CHAPTER THREE

Benefits, Challenges, and Considerations of Bioenergy

Biomass is a low-cost, domestic source of renewable energy with potential for large-scale production. U.S. DOE estimates that, with aggressive action, bioenergy could displace one-third of the current demand for petroleum fuels nationwide by the mid-21st century (U.S. DOE, 2005).

According to the American Council on Renewable Energy (ACORE), biopower projects could see a 10-fold increase—to 100 gigawatts (GW)—by 2025 with coordinated federal and state policies to expand renewable energy markets, promote and deploy new technology, and provide opportunities to encourage renewable energy use in multiple market sectors and applications (ACORE, 2007).

With the potential for increased production and use of biomass and bioenergy comes the potential for states to take advantage of benefits associated with bioenergy, but also the need to guard against pitfalls. Some benefits and challenges will be of greater interest to states in particular regions (e.g., arid vs. wet, nonattainment vs. in attainment) or with particular characteristics (e.g., urban vs. rural). States will want to weigh the challenges and benefits when deciding whether and how to pursue bioenergy development.

DOCUMENT MAP

CHAPTER THREE CONTENTS

A brief overview of benefits and challenges is provided below, followed by a more detailed discussion.

BENEFITS

Policy makers are looking to production and use of biomass for power, heat, fuels, and products as an effective means of advancing energy security, economic, and environmental goals.

For example, an analysis of the primary drivers cited in legislation for state renewable fuel standards (RFSs) found that state goals included (Brown et al., 2007):

- **Energy Security**: Increasing use of domestic fuels to reduce dependence on foreign oil and its potential disruptions, while keeping money for energy in local communities.
- **Economic**: Improving the rural economy by generating jobs, income, and taxes through demand for local biomass resources and construction of biomass conversion facilities.
- **Environmental**: Achieving air quality goals and improving public health by using bioenergy that reduces GHGs and other air pollutants and by turning waste products into bioenergy.

In addition, compared with some energy alternatives, bioenergy may be one of the easier options to adopt in the near term (e.g., coal-fired power plants can cofire biomass and vehicle engines can use biofuels with few if any modifications).

CHALLENGES

At the same time, there are potential challenges associated with deployment of any bioenergy project. While the benefits of using biomass instead of other fuel sources to meet state energy needs are numerous, states should be aware of several potential issues when exploring bioenergy. These include:

- **Environment**: Potentially adverse environmental impacts could result if increased production is not handled sustainably, including air and water pollution, negative impacts of direct and indirect land use changes, and increased water consumption.

- **Feedstock Supply**: For a variety of reasons, securing a suitable and reliable feedstock supply—particularly one that will be available over the long term at a reasonable cost—does not always prove easy. Many feedstocks are seasonal and may only be harvested once a year. In order to cover their fuel needs for energy production over the course of a year, bioenergy producers may need to utilize flexible conversion processes capable of using a variety of feedstocks available in different seasons.

- **Infrastructure**: The location and nature of feedstock inputs or bioenergy outputs produced at bioenergy plants can make their delivery difficult. Additionally, current infrastructure levels may not support market demand or can be constrained by other economic factors despite demand.

These benefits and challenges are described in the following sections. Note that not all are relevant to every type of bioenergy production or use.

3.1 ENERGY SECURITY BENEFITS

3.1.1 INCREASED ENERGY INDEPENDENCE THROUGH BIOFUELS

The United States currently imports 65 percent of the petroleum it consumes—the majority for transportation fuels (U.S. Energy Information Agency, 2008). Relying on foreign energy sources leaves the nation vulnerable to price increases and supply limits that foreign nations could impose. Reliance on foreign petroleum also contributes significantly to the U.S. trade deficit. Increasing the domestic energy supply by expanding biofuels production could help reduce U.S. dependence on foreign oil, thus increasing the nation's energy security.

3.1.2 DECREASED INFRASTRUCTURE VULNERABILITY THROUGH BIOPOWER

The vulnerability of our energy infrastructure to attacks is also an energy security concern. Increased use of domestic bioenergy can help reduce this vulnerability because bioenergy involves a domestic, dispersed energy infrastructure that may be less prone to attack.

When a reliable feedstock supply is available, biopower can be a baseload renewable resource, compared to other renewable resources such as wind and solar, which may be available on an intermittent basis, and compared to fossil fuels, supplies of which may become increasingly limited and more expensive.

ETHANOL'S NET ENERGY BALANCE

Net energy balance is the total amount of energy used over the full life cycle of a fuel, from feedstock production to end use. Technical debate is ongoing about the implications of some forms of bioenergy, most notably ethanol as a transportation fuel. In the 1980s, the net fossil fuel energy balance for corn to ethanol was negative, meaning the fossil energy input to create the ethanol was greater than the fossil energy displaced. Technology improvements have changed this such that most recent studies find that corn-based ethanol reduces petroleum usage. However, some studies find a negative net fossil energy balance for corn ethanol when all fossil energy sources (e.g., coal-fired electricity used to power the production plant) are taken into account (U.S. DOE, 2006).

Study results vary due to differing assumptions about energy sources, by-products, and system boundaries. For example, ethanol plants that take full advantage of CHP opportunities would have greater energy efficiency and a better energy balance. Use of biomass or biogas as the production facility's fuel for power and heat also reduces fossil energy use (E3 Biofuels, 2007; U.S. DOE, 2006).

U.S. EPA studied the effect of CHP on energy use in the dry mill conversion process used to produce ethanol from corn. The Agency analyzed the impact of this technology on total energy consumption (including power fuel use at the plant for ethanol production and subsequent reductions in central station power fuel use) for plants using natural gas, coal, or biomass as fuel. In all cases where plants utilized CHP technology, total net fuel consumption was reduced as electricity generated by the CHP systems displaced less efficient central station power. Energy use reductions of approximately 8 percent were modeled for the plants utilizing biomass-fueled CHP (U.S. EPA, 2007a).

In contrast to the varying net fossil energy balance results for corn-based ethanol, cellulose-based ethanol is found to provide both lower petroleum usage and a positive net fossil energy balance because less fossil fuel is required to acquire cellulosic feedstocks (e.g., grasses, wood waste, etc.) than corn (U.S. DOE, 2006).

U.S. DOE's Biomass Energy Databook (2006) provides detailed comparisons of energy inputs and GHG emissions for various ethanol scenarios compared to gasoline. For more information, see *http://cta.ornl.gov/bedb/pdf/Biomass_Energy_Data_Book.pdf*.

3.1.3 RELIABLE BASELOAD POWER SOURCE

Biomass power is a reliable, cost-effective source of baseload power. Unlike wind or solar, biomass feedstocks can be stored and used to generate power 24 hours a day, seven days a week. The ability to store feedstocks is beneficial for utilities because it enables them to consistently know when they will be available, in what quantities, and at what cost.

3.2 ECONOMIC BENEFITS

3.2.1 PRICE STABILITY FROM BIOPOWER

A key economic benefit of bioenergy is its potential to provide price stability in volatile energy markets. For example, opportunity fuels—waste materials from agricultural or industrial processes—can generally be obtained for no or very low cost, as is the case with biogas collection and use at wastewater treatment plants or animal feeding operations. In addition to displacing purchased fossil fuels, using opportunity fuels for biopower may also free up landfill space and reduce tipping fees associated with waste disposal. As bioenergy technologies continue to improve, the potential for bioenergy to be a cost-competitive energy choice increases.

Even when the cost of bioenergy is greater than fossil fuels, in some cases bioenergy can help stabilize energy prices by providing more diverse sources of energy for the fuel supply. For example, biomass-fueled CHP can provide a hedge against unstable energy prices by allowing the end user to supply its own power when prices for electricity are very high. In addition, a CHP system can be configured to accept a variety of feedstocks (e.g., biomass, biogas, natural gas) for fuel; therefore, a facility could build in fuel-switching capabilities to hedge against high fuel prices.

Using a diversity of renewable resources can also provide economic benefits. Two studies in the United Kingdom compared electric systems that rely on wind alone with systems that combine wind and biomass on the same grid. In both cases, the need for ancillary services and transmission line upgrades, and thus the overall costs of the system, were significantly reduced when wind was complemented with biomass generating capacity (IEA, 2005).

Example

ESSEX JUNCTION WASTEWATER TREATMENT FACILITY
ESSEX JUNCTION, VERMONT

Essex Junction's wastewater treatment facility uses two 30 kilowatt (kW) microturbines to generate electricity and thermal energy from the methane gas produced by its digester. Before CHP was installed, the plant used only half of the methane it produced. Now the plant uses 100 percent of the methane produced to heat the anaerobic digester, saving 412,000 kWh and $37,000 each year. These energy savings represent 36 percent of the facility's electricity demand. The project has an estimated payback of seven years.

Source: U.S. EPA, 2007f

3.2.1 ECONOMIC DEVELOPMENT FROM FEEDSTOCK PRODUCTION AND BIOENERGY

A major driver for many states in considering bioenergy expansion is the potential for economic development benefits. It is prudent to keep in mind, however, that the specifics of policy/program design and implementation, combined with the particular market forces at work in a state, will impact the extent to which a state will realize these benefits.

Nonetheless, the bioenergy supply chain has the potential to create jobs, income, and taxes associated with growing and harvesting or collecting the resource, facility construction, operation and maintenance, transportation, and feedstock processing. The funds retained in communities from local feedstock production and conversion create jobs and strengthen the local property and income tax base. Because biomass resources are primarily agricultural or forestry-based, rural communities have tended to benefit most from increased demand for feedstocks; however, if urban communities begin to further develop their use of waste/ opportunity fuels, they may also see localized benefits (U.S. DOE/SSEB, 2005).

Other potential economic benefits that can accrue from use of biomass for power, fuels, or products include (U.S. DOE/SSEB, 2005):

- Creating new uses and markets for traditional commodity crops.
- Creating opportunities to diversify rural income by growing new crops for biomass markets.
- Mitigating land-clearing costs for development or reforestation purposes.
- Providing markets and partially defraying costs for removal of undergrowth for forest health initiatives.
- Eliminating, mitigating, or transforming the need for agricultural and forestry-related subsidies.

Increased bioenergy can create or expand domestic industries nationally and regionally. The United States is already experiencing economic benefits from biofuels, according to a study by RFA. In 2006, the ethanol industry created more than 160,000 direct and indirect jobs; generated nearly $5 billion in federal, state, and local tax revenues; and reduced the federal trade deficit by more than $11 billion (Urbanchuk, 2007). Biomass power is a vital component of America's green economy. This $1 billion-a-year industry provides 14,000–18,000 jobs nationwide and contributes millions of dollars to local tax revenues yearly (Cleaves, Personal Communication, 2009).

Despite the potential economic benefits of biomass cultivation and bioenergy production, farmers may be reluctant to devote land to producing biomass feedstocks due to uncertainty in demand for these crops and up-front investment costs. To help communities and domestic industries take advantage of the economic benefits of biomass cultivation and bioenergy production, the Food, Conservation, and Energy Act of 2008 established the Biomass Crop Assistance Program to provide financial incentives to farmers to grow biomass feedstocks and connect with bioenergy producers (see text box).

PRODUCER PAYMENTS: BIOMASS CROP ASSISTANCE PROGRAM

As part of the Food, Conservation, and Energy Act of 2008, the Biomass Crop Assistance Program (BCAP) was created to financially support the establishment and production of crops for conversion to bioenergy and to assist with collection, harvest, storage, and transportation of eligible material for use in a biomass conversion facility. BCAP provides payments to farmers while they establish and grow biomass crops in areas around biomass facilities. To qualify for payments, potential biomass crop producers must participate in and be approved as part of a "BCAP project area" that is physically located within an economically viable distance from a biomass conversion facility. Contracts run for five years for annual and perennial crops and 15 years for woody biomass. The program provides three types of payments to producers: direct, annual and cost-share (sometimes called delivery) payments.

Source: USDA, 2008; NASDA, 2008

ECONOMIC DEVELOPMENT BENEFITS FROM BIOENERGY FACILITIES

- In 2005, RFA estimated that a typical **ethanol plant** producing 40 million gallons per year would provide a one-time boost of $142 million to the local economy during construction, expand the local economic base by $110.2 million each year through direct spending of $56 million, create 41 full-time jobs at the plant and a total of 694 jobs throughout the entire economy, and boost state and local sales tax receipts by $1.2 million for every $209,000 invested (U.S. DOE/SSEB, 2005).
- A 2002 study conducted in South Dakota estimated that a 24-million-gallon-per-year **biodiesel facility** under consideration would create 29 new jobs at the facility and another 748 jobs in the community. The facility would have a $22-million annual payroll and would generate $4.6 million in state and local tax revenues and $6.4 million in federal tax revenues (Leatherman and Nelson, 2002).
- For each megawatt of **biopower** produced from forest residue, U.S. DOE estimates that at least four jobs are created to procure and harvest the residue. Additional jobs would be created to transport the residue and construct, operate, and maintain the biopower facility (U.S. DOE, 2005).

3.3 ENVIRONMENTAL BENEFITS, CHALLENGES, AND CONSIDERATIONS

This section describes the potential environmental benefits and challenges of bioenergy in terms of air quality, land resources, waste, water resources, and food supply. The environmental effects of bioenergy can vary substantially because of the diversity in feedstock production, chemical content, and conversion processes. As with many multifaceted issues, bioenergy presents a complex set of environmental considerations and potential tradeoffs, some of which require active and attentive policy/program design and implementation to ensure the benefits outweigh the potential for negative consequences of missteps.

In such a complex area, policy makers can turn to detailed state or locally specific evaluations of potential environmental effects to ensure they are making informed decisions. A life-cycle assessment (LCA) can be used to quantify these effects.

LCA is a technique to assess the environmental aspects and potential impacts associated with a product, process, or service by (U.S. EPA, 2008a):

- Compiling an inventory of relevant energy and material inputs and environmental releases.
- Evaluating the potential environmental impacts associated with identified inputs and releases.
- Interpreting the results to help with more informed decision making.

A number of LCAs have been completed on bioenergy technologies and systems (see 3.6—Resources for Detailed Information).

3.3.1 AIR QUALITY BENEFITS AND CHALLENGES

Bioenergy can help improve air quality by reducing GHG emissions as well as emissions of several key air pollutants, depending on which biomass feedstocks and bioenergy conversion technologies are used (see Chapter 2 for descriptions of feedstocks and conversion technologies). These emission reductions can provide economic and environmental benefits by lowering emission-related operating costs, such as allowance/ permit costs and emissions-control equipment expenses (Hanson, 2005). At the same time (again depending on feedstocks and technologies), bioenergy can also increase certain air emissions relative to fossil fuels. These issues are described below.

Decreased GHG Emissions from Bioenergy

Biomass is generally considered to contribute nearly zero net GHG emissions (U.S. EPA, 2007b; IPCC, 2006). The reason for this accounting is because conversion of biomass feedstocks (whether in the form of biopower or biofuels) returns approximately the same amount of CO_2 to the atmosphere as was absorbed during growth of the biomass, resulting in little to no additional CO_2 released to the air. In contrast, when fossil fuels are burned, they release CO_2 into the atmosphere that was captured by photosynthesis and "stored" millions of years ago, thereby increasing the total amount of carbon in the atmosphere today. Fuel sources such as landfill gas and manure digester biogas actually reduce GHG emissions while producing energy.

Some recent studies dispute whether land use changes associated with biofuels (not biopower) production and international agricultural commodity markets counteract this benefit and actually increase GHG emissions (Searchinger et al., 2008; Delucchi et al., 2008; Wang and Haq, 2008). U.S. EPA is responsible for studying this issue carefully as part of the rulemaking process for the Federal Renewable Fuel Standard and ultimately enforcing new GHG reduction standards for renewable fuels as required by the Energy Independence and Security Act (EISA) of 2007.

Biofuels. The Argonne National Laboratory has estimated (excluding indirect land use) that when corn ethanol displaces an energy-equivalent amount of gasoline, GHG emissions are reduced by 18–29 percent; cellulosic ethanol yields an 85–86 percent reduction (Wang, 2005).

REDUCING GHG EMISSIONS WITH WASTE-TO-ENERGY

An example of GHG savings from bioenergy can be illustrated by the diversion of MSW from landfills to incinerators. MSW as a biomass feedstock reduces landfill methane emissions and substitutes for fossil-based power sources. EPA's life-cycle models (WARM and MSW Decision Support Tool) estimate that 0.55 to 1.0 tons of GHG emissions can be saved per ton of MSW combusted when incineration with energy recovery is selected over landfilling. MSW includes a large biogenic component (50 to 66 percent), and this fraction of the total can be considered carbon neutral from an energy generation perspective. Overall, a significant net GHG emissions savings could be realized from MSW combustion with energy recovery.

Source: U.S. EPA, 2008c

Biodiesel is regarded as having significant GHG reduction capabilities, depending on the source of the feedstock. USDA and U.S. DOE performed a comparative life-cycle analysis (excluding indirect land use) of soy-based biodiesel and petroleum diesel used in city buses and estimated that B20 (a blend of 20 percent biodiesel and 80 percent petroleum diesel) and B100 (100 percent biodiesel) can reduce CO_2 emissions by approximately 15 percent and 78 percent, respectively (NREL, 1998).

Biopower. A 2004 NREL study found that overall, compared to coal-generated electricity, producing electricity with biomass feedstocks will substantially reduce GHG emissions (20 to 200+ percent) and the fossil energy consumption per kilowatt-hour of electricity generated (Spath and Mann, 2004). In addition, emissions of methane, a potent GHG, can be reduced by utilizing biomass residues that would otherwise decompose in landfills (e.g., urban and industrial residues). Biopower generated from biogas captured from landfills, wastewater treatment facilities, or animal feeding operations can also reduce methane emissions. On a national scale, if all wastewater treatment facilities that operate anaerobic digesters and have sufficient influent flow rates (greater than 5 million gallons per day) were to install CHP, approximately 340 MW of clean electricity could be generated, offsetting 2.3 million metric tons of CO_2 emissions annually (U.S. EPA, 2007c).

USE OF BIOPOWER FOR OFFSETS

Entities (corporations, facilities, governments) interested in reducing their CO2 emissions are advised to first strive for cost-effective GHG reductions through internal projects, such as energy efficiency and on-site renewable energy projects. As cost-effective direct options are exhausted, entities may also consider supporting GHG reduction projects that occur outside their organizational boundary—known as "offsets."

Offsets represent GHG reductions that are quantified and verified at one location, but whose emission reductions are "credited" to another location or entity. Under all internationally recognized GHG protocols, biopower projects (including converting LFG to energy, capture and use of anaerobic digester gas, and solid fuel biomass feedstocks) can qualify for offset credits under certain circumstances due to their GHG benefits.

EPA's Climate Leaders program, for example, offers protocols for measuring the GHG benefits from biogas and biomass power projects that meet four key accounting principles:

- **Real**. The quantified GHG reductions must represent actual emission reductions that have already occurred.
- **Additional**. The GHG reductions must be surplus to regulation and beyond what would have happened in the absence of the project or in a business-as-usual scenario based on a performance standard methodology.
- **Permanent**. The GHG reductions must be permanent or have guarantees to ensure that any losses are replaced in the future.
- **Verifiable**. The GHG reductions must result from projects whose performance can be readily and accurately quantified, monitored, and verified.

For more information on offsets and other environmental revenue streams for which biomass might qualify, see *www.epa.gov/chp/documents/ers_program_details.pdf*.

Source: U.S. EPA, 2009; U.S. EPA, 2007d

Air Emissions Considerations with Feedstock Production

The application of fertilizers, pesticides, and herbicides associated with agricultural feedstocks (e.g., corn, soybeans, crop residues) can result in air pollutant emissions, including emissions of particulate matter (PM), nitrogen and sulfur compounds, heavy metals, and volatile organic compounds (VOCs) (U.S. DOE, 2003).

In general, crops grown for bioenergy require fewer pesticides and fertilizers than crops grown for food; nevertheless, mitigation of air pollutants from agriculture is important for all crop production, whether the crop is used for food, feed, or bioenergy. Practices that reduce the need for agricultural chemicals and fertilizers while retaining crop yields and quality contribute to sustainability and increase the viability of biomass as a feedstock resource (U.S. DOE, 2003).

Air Emission Considerations with Biopower

Air emissions associated with biopower vary by feedstock, technology, and the extent to which emission controls are used.

SO_2 and NO_X. Using certain biomass feedstocks—such as wood, wood waste, or crop residues—to produce biopower can reduce SO_2 and NO_X emissions because the sulfur and nitrogen content is much lower than in coal.

- Power plants reduce SO_2 and NO_X emissions when they cofire these biomass feedstocks with coal, compared to using coal alone (U.S. DOE, 2004; Mann and Spath, 2001).
- Biopower facilities using biomass feedstocks in certain types of direct combustion technologies (e.g., fluidized bed boilers) and gasification technologies (e.g., integrated gasification combined cycle, or IGCC) have reduced SO_2 and NO_X emissions, compared to coal-only electricity production (U.S. DOE, 2004a; Mann and Spath, 2001).

- Controlled burning of crop residues for power generation also can reduce SO_2 and NO_X emissions by up to 98 percent, compared to emissions from uncontrolled open burning, which many farmers use to burn their crop residues as waste (U.S. DOE, 2004).

Mercury. Mercury emissions from biopower facilities are significantly less—near zero—than those from coal-burning power plants (NREL, 2003).

Particulate matter. Biopower—and in particular, bioheat—can contribute to PM2.5 emissions. Industrial- and utility-scale biomass combustion facilities must comply with federal and state permits for air pollutants, which require controls for PM. As noted in the text box on this page, permitting requirements for small, non-residential boilers will also be in place in 2009.

However, the burning of wood and wood waste in traditional, residential wood stoves is a significant contributor to PM2.5 concentrations in some areas of the country. Since 1988, all wood stoves manufactured in the United States must be EPA-certified, which means they use one-third less wood than older stoves to produce the same heat and emit 50–70 percent less PM; however, only 20–30 percent of the 10 million wood stoves in use are the newer, certified type.

» **For more information, see *www.epa.gov/woodstoves/changeout.html*.**

RELEVANT FEDERAL AIR QUALITY STANDARDS

States must comply with federal air quality standards, including the National Ambient Air Quality Standards (NAAQS) established under the Clean Air Act for "criteria" pollutants, which include CO, lead, nitrogen dioxide, particulate matter (PM2.5, PM10), ground-level ozone, and sulfur dioxide (SO_2).

Most power generation facilities (both fossil fuel-based and bioenergy), as well as burning of transportation fuels (both gasoline and biofuels) in vehicles, emit some of these criteria pollutants. States that do not meet one or more of the NAAQS standards are considered "nonattainment" areas and are required to develop and submit State Implementation Plans (SIPs) that indicate how they will meet these standards.

To help meet federal NAAQS requirements for criteria pollutants, EPA provides guidance to states for developing SIPs that quantify and include emission reductions achieved from energy efficiency and renewable energy measures, including bioenergy. For more information, see *www.epa.gov/ttn/oarpg/t1/memoranda/ereseerem_gd.pdf*.

Bioenergy (as well as most fossil fuel-based) facilities may also be subject to additional federal standards for combustion sources and air-permitting requirements for new sources, including New Source Performance Standards (NSPS) and National Emission Standards for Hazardous Air Pollutants (NESHAP) for boilers, gas turbines, and internal combustion engines. Existing combustion sources must obtain NESHAP permits; new combustion sources must install maximum available control technologies (MACT) and meet additional requirements to qualify for both NSPS and NESHAP permits. Meeting these permitting requirements can take significant effort by project developers.

In 2009, EPA will be publishing a proposed area source rule that will apply new emission requirements to all non-residential small boilers. All bioenergy boilers—typically used to produce heat or steam—installed after that date will be subject to emission regulations for new boilers. All bioenergy boilers in place prior to that date will eventually be required to comply with regulations for existing boilers. For more information, see *www.epa.gov/woodheaters/resources.htm*.

States may also have their own permitting requirements in addition to, or that are more stringent than, federal requirements.

Air Emission Considerations with Biofuels

Analyses by EPA and others have found that the effects of biofuels on air pollutant emissions depend strongly on the type of renewable fuel, the engine type and performance, and the vehicle emissions control system performance. In addition, biodiesel impacts on emissions can vary depending on the type of biodiesel (soybean, rapeseed, or animal fats) and type of conventional diesel to which the biodiesel was added (U.S. EPA, 2002).

Ethanol

CO. Because ethanol contains oxygen, adding ethanol to gasoline allows engines to burn fuel more completely, reducing emissions of unburned hydrocarbons; CO emissions can be reduced by 20–30 percent. States with CO nonattainment areas require that fuel contain oxygen and ethanol is blended into gasoline for this reason (U.S. DOE, 2008).

NO_X. Past tests have shown that ethanol-gasoline blended fuels, such as E10 (a blend of 10 percent ethanol and 90 percent petroleum), increase NO_X emissions slightly. However, results on the use of E85 (a blend of 85 percent ethanol and 15 percent petroleum; used in flexible fuel vehicles [FFVs]) have shown that NO_X emissions do not increase (U.S. DOE, 2008).

VOCs. Certain VOCs that are present in gasoline, such as benzene (a carcinogen), are not present in ethanol; thus, adding ethanol to gasoline reduces emissions of these and other exhaust-related VOCs (U.S. DOE, 2008). However, other air toxics (formaldehyde, acetaldehyde, and 1,3-butadiene) are present in ethanol and blending ethanol with petroleum can increase non-exhaust VOCs (U.E. EPA, 2007e).

Biodiesel

CO, PM, SO_2. B20, a blend of 20 percent biodiesel and 80 percent petroleum diesel, helps reduce emissions of PM, CO, and hydrocarbons, compared to conventional diesel. These air emissions from biodiesel-diesel fuel blends generally decrease as the concentration of biodiesel increases. Biodiesel does not produce SO_2 emissions (U.S. EPA, 2002).

NO_X. The effect of biodiesel on NO_x can vary with engine design, calibration, and test cycle. At this time, the data are insufficient to conclude anything about the **average** effect of B20 on NOx; some studies indicate emissions slightly increase while others indicate a slight decrease or neutral response (U.S. EPA, 2002; NREL, 2009).

BIODIESEL VS. CONVENTIONAL DIESEL EMISSIONS IN HEAVY-DUTY ENGINES

One of the most common blends of biodiesel, B20, contains 20 percent biodiesel and 80 percent petroleum diesel by volume. When soy-based biodiesel at this concentration is burned in heavy-duty highway engines, the emissions, relative to conventional diesel, contain approximately:

- 11 percent less CO
- 10 percent less PM
- 21 percent less unburned hydrocarbons
- 2 percent more NO_x

Source: U.S. EPA, 2002

Decreased Air Emissions from Bioproducts Manufacturing

Compared to manufacturing that relies solely on fossil fuels, manufacturing of bioproducts can help reduce certain pollutant emissions, including VOCs and GHGs. This is because many biomass feedstocks used to manufacture bioproducts can also be used to generate power and heat for these same manufacturing processes, thus decreasing or eliminating the need for fossil fuels and associated emissions. Also, bioproducts are often manufactured using lower temperatures and pressures than fossil fuel-based manufacturing; therefore, less combustion may be needed, which may result in fewer air emissions (U.S. DOE, 2003).

NATURAL DISASTERS CAN GENERATE A SUBSTANTIAL VOLUME OF DEBRIS

U.S. EPA's Planning Guide for Disaster Debris highlights the need for communities to plan for the cleanup of debris after a major natural disaster. Based on lessons learned from communities that have experienced such disasters, this guide contains information to help communities prepare for and recover more quickly from the increased solid waste generated by a natural disaster. Major categories of disaster debris include damaged buildings, sediments, green waste, personal property, ash and charred wood—much of which can be productively utilized if plans are in place (e.g., through recycling, as fuel for biopower production).

For more information, see *www.epa.gov/osw/conserve/rrr/imr/cdm/debris.htm*.

3.3.2 WASTE REDUCTION BENEFITS

Reduced Solid Waste from Biopower

The use of biomass residues can reduce the amount of waste that must be disposed of in landfills. MSW is sometimes used in bioenergy production, which diverts the MSW from the waste stream. Burning MSW in boilers for heat or power can reduce the amount of waste that would otherwise be disposed of in landfills by up to 90 percent in volume and 75 percent in weight (U.S. DOE, 2004a). With a range of 137 to 266 million tons of MSW currently landfilled on an annual basis, the potential for volume reduction is significant (U.S. EPA, 2008c). Waste reduction not only saves increasingly limited landfill space, but also helps protect the environment (e.g., water quality in rivers and oceans).

In addition, using agricultural and forest residues for bioenergy production allows for these wastes to be disposed of through controlled combustion, rather than burned in open-air slash piles, which helps control and reduce potentially harmful emissions. Such pollution reduction also provides public health benefits (e.g., maintaining or improving drinking water supplies and reducing illnesses associated with air pollution) (U.S. DOE, 2004a).

Reduced Hazardous and Toxic Wastes from Bioproducts Manufacturing

Many bioproduct manufacturing processes use natural catalysts (e.g., enzymes) and solvents (e.g., water) and produce few or no toxic or hazardous by-products. (In contrast, manufacturing of fossil fuel-based products uses large amounts of aromatic solvents or strong inorganic acids and bases.) In most cases, solid wastes and liquid effluents from biological processes used to make bioproducts are biodegradable or can be recycled or disposed of without extensive treatment. Even in cases where bioproduct manufacturing does release wastes of concern (e.g., production of cellophane produces VOC emissions and high-acid wastewater), the pollution generated is often less than that of similar fossil-based products (e.g., cellophane produces two to three times less pollution than polyurethane). In addition, some chemicals used to make bioproducts could be replaced with more environmentally friendly bio-based chemicals (U.S. DOE, 2003).

3.3.3 LAND RESOURCE CONSIDERATIONS

Soil Impacts. Naturally, using biomass to produce energy can have an impact on land resources. These impacts vary with feedstock and can be positive or negative. Biomass grown for feedstock purposes (in contrast to waste/opportunity fuels) requires large areas of land and can deplete the soil over time. For example, there are long-term economic and environmental concerns associated with removal of large quantities of residues from cropland. Removing residue on some soils could reduce soil quality, promote erosion, and lead to a loss of soil carbon, which in turn lowers crop productivity and profitability (U.S. DOE, 2005).

Ecosystem Impacts. When natural areas or otherwise undeveloped land is converted to agricultural uses to produce biofuel feedstocks, the potential exists for damage to local ecosystems and displacement of species. To minimize land use impacts, fuel crops must be managed so they stabilize the soil, reduce erosion, and protect wildlife habitat.

Forest Health. Significant opportunities may exist to link forest health and bioenergy production. In many forests throughout the western United States, natural ecosystems have been significantly altered by fire suppression and logging practices, creating a high risk of intense wildfire. The surplus biomass from thinning unnaturally overgrown forest areas represents a potentially large renewable energy resource. Forest thinning can be done in a sustainable manner to minimize soil erosion and preserve wildlife habitat (Oregon Department of Energy, 2007). Development of forest biomass harvesting guidelines (see box below) can help ensure that thinning or residue removal is performed in line with the many aspects of forest health.

Land Area. Biomass power plants, much like fossil fuel power plants, require large areas of land for equipment and fuel storage. For example, a small biopower facility that processes 100 tons/day of woody biomass would require approximately 12,500 square feet exclusively for storing a 30-day supply of biomass (assuming average storage height of 12 feet and average density of 40lb/cubic foot). For a larger biopower facility that processes 680 tons/day of feedstock, more than 93,700 square feet of storage space could be needed, which is equivalent to more than two football fields (U.S. EPA, 2007d).

However, if biomass plants burn a waste source such as construction wood waste or agricultural waste, they can provide a benefit by freeing areas of land that might otherwise have been used for landfills or waste piles (U.S. EPA, 2008b).

EPA'S FUTURE MIDWESTERN LANDSCAPES STUDY

The rapid growth of the biofuels industry, which uses crops and other biomass to make liquid fuel, is causing changes in agricultural practices and land uses across the United States, and most strikingly in the Midwest. EPA has initiated the Future Midwestern Landscapes Study to examine projected changes in landscapes and ecosystem services in the Midwest. Given its immediate influence, biofuel production will be studied as a primary driver of landscape change.

By conducting this study, U.S. EPA aims to:

- Understand how current and projected land uses affect the ecosystem services provided by Midwestern landscapes.
- Provide spatially explicit information that will enable EPA to articulate sustainable approaches to environmental management.
- Develop web-based tools depicting alternative futures so users can evaluate trade-offs affecting ecosystem services.

For more information, see *www.epa.gov/ord/esrp/quick-finder/mid-west.htm*.

STATES DEVELOP FOREST BIOMASS HARVESTING GUIDELINES

Biomass harvesting guidelines are designed to fill gaps where existing best management practices may not be sufficient to protect forest resources under new biomass harvesting regimes. States that have developed biomass harvesting guidelines or standards that cover biomass removals include: Maine, Minnesota, Missouri, Pennsylvania, and Wisconsin. Existing guidelines cover topics such as dead wood, wildlife and biodiversity, water quality and riparian zones, soli productivity, silviculture, and disturbance. A Forest Guild (2009) report provides an assessment of existing guidelines and provides recommendations for future forestry guidelines focused on woody biomass removal.

For more information, see *www.forestguild.org/publications/research/2009/biomass_guidelines.pdf*.

ENVIRONMENTALLY SUSTAINABLE PRACTICES FOR BIOMASS FEEDSTOCK PRODUCTION

Bioenergy production has the potential to be a low-input, sustainable energy system. Practices that allow bioenergy to be developed in an environmentally sustainable manner include the following:

- Improvements in crop production are increasing crop yields per acre, thus requiring less land and fewer chemical inputs such as fertilizers and pesticides. Minimizing the use of fertilizers and pesticides for energy crops and crop residues can help protect water quality, air quality, wildlife, and public health.
- Degraded lands and abandoned and underutilized farmland can be used to grow biomass feedstocks rather than using existing farmland.
- Agricultural and forest land on which biomass feedstocks are grown can create new wildlife habitats and protect existing ones (e.g., crop harvesting can be prohibited during bird nesting seasons), while providing open spaces that enhance the quality of life in communities.
- Continued adoption of reduced- and no-till field practices for harvesting crop residues (e.g., corn stover, wheat straw) for cellulosic biofuel production can maintain enough residues in fields to control soil erosion and sustain soil quality.
- Development and use of water-efficient crops will help conserve the amount of water needed for both agricultural and energy crops.
- Transitioning from corn-based ethanol production to cellulosic biofuels will contribute to the environmental benefits of bioenergy because using waste/opportunity feedstocks means less water and chemical use, along with ancillary benefits from using waste productively.
- Production of microalgae can be accomplished in tanks or on degraded lands using brackish or saline water.

3.3.4 WATER RESOURCE CHALLENGES

Water Quality Considerations from Feedstock Production

Chemical fertilizers, pesticides, and herbicides associated with agricultural feedstocks pose a risk to water quality if they enter surface waters. These chemicals can contaminate surface water, groundwater, and drinking water supplies.

Fertilizer Runoff. The influx of fertilizer nutrients into water supplies can lead to eutrophic conditions where algae growth becomes excessive. As this increased plant matter dies, oxygen is consumed in the decomposition process, which can lead to hypoxia—the state of extremely low dissolved oxygen that is deadly for many aquatic species. In the Gulf of Mexico this problem is particularly acute due to the high concentration of farms in the Mississippi River watershed. Agricultural runoff enters the Gulf of Mexico via the Mississippi River and creates a hypoxic zone every summer that damages many valuable fisheries.

» **For more information, see *www.epa.gov/owow/msbasin/hypoxia101.htm*.**

Practices that reduce the need for these chemicals while retaining crop yields and quality contribute to the sustainability and viability of bioenergy production (U.S. DOE, 2003). One of the proposed solutions to the nutrient runoff problem has been to increase the acres of perennial crops (e.g., switchgrass) relative to annual crops (e.g., corn). Perennial crops require fewer applications of pesticides and fertilizers. When strategically placed, they can absorb the runoff from annual crop plantings. Other benefits of perennial crops include less erosion and less soil compaction due to less soil disturbance (U.S. DOE, 2005).

Another potential solution to the nutrient runoff problem is to preserve or plant riparian buffers (vegetated regions adjacent to streams and wetlands). Based on recent studies, riparian buffers of various types (grass, forest, wetland, and combinations thereof) can be effective at reducing nitrogen in riparian zones, especially nitrogen flowing in the subsurface, in areas where soil type, hydrology, and biogeochemistry are conducive to microbial denitrification and plant uptake. While some narrow buffers (1 to 15 meters) may remove nitrogen, wider buffers (>50 meters) more consistently remove significant portions of nitrogen (U.S. EPA, 2005).

In contrast to potential adverse water quality impacts from diverting previously uncultivated lands to energy crops, redirecting large quantities of animal manure to bioenergy uses can lessen nutrient runoff and reduce contamination of surface water and groundwater resources (U.S. DOE, 2005).

Herbicides and Pesticides. Bioenergy crops such as tree crops and switchgrass require herbicide application prior to establishment and during the first year to minimize competition from weeds until the crops are well established. However, tree crops and switchgrass need only one-tenth the amounts of herbicides and pesticides required on average by agricultural crops. Studies are showing that herbicide migration into groundwater is less likely to occur with application to biomass crops (ORNL, 2005).

Temperature and Chemical Pollution. Water pollution is also a potential concern with biomass power plants. As is the case with fossil fuel power plants, pollutants can build up in the water used in the biomass power plant's boiler and cooling system. In addition, the water used for cooling is much warmer when it is returned to the lake or river than when it was removed. Pollutants and higher water temperatures can harm fish and plants in the lake or river where the power plant water is discharged. This discharge usually requires a permit and is monitored.

Water Use Changes from Feedstock Production and Biofuels

Water use is another concern associated with feedstock production and biomass processing. Most current agricultural feedstocks have irrigation requirements, and biofuels plants currently use several gallons of water for every gallon of fuel produced. Because these plants are usually built close to where the feedstocks are grown to minimize transportation costs, local water supplies are drawn upon to serve both irrigation and production needs. Water use is a particular concern in arid regions and where water resources are already being depleted (Oregon Environmental Council, 2007).

3.3.5 FOOD SUPPLY CHALLENGES

One concern regarding the expansion of bioenergy is that crops grown for food, particularly corn, could be diverted from the global food chain to the biofuels supply chain. In the case of corn, only a small amount of U.S. corn is currently exported to undernourished populations. The 24 countries where at least one-third of the population is undernourished import less than 0.1 percent of U.S. corn (Muller et al., 2007).

A more pressing concern may be the conversion of land from agricultural crop production to biomass feedstock production in developing countries where food shortages exist. The demand for biofuels from wealthy countries could exacerbate this problem in developing countries. International and national policies may be needed to protect local food supplies. The issue of bioenergy's relationship to agriculture also needs additional analysis, along with further investigation of the many other issues that affect world food, land use, hunger, and poverty (Muller et al., 2007).

3.4 FEEDSTOCK SUPPLY CHALLENGES

3.4.1 LOCATING HIGH-QUALITY FEEDSTOCKS FOR BIOENERGY

It is critical for bioenergy producers to have access to a reliable, high-quality biomass feedstock supply. For both biofuels and biopower, feedstocks should ideally be available:

- For a relatively fixed cost over long periods of time (i.e., for the life of the bioenergy project).
- From a consistent source or sources in close proximity to the bioenergy plant.
- With high-quality characteristics, such as high heating value, low moisture and ash content, and consistent particle size.

Obtaining biomass feedstocks with these qualities can be challenging. Factors that can cause uncertainty in the availability of a suitable feedstock over time include:

- **Transportation Constraints**. Transportation costs impose limits on the areas over which a biomass feedstock can be obtained cost effectively.
- **Competition for Feedstocks**. Competition can include:
  - *Alternative end uses:* If the feedstock has more than one end use, a bioenergy producer might need to compete with other markets for the use of the resource.
  - *Competing land uses:* Biomass producers may shift production to other resources if they become more profitable to grow than the original feedstock.

STORAGE CHALLENGES

Once feedstocks are identified and transported to biorefineries, they are accumulated in piles, pretreated and/or processed, and then placed in buffer storage containers prior to use. Challenges associated with storing feedstocks include:

Volume. Biomass feedstocks can have low bulk densities, and as a result, prep-yards and storage facilities must be large enough to accommodate the large volumes necessary for bioenergy production. For example, a 30-day supply of woody biomass (average density 40 pounds per cubic foot) for a biorefinery with a 680 tons per day conversion system would cover an area larger than two football fields, if piled to an average height of 12 feet.

Pile management. As feedstocks arrive at biorefineries they are piled in prep-yards prior to treatment and processing, using either front end loaders or a radial stacker (depending on the volume required). Piles must be carefully managed to maintain the quality of the feedstock, which may require a range of precautions from dust control to combustion prevention.

Shelf life. Because biomass feedstocks consist of organic material, they are susceptible to degradation and decomposition over time. Feedstocks have a "shelf life" that is dependent on their moisture content and the climate in which they are stored. To ensure that feedstocks remain stable prior to use, storage facilities may need to install environmental control technologies, which can be costly.

Source: U.S. EPA, 2007d; U.S. DOE, 2004b

- *Competition among bioenergy producers:* Bioenergy producers may have to compete with one another for a scarce feedstock supply as an increasing number of bioenergy projects are deployed.

- **Natural causes**. Weather, agricultural pests, and plant disease can decrease the quantity and quality of the desired supply available from a given agricultural or energy crop source.

- **Seasonality of feedstocks**. Some feedstocks are seasonal and may have limited availability depending on the time of year. Bioenergy producers may need to engage with multiple suppliers and/or employ flexible conversion processes capable of using a variety of feedstocks to ensure a steady supply of feedstock and consistent levels of energy output throughout the year. Working with multiple landowners to obtain feedstocks may prove challenging since landowners may have competing objectives related to forest stewardship, forest management plans, financial concerns, and other priorities.

These factors contribute to uncertainty and/or volatility in feedstock prices. The first two factors—transportation and competition—are critical, and can be influenced by policy or program design.

Transportation

The cost of a biomass resource is influenced in large part by transportation costs—the expenditure required to bring the feedstock to the bioenergy plant. Because biomass provides less energy per unit of weight or volume than do fossil fuels, more feedstock is required to generate a given output. Therefore, the resource cannot be profitably transported as far as coal or oil, so bioenergy facilities must be located within an area of concentrated feedstock.

Example

BIOMASS COMMODITY EXCHANGE

Wisconsin is developing the Biomass Commodity Exchange (BCEX) to help organize the way new businesses and landowners connect to provide biomass for bioenergy applications. The BCEX project has been charged with creating an implementation plan for a commodity exchange as a means to increase the efficiency of the supply chain providing biomass to the existing biofuels industries and the emerging concept of the forest biorefinery. The implementation plan will also examines the future trade of closed-loop energy crops, such as willow, poplar and switchgrass and as an approach to offset CO2 emissions through synergies created with other regulated exchanges such as the Chicago Climate Exchange.

For more information, see *www.biomasscommodityexchange.com*.

The distance that biomass can be transported profitably depends on numerous factors, including the cost of transportation fuel and quality of the biomass, which are subject to considerable variability by feedstock and location. DOE estimates feedstock transportation costs as usually in the range of \$0.20 to \$0.60 per dry ton per mile (U.S. DOE, 2005). All transportation costs will vary with local conditions, but one of the primary factors influencing transportation costs is the cost of diesel fuel. Also, using barges and rail to transport feedstocks is less expensive than trucking per unit of feedstock.

Competition for Feedstocks

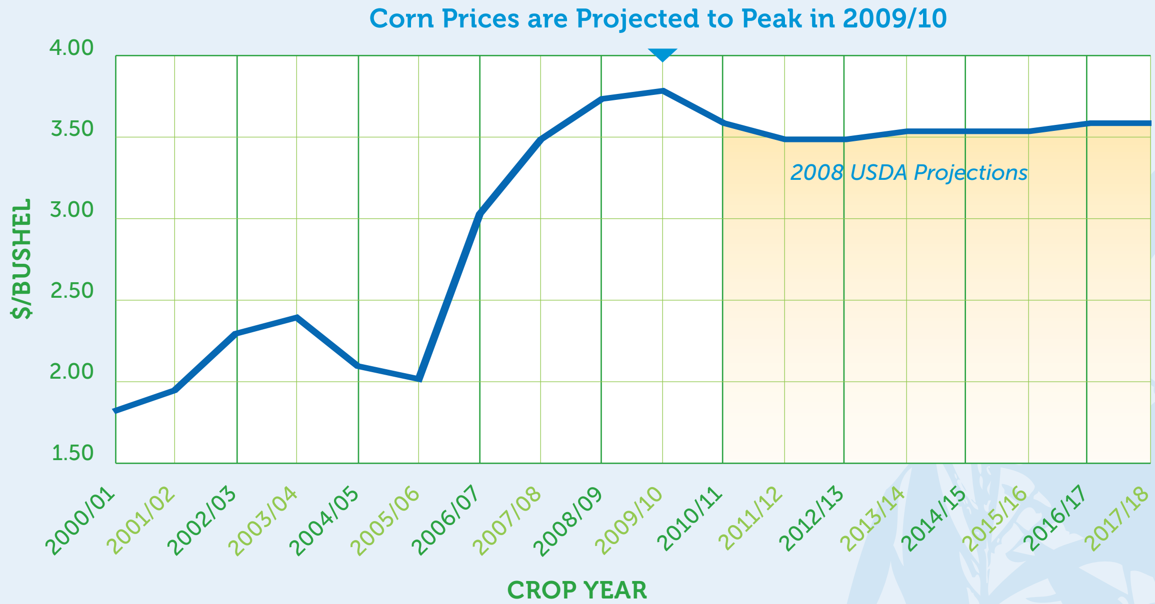
In some situations, biomass producers might be reluctant to agree to long-term supply contracts, which can also contribute to cost uncertainties. For example, biomass producers want the freedom to sell to whichever market or end user is willing to pay the most, and may therefore be hesitant to agree to long-term contracts if the feedstock has multiple end uses. Biomass producers may also be reluctant to enter into long-term contracts when the potential exists for commodities other than the feedstock to become more profitable during the life of the contract (e.g., from soybeans to corn). As producers shift production away from the original feedstock to other resources, the cost of obtaining a given quantity of the feedstock will increase.

For example, as shown in Figure 3-1, the price of corn has increased significantly in recent years and is projected to remain high by historical standards for the foreseeable future. Some studies have attributed these trends to increased corn-based ethanol production, although debate exists as to how much of this price increase can be attributed to other factors such as rising energy prices. Nonetheless, if corn prices are predicted to increase, farmers will be even more reluctant to enter into long-term contracts because they would often prefer to hedge in hopes of higher prices later.

Feedstock availability and price will ultimately determine the feasibility of a proposed bioenergy plant. Potential bioenergy investors will extend the capital needed to finance proposed projects only if the projects will generate an attractive return. Typically, investors look to recover their initial capital outlays in just a few years. Any variability in the availability or cost of suitable biomass feedstocks could significantly reduce the return on their investment. Therefore, investors are unlikely to help finance a project unless both long-term feedstock supply plans and purchase agreements for the energy produced are in place.

FIGURE 3-1. U.S. CORN PRICES, 2000 TO 2018

Source: USDA Agricultural Projections to 2018, February 2008



Some states have enacted policies and other measures to reduce the risk of investing in bioenergy. To learn more about the actions that states can take to make the investments more attractive, see Chapter 5, How Can States Facilitate Financing of Bioenergy Projects?

3.5 INFRASTRUCTURE CHALLENGES

3.5.1 PRODUCT DELIVERY CHALLENGES FOR ETHANOL

Pipeline Limitations

All motor fuels must be transported from refineries to refueling stations as efficiently and cost effectively as possible. When the fuel must be transported a great distance, as is often the case, pipelines are typically the least-cost option.

Unlike conventional refined motor fuels (e.g., gasoline, diesel), which are routinely shipped via pipeline, the distribution of ethanol through the nation's pipeline network poses challenges largely due to several properties of the biofuel:

- Ethanol will easily absorb water that has accumulated in pipelines, potentially rendering it useless as a motor fuel.
- Because it readily absorbs water, ethanol cannot be separated from other products in a petroleum pipeline by the typical method of sending water between batches of different petroleum products.
- Ethanol is an effective solvent/cleansing agent and therefore may be contaminated by residues of other materials that have been shipped through the pipeline.
- Ethanol is corrosive and can damage pipeline parts and storage tanks.

In addition, the current U.S. petroleum pipeline network is not optimally sited for ethanol distribution, production of which is heavily concentrated in the Midwest.

Example

ETHANOL PIPELINE IN CENTRAL FLORIDA

In September 2008, Kinder Morgan Energy Partners, L.P. successfully performed test shipments of batches of denatured ethanol in its 16-inch Central Florida Pipeline—otherwise used to transport gasoline between Tampa and Orlando. Approximately $10 million in modifications were made to the line in preparation for the ethanol shipments, including chemically cleaning the pipeline, replacing equipment that was incompatible with ethanol, and expanding storage capacity at the Orlando terminal. As a direct result of the tests, Kinder Morgan announced in December 2008 that the pipeline would become the first in the United States to carry commercial batches of ethanol. Kinder Morgan has also proposed creating a dedicated 8-inch "inter-terminal" ethanol pipeline to supply its Hooker's Point terminal in Tampa.

Source: Kinder Morgan, 2008a and 2008b

As a result of these factors, ethanol is typically not transported in large quantities by pipeline, but instead by barge, rail, or truck, which are all more costly and less efficient than shipping via pipelines. In 2005, rail was the primary transportation mode for ethanol, shipping 60 percent of ethanol production, or approximately 2.9 billion gallons. Trucks shipped 30 percent and barges 10 percent (USDA, 2007). It typically costs roughly $0.17 to $0.20 per gallon to transport ethanol by rail, whereas it would cost approximately $0.05 per gallon to transport by pipeline (RFA, 2008). This added expense hurts the competitiveness of ethanol relative to conventional refined fuels.

Although it is possible to convert some existing pipelines for ethanol shipment, the cost of doing so is usually prohibitive and difficult to justify. Developing a new, dedicated ethanol distribution infrastructure would help to address many of these challenges; however, the high construction and capital costs and the challenge of obtaining new rights-of-way make building a new pipeline distribution system unlikely unless the need arises to ship very large quantities of ethanol. The U. S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA) is researching a variety of technologies that could make large-quantity distribution of ethanol by pipeline more feasible in the future.

» **For more information, see *http://primis.phmsa.dot.gov/comm/Ethanol.htm?nocache=406*.**

Example

DEVELOPING INFRASTRUCTURE: TENNESSEE'S BIOFUEL GREEN ISLAND CORRIDOR NETWORK

In 2006, the state of Tennessee established a grant program to facilitate development of the Biofuel Green Island Corridor Network along Tennessee's interstate system and major highways. The goal of this program is to help establish readily available "green island" refueling stations for B20 and E85 no more than 100 miles apart along heavily traveled transportation corridors. Ultimately, the state hopes to have at least one B20 and one E85 station in 30 priority counties, and three of each station type within all major urban areas. The state has allocated $1.5 million in state funds and $480,000 in funds from the federal Congestion Mitigation and Air Quality Improvement (CMAQ) program to pay for up to 80 percent of fuel station installation costs, offering grantees a maximum of $45,000 per pump or $90,000 per location. The program has also focused on installing visible and easily recognizable signage along the corridors to indicate where B20 and E85 stations are located and encourage their use. As of October 2008, there were 22 E85 stations and about 27 B20 stations in Tennessee.

Source: Tennessee Department of Transportation, 2009

Fueling System Limitations

A second major infrastructure challenge to increased ethanol use is to ensure there are sufficient fueling stations offering access to E-85 blends of ethanol to support the increasing volumes of renewable fuels as set forth in EISA.

As of 2008, there were more than 1,600 stations offering E85 in the United States. However, due to the distribution issues discussed above, most of these stations are located in the Midwest, where most ethanol production currently occurs. The highest concentrations of E85 stations are found in Illinois, Indiana, Iowa, Minnesota, and Wisconsin; although E85 is commercially available in more than 40 states across the country.

TRANSATLAS INTERACTIVE ALTERNATIVE FUEL MAP

The U.S. Department of Energy (DOE) and the National Renewable Energy Lab (NREL) have developed a comprehensive mapping tool to help industry and government planners implement alternative fuels and advanced vehicles. The new TransAtlas tool combines different types of geographic data to identify areas with potential for developing advanced transportation projects. NREL employed user-friendly Google Maps to display the locations of existing and planned alternative fueling stations, concentrations of different vehicle types, alternative fuel production facilities, roads, and political boundaries.

For more information, see *www.afdc.energy.gov/afdc/data/geographic.html*.

DOE estimates that 6.8 million light-duty FFVs are on U.S. roadways, and this number is likely to grow. FFVs are designed with specific modifications that allow them to run on either traditional gasoline (which may contain as much as 10 percent ethanol, depending on state regulations) or E85.[3] Unfortunately, many owners of FFVs do not realize their vehicles can run on E85 and/or don't know where to find E85 stations. Many more fueling stations offering E85 are needed, as is greater market visibility, if states want to capitalize on the existing potential market of FFV owners.

» **To locate E85 fueling stations, see *www.afdc.energy.gov/afdc/ethanol/ethanol_locations.html*.**

3 Vehicles that are not designated as E85-compatible should not use E85 fuel because the high content of ethanol can damage the engine and fueling system. ***http://www.afdc.energy.gov/afdc/e85toolkit/eth_vehicles.html***

3.6 RESOURCES FOR DETAILED INFORMATION

Resource	Description	URL
Bioenergy		
Economic Impacts of Bioenergy Production and Use, U.S. DOE, SSEB Southeast Biomass State and Regional Partnership, October 2005.	Summarizes the benefits of bioenergy production in the U.S., including job creation, reduced demand for fossil fuels, and expanded tax bases.	*www.vienergy.org/Economics.pdf*
State Energy Alternatives Web Site, U.S. DOE, National Conference of State Legislatures.	Provides information on state-specific biomass resources, policies, and status as well as current biofuels and biopower technology information.	*http://apps1.eere.energy.gov/states/*
An Assessment of Biomass Harvesting Guidelines, Evans and Perschel, Forest Guild, 2009.	Presents an assessment of existing biomass harvesting guidelines and provides recommendations for the development of future guidelines.	*www.forestguild.org/publications/research/2009/biomass_guidelines.pdf*
Planning for Disaster Debris, U.S. EPA, 2008.	Provides information and examples for developing a disaster debris plan that will help a community identify options for collecting, recycling, and disposing of debris in the event of a natural disaster.	*www.epa.gov/osw/conserve/rrr/imr/cdm/pubs/disaster.htm*
Biopower/Bioheat		
Biomass Power and Conventional Fossil Systems with and without CO_2 Sequestration—Comparing the Energy Balance, Greenhouse Gas Emissions, and Economics, NREL, January 2004.	Provides a comparative analysis of a number of different biopower, natural gas, and coal technologies.	*www.nrel.gov/docs/fy04osti/32575.pdf*
Economic Impacts Resulting from Co-Firing Biomass Feedstocks in Southeastern U.S. Coal-Fired Power Plants, Presentation by Burton English et al., University of Tennessee.	Summarizes the economic impacts in eight southeastern states from using biomass to co-fire power plants that traditionally have only used coal for fuel.	*www.farmfoundation.org/projects/documents/english-cofire.pptprojects/documents/english-cofire.ppt*
Green Power Equivalency Calculator, U.S. EPA.	Allows any bioenergy user to communicate to internal and external audiences the environmental impact of purchasing or directly using green power in place of fossil fuel derived energy by calculating the avoided carbon dioxide (CO2) emissions. Results can be converted into an equivalent number of passenger cars, gallons of gasoline, barrels of oil, or American households' electricity use.	*www.epa.gov/grnpower/pubs/calculator.htm*
Job Jolt: The Economic Impacts of Repowering the Midwest: The Clean Energy Development Plan for the Heartland, Regional Economics Applications Laboratory, November 2002.	Analyzes the economic and job creation benefits of implementing a clean energy plan in the 10-state Midwest region.	*www.michigan.gov/documents/nwlb/Job_Jolt_RepoweringMidwest_235553_7.pdf*

Resource	Description	URL
Biofuels/Bioproducts		
Alternative Fueling Station Locator, U.S. DOE.	Allows users to find alternative fuels stations near a specific location on a route, obtain counts of alternative fuels stations by state, view U.S. maps, and more. The following alternative fuels are included in the mapping application: compressed natural gas, E85, propane/liquefied petroleum gas, biodiesel, electricity, hydrogen, and liquefied natural gas.	*www.afdc.energy.gov/afdc/data/geographic.html*
Biomass Energy Data Book, ORNL, September 2008.	Describes a meta-analysis of energy balance analyses for ethanol, revealing the sources of differences among the different studies.	*http://cta.ornl.gov/bedb/pdf/Biomass_Energy_Data_Book.pdf*
Changing the Climate: Ethanol Industry Outlook 2008, Renewable Fuels Association (RFA), 2008.	Forecasts that 4 billion gallons of ethanol production capacity will come on line from 68 biorefineries being constructed in 2008 and beyond, increasing the 2007 figure by nearly 50%.	*www.ethanolrfa.org/objects/pdf/outlook/RFA_Outlook_2008.pdf*
Contribution of the Ethanol Industry to the Economy of the United States, RFA, 2007.	Finds that the industry spent $12.5 billion on raw materials, other inputs, and goods and services to produce about 6.5 billion gallons of ethanol in 2007. An additional $1.6 billion was spent to transport grain and other inputs to production facilities; ethanol from the plant to terminals where it is blended with gasoline; and co-products to end-users.	*www.ethanolrfa.org/objects/documents/576/economic_contribution_2006.pdf*
Economic and Agricultural Impacts of Ethanol and Biodiesel Expansion, University of Tennessee, 2006.	Finds that producing 60 billion gallons of ethanol and 1.6 billion gallons of biodiesel from renewable resources by 2030 would likely result in development of a new industrial complex with nearly 35 million acres planted dedicated to energy crops.	*http://beag.ag.utk.edu/pp/Ethanolagimpacts.pdf*
Ethanol and the Local Community, RFA, 2002.	Summarizes possible effects of ethanol production on local economic development.	*www.ethanolrfa.org/objects/documents/120/ethanol_local_community.pdf*
Greener Fuels, Greener Vehicles: A State Resource Guide, National Governors' Association, 2008.	Discusses alternative transportation fuels and vehicle technologies.	*www.nga.org/Files/pdf/0802GREENERFUELS.PDF*
Greenhouse Gas Impacts of Expanded Renewable and Alternative Fuels Use, U.S. EPA, April 2007.	Provides a summary of GHG emissions from a variety of advanced fuel options.	*www.epa.gov/oms/renewablefuels/420f07035.htm*
New Analysis Shows Oil-Savings Potential of Ethanol Biofuels, National Resources Defense Council (NRDC), 2006.	Describes NRDC's meta-analysis of energy balance papers and its standardized methods.	*www.nrdc.org/media/pressreleases/060209a.asp*
A Rebuttal to "Ethanol Fuels: Energy, Economics and Environmental Impacts," National Corn Growers Association, 2002.	Refutes the contention in a previous article that more energy goes into producing ethanol than ethanol itself can actually provide, creating a negative energy balance.	*www.ethanolrfa.org/objects/documents/84/ethanolffuelsrebuttal.pdf*
Renewable Fuel Standard Program, U.S. EPA.	Describes efforts undertaken by U.S. EPA toward a National Renewable Fuels Standard under requirements of the Energy Policy Act of 2005. While these requirements are superseded by more recent legislation, links from this page provide useful background. In particular, the discussion of estimated costs summarizes the expected incremental costs of policies advancing ethanol.	*www.epa.gov/oms/renewablefuels/*

3.6 RESOURCES FOR DETAILED INFORMATION *(cont.)*

Resource	Description	URL
Regulatory Impact Analysis: Renewable Fuel Standard Program, U.S. EPA, 2007.	Examines proposed standards that would implement a renewable fuel program as required by the Energy Policy Act of 2005. It notes, however, that renewable fuel use is forecast to exceed the standards due to market forces anyway.	*www.epa.gov/OMS/renewablefuels/420r07004-sections.htm*
SmartWay Grow & Go Factsheet on Biodiesel, U.S. EPA, October 2006.	Describes how biodiesel is made, its benefits versus vegetable oil, performance, availability, affordability, and other characteristics.	*www.epa.gov/smartway/growandgo/documents/factsheet-biodiesel.htm*
SmartWay Grow & Go Factsheet on E85 and Flex Fuel Vehicles, U.S. EPA, October 2006.	Describes E85-fuel and flex-fuel vehicles, including their affordability and benefits.	*www.epa.gov/smartway/growandgo/documents/factsheet-e85.htm*
State-Level Workshops on Ethanol for Transportation: Final Report.	Summarizes a series of DOE-sponsored, state-level workshops exploring and encouraging construction of ethanol plants.	*www.nrel.gov/docs/fy04osti/35212.pdf*
TransAtlas Interactive Alternative Fuel Map, U.S. DOE.	Provides user-friendly Google Maps to display the locations of existing and planned alternative fueling stations, concentrations of different vehicle types, alternative fuel production facilities, roads, and political boundaries.	*www.afdc.energy.gov/afdc/data/geographic.html*
Analysis of Potential Causes of Consumer Food Price Inflation, RFA, 2007.	Asserts that the "marketing bill," not increased ethanol production, is responsible for rising food prices.	*www.ethanolrfa.org/resource/facts/food/documents/Informa_Renew_Fuels_Study_Dec_2007.pdf*
Ethanol Juggernaut Diverts Corn from Food to Fuel, Raloff, Janet, Science News, 2007.	Makes the case that ethanol is driving up food prices.	*www.sciencenews.org/view/generic/id/8179/title/Food_for_Thought__Ethanol_Juggernaut_Diverts_Corn_from_Food_to_Fuel*
Food versus Fuel in the United States, Institute for Agriculture and Trade Policy, 2007.	Finds that biofuel production is not diverting food from tables in the U.S. or abroad.	*www.iatp.org/iatp/publications.cfm?accountID=258&refID=100001*
U.S. Corn Growers: Producing Food and Fuel, National Corn Growers Association, 2006.	Provides the corn growers' perspective that producing food and fuel from corn is working out well, without undue impact on food prices.	*www.ncga.com/files/pdf/FoodandFuelPaper10-08.pdf*
Aggressive Use of Bioderived Products and Materials in the U.S. by 2010, A.D. Little, Inc., 2001.	The presentation and report summarize near-term opportunities to dramatically increase the use of biomass to make nonfuel products.	*www.p2pays.org/ref/40/39031.pdf*
Industrial Bioproducts: Today and Tomorrow, U.S. DOE, July 2003.	The report finds that a bioindustry could harness the energy and molecular building blocks of biomass (crops, trees, grasses, crop residues, forest residues, animal waste, and municipal solid waste) to create products now manufactured from petroleum, making us far less dependent on fossil fuels.	*www.brdisolutions.com/pdfs/BioProductsOpportunitiesReportFinal.pdf*
Preliminary Screening Technical and Economic Assessment of Synthesis Gas to Fuels and Chemicals with Emphasis on the Potential for Biomass-Derived Syngas, NREL, 2003.	Summarizes opportunities for biomass to be used to manufacture a variety of products beyond fuels alone.	*www.nrel.gov/docs/fy04osti/34929.pdf*

3.6 RESOURCES FOR DETAILED INFORMATION *(cont.))*

Resource	Description	URL
Environmental Life Cycle Implications of Fuel Oxygenate Production from California Biomass – Technical Report, NREL, 1999.	Looks at the costs and benefits of biomass-derived ethanol, ETBE, and E10 as fuel oxygenates across their life cycles.	*www-erd.llnl.gov/FuelsoftheFuture/pdf_files/lifecyclecalif.pdf*
Quantifying Cradle-to-Farm Gate Life-Cycle Impacts Associated with Fertilizer used for Corn, Soybean, and Stover Production, NREL, May 2005.	Documents the costs, such as eutrophication, and benefits of nitrate and phosphate fertilizers used in production of three crops.	*www1.eere.energy.gov/biomass/pdfs/37500.pdf*
Life Cycle Analysis of Ethanol from Corn Stover, NREL, 2002.	This comprehensive accounting of ethanol's flows to and from the environment focuses on ethanol produced from corn stover	*www.nrel.gov/docs/gen/fy02/31792.pdf*
Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus: Final Report, NREL, 1998.	Examines the relative costs and benefits of using biodiesel versus petroleum diesel in an urban bus.	*www.nrel.gov/docs/legosti/fy98/24089.pdf*
Life Cycle Assessment of Biodiesel versus Petroleum Diesel Fuel, Institute of Electrical and Electronics Engineers, 1996.	The proceedings of the 31st Intersociety Energy Conversion Engineering Conference, held August 11–16, 1996, in Washington, DC.	Accessible by subscription only
Life Cycle Assessment of Biomass-Derived Refinery Feedstocks for Reducing CO2, NREL, 1997.	Discusses the two processes for producing 1,4-butanediol. The first process is the conventional hydrocarbon feedstock-based approach, utilizing methane to produce formaldehyde, and acetylene with synthesis under conditions of heat and pressure. The second is a biomass-based feedstock approach where glucose derived from corn is fermented.	Not available online
Life Cycle Assessment of Biomass Cofiring in a Coal-Fired Power Plant, NREL, 2001.	Reports on a cradle-to-grave analysis of all processes necessary for the operation of a coal-fired power plant that co-fires wood residue, including raw material extraction, feed preparation, transportation, and waste disposal and recycling.	Accessible by subscription only
Understanding Land Use Change and U.S. Ethanol Expansion, RFA, November 2008.	Discusses historical agricultural land use and crop utilization trends, explores the role of increased productivity, looks at the contributions of ethanol feed co-products, and examines global agricultural land use projections obtained from Informa Economics.	*www.ethanolrfa.org/objects/documents/2041/final_land_use_1110_w_execsumm.pdf*
National Biofuels Action Plan, Biomass Research and Development Board, October 2008.	Outlines areas where cooperation between federal agencies will help to evolve bio-based fuel production technologies into competitive solutions for meeting U.S. fuel demands. Seven key areas for action are identified: feedstock production; feedstock logistics; conversion of feedstock to fuel; distribution; end Use; sustainability; and Environment, Health, and Safety.	*www1.eere.energy.gov/biomass/pdfs/nbap.pdf*
Tools for Evaluating Benefits		
AirCRED, Argonne National Laboratory, August 2007.	This tool is used to support local air emission reductions claims associated with alternative-fuel vehicles within the State Implementation Planning process.	*www.transportation.anl.gov/modeling_simulation/AirCred/index.html*

3.6 RESOURCES FOR DETAILED INFORMATION *(cont.))*

Resource	Description	URL
Biomass Technology Analysis Models and Tools.	Web sites of models and tools that demonstrate biomass technologies and uses, and can be used in life-cycle assessments. Most tools can be applied on a global, regional, local, or project basis.	*www.nrel.gov/analysis/analysis_tools_tech_bio.html*
Biomass Feedstock Composition and Property Database.	Provides data results from analysis of more than 150 samples of potential biofuels feedstocks, including corn stover, wheat straw, bagasse, switchgrass and other grasses, and poplars and other fast-growing trees.	*www1.eere.energy.gov/biomass/feedstock_databases.html*
CHP Emissions Calculator, U.S. EPA.	Enables a quick and easy analysis of the criteria air pollutant and GHG emission reductions from incorporating CHP designs into plants and production facilities. It also translates these reductions into "cars" and "trees" to convey their value to a nontechnical audience.	*www.epa.gov/chp/basic/calculator.html*
Clean Air Climate Protection Software, ICLEI and NACAA.	Helps local governments create greenhouse gas inventories, quantify the benefits of reduction measures, and formulate local climate action plans.	*www.cacpsoftware.org/*
Emissions & Generation Resource Integrated Database (EGRID), U.S. EPA.	Provides a comprehensive database of electric-sector emissions at the plant, state, and regional levels. These can be compared to emissions from biopower to estimate emissions' effects.	*www.epa.gov/cleanrgy/egrid/index.htm*
Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model, Argonne National Laboratory, August 2007.	Includes full fuel-cycle and vehicle-cycle emissions and energy estimation capability. While not a full life-cycle assessment tool, it allows estimation of upstream emissions and energy effects. For some state policy questions, it may provide sufficient analytic detail on its own. For decisions with greater financial implications, it may be most appropriate to use for initial screening to support development of a more detailed study. States may wish to use GREET directly or to consider analyses that have been done using this tool.	*www.transportation.anl.gov/modeling_simulation/GREET/*
Job and Economic Development Impact (JEDI) Models.	Easy-to-use, spreadsheet-based tools that analyze the economic impacts of constructing and operating power generation and biofuel plants at the local and state levels.	*www.nrel.gov/analysis/jedi*
Power Profiler, U.S. EPA.	Provides a quick estimate of electricity emissions rates by location, which could be compared to emissions from biopower to estimate emissions effects.	*www.epa.gov/grnpower/buygp/powerprofiler.htm*
Standard Biomass Analytical Procedures.	Provides tested and accepted methods for performing analyses commonly used in biofuels research.	*www1.eere.energy.gov/biomass/analytical_procedures.html*
Theoretical Ethanol Yield Calculator.	Calculates the theoretical ethanol yield of a particular biomass feedstock based on its sugar content.	*www1.eere.energy.gov/biomass/ethanol_yield_calculator.html*
Thermodynamic Data for Biomass Conversion and Waste Incineration, NREL, National Bureau of Standards.	Provides heat of combustion and other useful data for biopower and biofuels research on a wide range of biomass and non-biomass materials.	*www1.eere.energy.gov/biomass/pdfs/2839.pdf*

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