net Metering: A utility practice that allows owners of qualifying renewable generation resources to capture the value of electric energy they produce beyond their own needs. For example, owners of solar energy systems and small-scale wind turbine projects can sell excess electricity back to the utility and buy more power only as they need it.

Nitrogen oxide (NO_X): Regulated air pollutants, primarily NO and NO_2. Nitrogen oxides are precursors to the formation of smog and contribute to the formation of acid rain.

Nonattainment area (NAA): A geographic area in which air quality is worse than that allowed by federal air pollution standards.

Non-renewable energy: Oil, natural gas, coal or another natural resource, such as a metallic ore, that is not replaceable after it has been used.

Nuclear reactor: An apparatus in which a heavy nucleus (such as uranium) splits into two lighter nuclei in a controlled chain reaction to produce heat energy. A reactor includes fissionable material as fuel, moderating material to control the fission; a heavy-walled pressure vessel to house reactor components; shielding to protect personnel; a system to conduct heat away from the reactor; and instrumentation for monitoring and controlling the reactor's systems.

Oxygenate: Adding oxygen to a fuel, especially gasoline, to make it burn more efficiently.

Parabolic trough: A container concentrating solar power systems consisting of a linear, parabolic-shaped reflector that focuses the sun's energy on a receiver pipe, heating a transfer fluid flowing through the pipe; the transfer fluid then generates superheated steam that is fed to a turbine and electric generator to produce electricity. See also *concentrating solar power (CSP)* and *solar energy*.

Particulate matter (PM): Small pieces of matter suspended in the air measured in microns, which are denoted by subscript; i.e. particulate matter that is 10 microns wide is PM_{10}. Particulate matter can be released naturally or through human activities such as burning fossil fuels in vehicles or in power plants.

Passive solar energy system: Solar heating or cooling that uses natural energy flows to transfer heat.

Petrochemical: A compound made from petroleum or natural gas, such as benzene, ammonia, acetylene and polystyrene.

Petroleum: A name given to a class of gaseous, liquid and solid hydrocarbons occurring naturally beneath the earth's surface.

Photovoltaic: A system that converts direct sunlight to electricity using semi-conductor materials.

Pollution: The placement into the environment of contaminants that cause harm or discomfort to humans or other living organisms, or damage the environment. Pollution can be in the form of chemical substances or noise, heat or light. Pollution is considered a contaminant when it is above natural levels.

Power: The rate of transfer or absorption of energy per unit of time in a system.

Price-Anderson Nuclear Industries Indemnity Act (Price-Anderson Act): Federal legislation, first passed in 1957 governing liability-related issues for all non-military nuclear facilities constructed before 2026. The act partially indemnifies the nuclear industry against liability claims arising from nuclear incidents while still ensuring compensation coverage for the public. The act establishes a no fault insurance-type system with the first $10 billion industry-funded. Claims above $10 billion are covered by the U.S. government. Price-Anderson was renewed in 2005 for a 20-year period.

Production: Processes and methods used in transformation of tangible inputs (raw materials or semi-finished goods) and intangible inputs (ideas and information) into goods or services.

Production Tax Credit (PTC): A federal subsidy that currently provides a 10-year corporate income tax credit of 2.0 cents per kWh, effectively reducing the cost of eligible energy technologies (including wind, landfill gas, biomass, hydroelectric, geothermal, electric, municipal solid waste, some coal and small hydroelectric sources).

Propane: A flammable, colorless hydrocarbon gas used as a fuel, propellant and refrigerant. Its chemical formula is C_3H_8.

Psi: Pounds per square inch. PSI measures pressure.

Public Utility Commission of Texas (PUC): Formed in 1975 by the Legislature as a rate regulatory body, PUC now, since deregulation, oversees electric and telecommunications companies to ensure Texas consumers have access to competitive utility services. The PUC oversees competition in the wholesale and retail electricity and telecommunications markets, and regulates rates and services of non-competitive electric utilities and local exchange companies. See also *Electric Reliability Council of Texas (ERCOT).*

Pulverized: Reduced to dust or powder by crushing, pounding or grinding.

Quad: A quadrillion, or 1,000,000,000,000,000 (10^{15}). U.S. energy production and consumption often is described using this unit of measurement; for instance, a quadrillion *Btu* is called one quad.

Railroad Commission of Texas (RRC): A Texas state agency that regulates oil and natural gas exploration and production, pipeline transporters, natural gas utilities, rail safety and surface mining operations.

Rankine Cycle: A thermodynamic cycle that can be used to calculate the ideal performance of a heat engine that uses a condensable vapor as its working fluid.

Reactor: A facility that contains a controlled nuclear fission chain reaction. Also see *nuclear reactor.*

Reclamation: The conversion of unusable land into land suitable for farming or other uses; or the extraction of useful substances from waste or refuse.

Recycling: A process or treatment used to make waste materials suitable for reuse.

Refinery: A facility used to process crude oil or metals.

Refinery gain: A term used in the petrochemical industry to describe the 44.6 gallons of refined products that are derived from a 42-gallon barrel of crude oil.

Refinery gas: A generic term for gases produced by refining crude oil, also known as “still gases." These gases include methane, butane, ethane and propane.

Renewable energy: Energy that comes from sources that can be replaced, such as sun, wind, waves, biofuels. See also ethanol, biodiesel, biofuels and solar energy.

Renewable Energy Credits (RECs): Tradable energy credits that competitive electricity retailers can purchase or trade among one another to meet their individual renewable energy requirements. (One REC or credit represents one megawatt-hour of qualified renewable energy generated from a renewable energy resource.) In Texas, state law requires retail electric providers to acquire renewable energy based on their market share of electricity sales.

Renewable Portfolio Standard (RPS): A state policy requiring electricity providers engaged in the competitive market to acquire a minimum amount of electricity from renewable energy sources.

Reserves: Estimates of the volumes of oil and gas remaining in underground formations that are both economically and operationally recoverable.

Royalty: The compensation paid to the owner of an asset based on income earned by the asset's user. For example, an oil company pays royalties to the owners of mineral rights.

Scrubber: A device to clean combustible gas or stack gas by the spraying of water.

Sequestration: The process of setting something apart. In energy and environmental terms, sequestration means capturing carbon dioxide emissions from large commercial facilities such as coal-fired electricity plants and injecting the emissions underground for permanent storage.

Short ton: 2,000 pounds. A ton, as commonly used in the U.S. and Canada. See also *long ton, metric ton* and *ton (or tonne).*

Smog: A pollution phenomenon occurring primarily in cities that is attributable to industrial and vehicular sources.

Solar energy: Energy derived from sunlight. See also *concentrating solar power (CSP), parabolic trough* and *renewable energy.*

Solid waste: Discarded materials other than fluids.

Solution mining: Another term for *in situ leach mining.*

Source Emission Reduction Plan (SERP): A contingency plan developed to reduce emissions during an air quality emergency.

Southeastern Reliability Council (SERC): Manages the electric power grid and marketplace by ensuring grid reliability, grid accommodation of scheduled energy transfers and overseeing retail transactions for the southeastern region of the U.S. Parts of southeastern Texas are within the SERC grid.

Southwest Power Pool (SPP): Manages the electric power grid for the southwestern region of the U.S., including parts of the Texas panhandle region.

Stripper well: An oil well producing fewer than 10 barrels per day.

Subsidy: Programs through which government or a public body provide a specific financial benefit to a private company, organization, or charity to help it function or pay expenses.

Surface water: Water naturally open to the atmosphere through lakes, ponds, reservoirs, rivers, and oceans.

Sulfur dioxide (SO_2): A compound and pollutant emitted by coal- and oil-fired power plants, steel mills, refineries, pulp and paper mills and nonferrous smelters. SO_2 can cause respiratory and cardiovascular harm, contribute to acid rain and impair visibility.

Sustainable: An ecosystem condition in which biodiversity, renewability and resource productivity are maintained over time.

Tax: Money levied by a government on its citizens for the operation of the government.

Tax credit: The term tax credit describes two different situations. The first is a partial payment already made towards taxes due. The second is a benefit paid through the tax system that increases net income to an individual.

Tcf: One trillion cubic feet.

Thermodynamics: The scientific study of the mutual conversion of heat and other forms of energy.

Ton (or tonne): 2,000 pounds; in the U.S., sometimes called a "short ton." A metric or "long" ton (sometimes spelled "tonne") is 1,000 kilograms, or 2,204.6 pounds. See also *metric ton*, *long ton* and *short ton*.

Toxic substances: A chemical or mixture of chemicals that presents a high risk of injury to human health or to the environment.

Transmission: The long-distance transport of a fuel or electricity. In regulatory terms, transmission is the segment between the fuel production or generation area and the consumption area.

Turbine: A machine for converting the heat energy in steam or high-temperature gas into mechanical energy. In a turbine, a high-velocity flow of steam or gas passes through successive rows of radial blades fastened to a central shaft.

Uranium: A heavy, silver-gray radioactive metal occurring in three isotopes. Its symbol is U. One isotope of uranium (U_{235}) is used as fuel in nuclear reactors and weapons.

Volatile organic compounds (VOC): Non-methane hydrocarbon gases. VOC are released during the combustion or evaporation of fuel.

Watt: The common base unit of power in the metric system. One watt equals one joule per second. One joule is the power developed in a circuit by a current of one ampere flowing through a potential difference of one volt. One watt = 3.413 Btu/hr. See also *Ampere* and *Joule*.

Western Electricity Coordinating Council (WECC): Manages the electric power grid and marketplace by ensuring grid reliability, grid accommodation of scheduled energy transfers and overseeing retail transactions for the western region of the U.S. Portions of far West Texas are contained within WECC's grid.

Wellhead: The area immediately surrounding the top of a well, or the top of the well casing.

West Texas Intermediate (WTI): A highly desirable grade of crude oil produced from West Texas oilfields. WTI is the benchmark U.S. domestic price of oil and widely quoted in financial publications.

Wind farms: Large, utility-scale turbines grouped together into power plants and connected to the electrical utility grid; their power is sold to utility customers. See also *decommissioning* and *wind turbines*.

Wind turbines: Converts the wind's kinetic energy into mechanical power that a generator, in turn, converts into electricity. See also *decommissioning* and *wind farms*.

Wood waste: This includes bark, scrap lumber, sawdust, mixed soil and rock generated as waste material from log decks and milling facilities, inert construction and demolition wastes. Wood waste can also be ash from the burning of wood wastes from on-site, wood-fired boilers, kiln dryers and burners.

CHAPTER 32

Appendix 1: The Electricity Market

Electricity customers in Texas are served by three distinct electric networks defined by specific geographic boundaries, each of which have unique rules that govern the operation of electricity markets within their footprint. Texas' westernmost counties (El Paso and portions of Hudspeth and Culberson) are part of the Western electric grid of the United States and southwestern Canada. Substantial land areas in the Texas Panhandle as well as contiguous areas in East Texas from Texarkana to Beaumont are part of the Eastern electric grid of the United States. The remainder of Texas is contained within the Electric Reliability Council of Texas (ERCOT), representing approximately 75 percent of the land area and 85 percent of the electric consumption in the state. This appendix describes key features of the electricity market in ERCOT.

BILATERAL MARKET

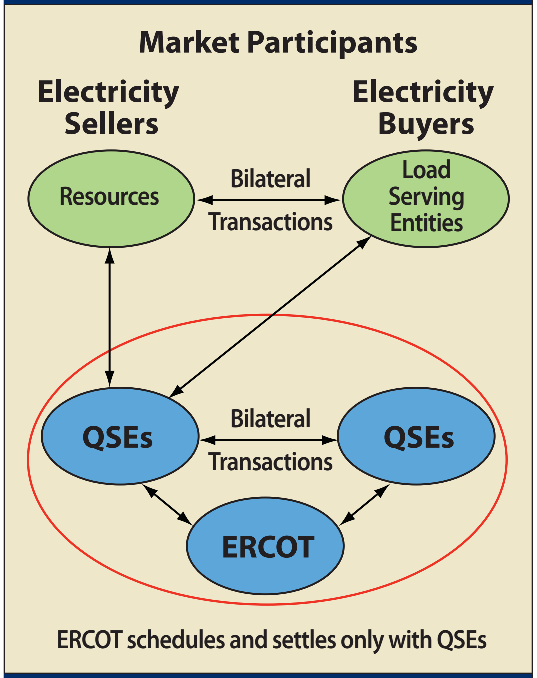
Most energy (over 95 percent) consumed within the ERCOT power region is purchased through the bilateral market, so called because it involves contracts between power generating companies and load serving entities (LSEs), which can be retail electric providers, municipally owned utilities and cooperatives. The scheduling of power purchased through these agreements is reported to ERCOT through Qualified Scheduling Entities (QSEs).

ERCOT-certified QSEs provide the schedules of all power loads and generation that they are representing in the ERCOT power region (**Exhibit 32-1**). QSEs may represent generators, power marketers (those who buy and sell energy in the bilateral market) and/or load serving entities; all generators and LSEs must be represented by a QSE.

These QSEs are required to inform ERCOT of the private contractual agreements in the bilateral market for each 15-minute period of the day, so that ERCOT can ensure that the supply and demand for energy are sufficiently balanced.

EXHIBIT 32-1

Wholesale Market Operations



Source: The Electric Reliability Council of Texas.

BALANCING MARKET

Electricity load fluctuates constantly, and any changes in load demand within the ERCOT power region that are not offset by a change in resource schedules (in essence, under- or over-scheduling) require ERCOT to meet the demand by purchasing electricity from QSEs representing generators (in the event of "under-scheduling") or by compensating those QSEs to reduce generation (in the event of "over-scheduling"). In either case, the expense is recouped from the QSEs representing LSEs. This additional power (or reduction in power) is purchased in the "balancing" market.

ERCOT determines the amount of energy needed by examining the schedules submitted by QSEs and the anticipated demand. Energy purchased in the balancing market ("balancing energy") covers any shortfalls in demand the schedules do not meet. This allows owners of undedicated generation to sell power into the balancing market.

ERCOT determines a "market-clearing price" every 15 minutes that it will pay to generators that sell energy in the balancing market. The market-clearing price is the price ERCOT pays for the last megawatt procured in the bid-stack for balancing energy and is paid to all generators providing this service.

As noted above, QSEs also may over-schedule energy, meaning more energy is scheduled to be generated than is demanded. In this scenario, ERCOT pays generators in the balancing market to reduce generation. Again, ERCOT recoups the cost from QSEs representing load.

ANCILLARY SERVICES

Ancillary services include various types of energy and capacity products to meet their reliability requirements. ERCOT has stated that ancillary services resemble insurance that market participants must acquire to do business. The cost of this "insurance" is paid by all LSEs and is based on their "load ratio share," or the LSE's share of the overall load.[1]

QSEs can either purchase their ancillary services through a bilateral contract, supply it themselves, if able, or ask ERCOT to procure it for them in a competitive market.

Ancillary services can be divided into two categories, *capacity* and *energy*, which are defined below. **Exhibit 32-2** shows the various ancillary services.

EXHIBIT 32-2

Ancillary Services

Capacity

Responsive Reserve	Responsive or "spinning" reserves are daily operating reserves that will respond quickly to restore interconnection frequency in case of a disruption.
Non-Spinning Reserve	This service provides additional electrical generation capacity within 30 minutes.
Replacement Reserve	This service is utilized when additional capacity is called on to provide additional Balancing Energy Bids, to cover system capacity or congestion.
Out of Merit Capacity	Similar to Replacement Reserve, but not acquired through the Replacement Reserve market process due to immediate operational needs.
Black Start	This service, acquired by ERCOT for the benefit of all customers, is power that can be generated without the support of the ERCOT transmission grid in case of a partial or total blackout.
Reliability Must-Run Capacity	This is capacity from a generator that would otherwise be mothballed or retired except that it is necessary to provide "voltage support, stability or management of localized transmission constraints."[2]

Energy

Balancing Energy	Energy that is deployed to resolve congestion or when the actual demand for energy does not equal the scheduled amount of energy.
Reliability Must-Run Energy	This is energy from a generator that would otherwise be mothballed or retired except that it is necessary to provide "voltage support, stability or management of localized transmission constraints."[3]
Out of Merit Energy	This is energy available from resources but not deployed through the market clearing process or scheduled by the QSEs.

Source: The Electricity Reliability Council of Texas.

TRANSMISSION CONGESTION MANAGEMENT

Electricity purchased for use in a particular geographical area is not necessarily generated there. Generators often are located near the fuel source; near bodies of water used for cooling; or in rural areas. And, in a market with varying prices, cheaper power may be purchased from a generator at some distance away from the user. Moving electricity across the grid from generation to end user often results in congestion — that is, the transmission lines cannot carry the amount of power being generated. This endangers the reliability of electricity.

The ERCOT grid is currently divided into congestion management zones (**Exhibit 32-3**). When power flowing between two zones reaches a level that may jeopardize reliability, ERCOT will deploy "balancing energy service," which in effect decreases the amount of energy coming from the generators in the "sending" zone and increases production in the "receiving" zone. This combination of actions serves to decrease the flow of electricity between zones to a reliable level.

This balancing is accomplished by requiring generators to increase output in the receiving zone, and decrease it in the sending zone. These actions are often more expensive for the end user. Ideally, generation plants with the cheapest energy are called on before more costly generation. When reliability is at risk, however, ERCOT must dispatch more expensive generation to solve the congestion.

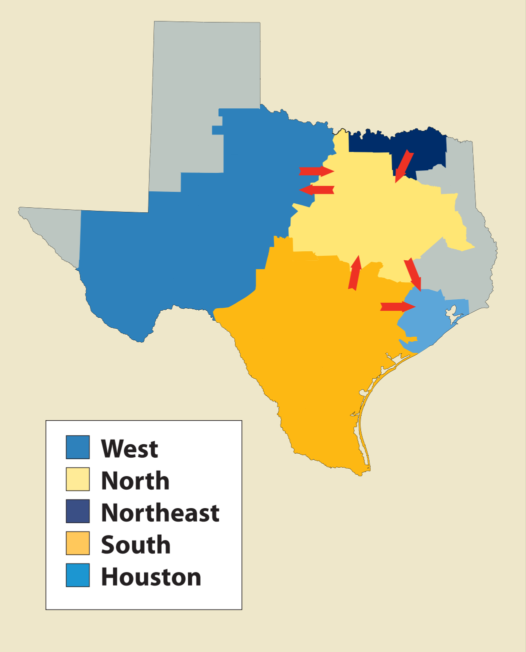
ERCOT calculates the cost of congestion relief between the market zones and charges those QSEs scheduling energy between the zones. This system assigns costs for congestion between zones, but does not address congestion *within* a zone. To address this problem, the ERCOT independent system operator (ISO) market is moving to nodal pricing.

NODAL PRICING

Beginning in December 2008, ERCOT is scheduled to move to a nodal market. Unlike the current, zonal market discussed above, the nodal market will calculate the costs of transmission from generation to more than 4,000 delivery points or nodes across the state.[4]

EXHIBIT 32-3

ERCOT Congestion Management Zones



Source: The Electric Reliability Council of Texas.

Nodal pricing is expected to decrease congestion by exposing pockets where electricity is expensive, and encouraging either generation or transmission solutions to lower those costs.

ENDNOTES

[1] Interviews with Joel Mickey and Theresa Gage, Electric Reliability Council of Texas, April 19, May 3, and June 5, 2007.

[2] Electric Reliability Council of Texas, *ERCOT Protocols* (Austin, Texas), Section 5, pp. 2-25, available in Word format at http://www.ercot.com/mktrules/protocols/current.html. (Last visited April 24, 2008.)

[3] Electric Reliability Council of Texas, *ERCOT Protocols*, Section 5, pp. 2-25.

[4] Electric Reliability Council of Texas, About Texas Nodal, http://nodal.ercot.com/about/index.html. (Last visited April 24, 2008.)

CHAPTER 33

Appendix 2: Methodology for Estimating Subsidy Support

ESTIMATE SCOPE

Chapter 28 does not attempt to estimate all government energy subsidies. It estimates only those that relate to the production of energy from specific fuels.

This study estimated the effect of federal, state and local subsidies on what consumers must pay to purchase a particular type of fuel. The consumer may be a utility buying fuel to produce energy; a company buying fuel to generate its own energy or to power vehicles; or an individual consumer making similar choices.

Some energy government subsidies fell outside of the scope of this estimate. **Exhibit 33-1** below lists these subsidies.

Many electricity subsidies are allocated to specific fuel types. Those that are not allocated are noted in the text.

METHODOLOGY

To prepare this estimate, the Comptroller used estimates of the impact of tax credits and exemptions supplied by the Office of Management and Budget and the Joint Committee on Taxation. In some instances, these estimates had to be allocated among several different fuels according to available industry data, usually from the U.S. Energy Information Administration.

The Comptroller also reviewed data from federal and state agency budgets for spending information. Budgetary appropriations not offset by industry fees were counted as subsidies.

To identify potential subsidies, the Comptroller team reviewed the subsidy reports listed in Chapter 28 and other sources, such as the U.S. Department of Energy's DSIRE database (http://www.dsireusa.org).

METHODOLOGY FOR ESTIMATING TEXAS TAX SUBSIDIES

The Comptroller used Texas tax data to estimate Texas tax subsidies for 2006.

EXHIBIT 33-1

Government Energy Subsidies Outside the Scope of the Comptroller's Estimate

Energy Subsidy	Reason for Exclusion From Estimate for 2006
Transportation subsidies for highways, waterways, and airports	• Not linked to specific types of fuels
Conservation or efficiency subsidies*	• Not linked to specific types of fuels
Government regulations	• Indirect impact on cost of fuel • Impact not quantified • Frequently are partially paid by fees charged to the industry being regulated
Externalities – environmental costs of pollution from different types of fuels	• No consensus on how to quantify costs • Costs paid by general public, not part of the immediate cost of a particular fuel for purchaser making choice
Defense expenditures related to security of Persian Gulf	• Difficult to quantify subsidy • Complex relationship with fuel price

*Conservation and efficiencies are discussed in Chapter 23, but are not included in this analysis of subsidies.
Source: Texas Comptroller of Public Accounts.

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Jay Caspary, Southwest Power Pool
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Ed Clark, Austin Energy
Sigrid J. Clift, The University of Texas at Austin, Bureau of Economic Geology
Doug Coe, U.S. Nuclear Regulatory Commission
Daniel Cohan, Rice University
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Eric Craven, Texas Electric Cooperatives
Eddy Daniels, NRG Energy, Inc.
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Dave Denney, Bob Bullock Texas State History Museum
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Richard J. Erdlac, Jr., Energy America Geothermal
John Fainter, Association of Electric Companies of Texas
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D. Wayne Fleenor, Ross Communications
Rafael Flores, TXU Power (now Luminant)
Michelle Foss, The University of Texas at Austin, Bureau of Economic Geology
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Theresa Gage, Electric Reliability Council of Texas
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Samuel Goldblatt, U.S. Bureau of Labor Statistics
Diane Goss, Texas Commission on Environmental Quality
Mike Grable, Electric Reliability Council of Texas
Theresa Gross, Public Utility Commission of Texas
Gürcan Gülen, The University of Texas at Austin, Bureau of Economic Geology
Jeff Haberl, Energy Systems Laboratory
Kenneth R. Hall, Texas A&M University System, Texas Engineering Experiment Station
Terrie Hammett, Railroad Commission of Texas
Susan Harlow, U.S. Department of Energy, Office of Nuclear Energy
Diana Hart, Exelon Power
Richard Hebner, The University of Texas at Austin, Center for Electromechanics
Janine Henderson, U.S. Department of Energy, Office of Nuclear Energy
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Mark Holtzapple, Texas A&M University, Department of Chemical Engineering
John Hoskins, Tennessee Valley Authority
Ken Howard, Texas General Land Office
John Howe, Verenium Corporation
Russell Huff, Texas Municipal Power Agency
Bill Husta, Texas General Land Office
German Ibanez, NRG Energy, Inc.
Dan Jones, Potomac Economics
Raymond J. Juzaitis, Texas A&M University, Department of Nuclear Engineering
Mark Kapner, Austin Energy
Diane Kearney, U.S. Department of Energy, Energy Information Administration

Joseph Kelliher, Federal Energy Regulatory Commission
Dan Kelly, Railroad Commission of Texas
Mahlon Kennicutt, Texas A&M University
Carey King, The University of Texas at Austin, Center for International Energy and Environmental Policy
Kelso King, King Energy Consulting
Tom Kleckner, TXU Power (now Luminant)
Rachelle Koczman, Texas Department of Transportation
John A. "Skip" Laitner, American Council for an Energy Efficient Economy
David K. Langford, Texas Wildlife Association
Don Lewis, Texas Department of Transportation
Kevin Lillis, U.S. Department of Energy, Energy Information Administration
M. Sam Mannan, Texas A&M University, Department of Chemical Engineering
Patrice "Pete" Parsons Marshall, Texas H2 Coalition
David J. Massey, College Station Utilities
Diane Mazuca, Texas Commission on Environmental Quality
Michael McCluskey, Austin Energy
Roy McCoy, Electric Reliability Council of Texas
Kathy McCullah, Tennessee Valley Authority
Polly McDonald, Railroad Commission of Texas
Ned Meister, Texas Farm Bureau
Michael Mellish, U.S. Department of Energy, Energy Information Administration
Joel Mickey, Electric Reliability Council of Texas
Paula Mueller, Public Utility Commission of Texas
Shirley Neff, Association of Oil Pipe Lines
Ernest Oviedo, Railroad Commission of Texas
Elizabeth Paris, U.S. Senate Finance Committee
Gary Parsons, Texas Municipal Power Agency
K.L. Peddicord, Texas A&M University System, Texas Engineering Experiment Station
Rusty Perrin, U.S. Department of Energy, Office of Science
Steve Pitner, Railroad Commission of Texas
Brad Porlier, NRG Energy Texas LLC
Eric Potter, The University of Texas at Austin, Bureau of Economic Geology
Richard A. Ratliff, Texas Department of State Health Services
Debra Ravel, Railroad Commission of Texas
W.D. Reece, Texas Engineering Experiment Station, Texas A&M University
Allen Regehr, Texas Department of Agriculture
Emily Reynolds, Tennessee Valley Authority
Cynthia Rheaume, U.S. Department of Energy, Office of Environmental Management
Maria Richards, Southern Methodist University, Department of Geological Sciences
Josh Robertson, Salt River Project Agricultural Improvement and Power District
Thomas W. Rose, TXU Power (now Luminant)

Ryan Rowney, Lower Colorado River Authority
Kent Saathoff, Electric Reliability Council of Texas
Jim Schlimgen, Railroad Commission of Texas
Mike Sloan, Virtus Energy Research Associates, Inc.
Susan Sloan, American Wind Energy Association
Beverly Smith, U.S. Nuclear Regulatory Commission
Tom Stewart, TXU Power (now Luminant)
Renu Suri, U.S. Nuclear Regulatory Commission
Pat Sweeney, Austin Energy
John M. Sweeten, Texas AgriLife Research
Andrew Swift, Texas Tech University, Wind Science and Engineering Research Center
Karen Tappert, U.S. Department of Energy, Office of Nuclear Energy
John Thomas, Tennessee Valley Authority
Richard Thompson, The University of Texas at Austin, Center for Electromechanics
Jess Totten, Public Utility Commission of Texas
Sid Underwood, TXU Power (now Luminant)
Gary Vliet, The University of Texas at Austin, Department of Mechanical Engineering
Jan Walker, United States Department of Defense, Defense Advanced Research Projects Agency
Mark Walker, NRG Energy Texas LLC
Tim Walter, Railroad Commission of Texas
Michelle Warren, Texas General Land Office
Kathy Way, Railroad Commission of Texas
Michael E. Webber, The University of Texas at Austin, Center for International Energy and Environmental Policy
Brian Weeks, Gas Technology Institute
Craig Wheeler, The University of Texas at Austin, Department of Astronomy
Suzanne Whitehurst, Independent Petroleum Association of America
Steven Wiese, Clean Energy Associates
Mike Williams, Texas Electric Cooperatives
John Wood, U.S. Department of Energy, Energy Information Administration
Gregory L. Wortham, West Texas Wind Energy Consortium
Jolene York, Railroad Commission of Texas
Douglas Young, Texas State Preservation Board
Jay Zarnikau, Frontier Associates, LLC
Mark Zion, Texas Public Power Association

Contributors

EXECUTIVE ADMINISTRATION

Susan Combs, Comptroller
Martin Hubert, Deputy Comptroller
Lisa Woods, Associate Deputy Comptroller
Mike Reissig, Associate Deputy Comptroller
Pete Slover, Special Counsel to the Comptroller
Sarah Whitley, Senior Advisor to the Comptroller
Patricia Vojack, Legislative Director

RESEARCH AND ANALYSIS

Lisa Minton, Director, Research and Analysis
Tom Currah, Manager, Research and Analysis; Project Manager
Laure McLaughlin, Team Leader, Non-Renewable Fuels
Maria Mendez-Lewis, Co-Team Leader, Renewable Fuels
Clint Winters, Co-Team Leader, Renewable Fuels
Phyllis Coombes, Co-Team Leader, Subsidies
Linda Gibson, Co-Team Leader, Subsidies
Will Counihan, Team Leader, Energy Uses
Vicki Anderson
Margot Clarke
Melissa Dubowski
Jojo Estrada
Leonard Gabriel
Olga Garza
David Green
Rand Harris
Shannon Hawkins
Will Holford
Tedd Holladay
Constance Matheny
Catherine Schneider
Diane Thomas
John Villarreal
Sally Ward

PUBLIC OUTREACH AND STRATEGIES

Delane Caesar, Director, Public Outreach and Strategies
Beth Hallmark, Creative Director, Editorial and Web Team
Dan Lynch, Creative Director, Graphics Team
Dwain Osborne, Graphics Team Leader
Jo Ann Reyes, Energy Project Layout Production Artist
Drew Scherz, Web Team Leader
Bruce Wright, Energy Project Editor
Gilbert Conwoop
Robert Doyal
Jack Grieder
Becky Head
Julie Lewis
Shannon McCann
Edd Patton
Tyra Peterson
Sherryl Orsak
Raul Santos
Barbara Schlief
Rudy Torres
Brad Wright
Carl Yeh

REVIEWERS

John Heleman, Chief Revenue Estimator
Dean Ferguson, Assistant Manager, Revenue Estimating
Robert Wood, Director, Local Government Assistance and Economic Development
Buddy Breivogel, Manager, Property Tax Administrative Operations
Don Hoyte, Manager, Regional Fiscal Analysis
Dub Taylor, Manager, State Energy Conservation Office
Mary Colletti, Manager, Legislative Affairs
Trey Powers, Legislative Liaison
Patricia Bailey, Property Tax
Doug Freer, Revenue Estimating
Russell Gallahan, Local Government Assistance
Pam Groce, State Energy Conservation Office
Andy Liebler, Regional Fiscal Analysis
Roger Mulder, State Energy Conservation Office
Ron Ommerman, Revenue Estimating
Lynn Pham, Revenue Estimating
Gary Preuss, Revenue Estimating
Gary Price, Regional Fiscal Analysis
David Schiller, State Energy Conservation Office
Ed Warren, Revenue Estimating
John Wieferman, Revenue Estimating
Tim Wooten, Property Tax

COMMUNICATIONS

Allen Spelce, Director, Communications
RJ DeSilva, Agency Spokesperson
Sheila Clancy
Jocelyn Sexton
Brian Wellborn

AGENCY ADMINISTRATION

Raette Hearne, Director, Agency Administration
Ben Dukes, Manager, Quick Copy
Donnie Hunter, Outgoing Mail Operations Team Lead
Juanita Robinson, Manager, Document Processing
Gilbert Trevino, Quick Copy