Annual Energy Outlook 2010
Early Release Overview

December 2009

Energy Trends to 2035

In preparing the *Annual Energy Outlook 2010* (*AEO2010*), the Energy Information Administration (EIA) evaluated a wide range of trends and issues that could have major implications for U.S. energy markets. This overview focuses primarily on one case, the *AEO2010* reference case, which is presented and compared with the updated *Annual Energy Outlook 2009* (updated *AEO2009*) reference case released in April 2009[1] (see Table 1). Because of the uncertainties inherent in any energy market projection, particularly in periods of high price volatility, rapid market transformation, or active changes in legislation, the reference case results should not be viewed in isolation. Readers are encouraged to review the alternative cases when the complete *AEO2010* publication is released in order to gain perspective on how variations in key assumptions can lead to different outlooks for energy markets.

To provide a basis against which alternative cases and policies can be compared, the *AEO2010* reference case generally assumes that current laws and regulations affecting the energy sector remain unchanged throughout the projection (including the implication that laws which include sunset dates do, in fact, become ineffective at the time of those sunset dates). EIA considers this practice to be a prudent approach to addressing the impact of legislation and regulations. Currently, there are many pieces of legislation and regulation that appear to have a high probability of being enacted in the not-too-distant future, and some laws include sunset provisions that may be extended; however, it is difficult to discern the exact forms that the final provisions of pending legislation or regulations will take, and sunset provisions may or may not be extended. Even in situations where existing legislation contains provisions to allow revision of implementing regulations, those provisions are not exercised consistently.

As in past *AEO* editions, the complete *AEO2010* will include many additional cases. The standard set of cases in the complete *AEO* will be expanded to include additional cases that reflect the impact of extending a variety of current energy programs beyond their current expiration or the permanent retention of a broad set of current programs that are currently subject to sunset provisions, among others. In addition to the alternative cases prepared for *AEO2010*, EIA has examined many proposed policies at the request of Congress in 2009, and reports describing the results of those analyses are available on EIA's web site.[2]

Key updates in the *AEO2010* reference case include:

- This year, for the first time, a projection period that extends through 2035
- Revised handling of corporate average fuel economy (CAFE) standards to reflect the standards proposed jointly by the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA) for light-duty vehicles (LDVs) in model years 2012 through 2016
- Updated projections of investment costs for many categories of capital-intensive energy projects
- Recognition of changes in environmental rules at both the Federal and State levels
- Implementation of a new lower 48 onshore oil and natural gas supply submodule that improves EIA's ability to address issues related to changes and improvements in technology, access to land for exploration and production, and legislative policies
- Updated characterization of natural gas shale plays, reflecting the continued evolution of "shale gas" resources and extraction technologies.

Economic Growth

- Real gross domestic product (GDP) grows by 2.5 percent per year from 2008 to 2030 in the *AEO2010* reference case (similar to the GDP growth rate in the updated *AEO2009* reference case) and by 2.4 percent per year from 2008 to 2035. The Nation's population, labor force, and productivity grow at annual rates of 0.9 percent, 0.6 percent, and 2.0 percent, respectively, from 2008 to 2035.
- Beyond 2011, the economic assumptions underlying the *AEO2010* reference case reflect trend projections that do not include short-term fluctuations. The near-term scenario for economic growth is consistent with that in EIA's September 2009 *Short-Term Energy Outlook*.

[1]The *AEO2009* reference case, originally released in December 2008, was updated to reflect the provisions of the American Recovery and Reinvestment Act (ARRA), enacted in mid-February 2009.

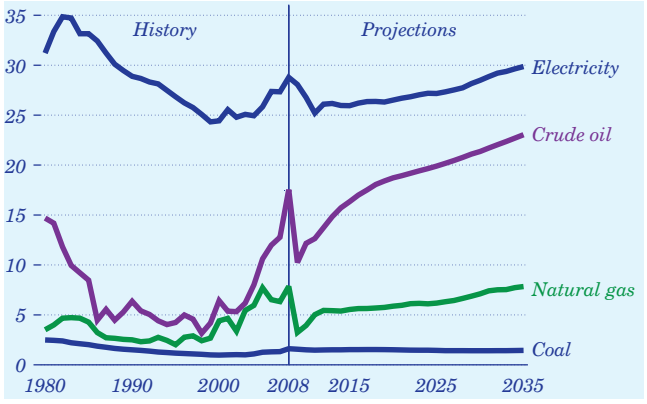
[2]See "Responses to Congressional and Other Requests," at www.eia.doe.gov/oiaf/service_rpts.htm.

Energy Prices

Crude Oil

- World oil prices declined sharply from their mid-2008 peak in the latter half of 2008 but have generally risen throughout 2009. Prices continue to rise gradually in the reference case (Figure 1), as the world economy rebounds and global demand grows more rapidly than liquids supplies from producers outside of the Organization of the Petroleum Exporting Countries (OPEC). In 2035, the average real price of crude oil in the reference case is $133 per barrel in 2008 dollars, or about $224 per barrel in nominal dollars. Alternative cases in the complete *AEO2010* will address the impacts that higher and lower world crude oil prices have on U.S. energy markets.
- The *AEO2010* reference case assumes that limitations on access to energy resources restrain the growth of non-OPEC conventional liquids production between 2008 and 2035 and that OPEC targets a relatively constant market share of 41 percent of total world liquids production.
- Contributing to world oil price uncertainty is the degree to which non-OPEC countries and countries outside the Organization for Economic Cooperation and Development (OECD), such as Russia and Brazil, restrict economic access to potentially productive resources. Other factors causing uncertainty include OPEC investment decisions, which will affect future world oil prices and the economic viability of unconventional liquids.
- The *AEO2010* reference case also includes significant long-term potential for supply from non-OPEC producers. In several resource-rich regions (including Brazil, Russia, and Kazakhstan), high oil prices, expanded infrastructure, and further investment in exploration and drilling contribute to additional non-OPEC oil production (Figure 2). Also, with the economic viability of Canada's oil sands enhanced by higher world oil prices and advances in production technology, production from oil sands reaches 4.5 million barrels per day in 2035.

Figure 1. Energy prices, 1980-2035 (2008 dollars per million Btu)



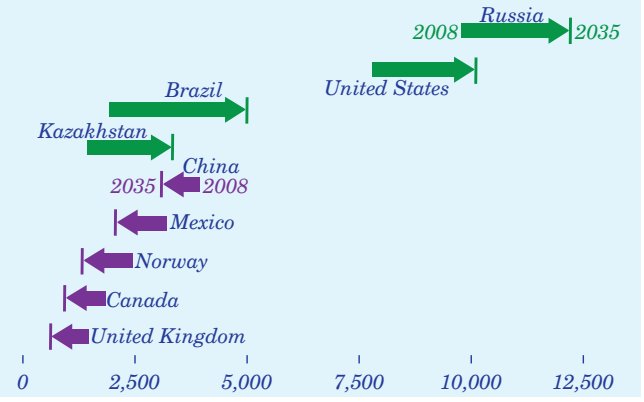
Liquid Products

- Real prices (in 2008 dollars) for motor gasoline and diesel in the *AEO2010* reference case are $3.68 per gallon and $3.83 per gallon in 2030, lower than in the updated *AEO2009* reference case, largely due to the lower crude oil prices in the *AEO2010* reference case. In 2035, real gasoline and diesel prices reach $3.91 per gallon and $4.11 per gallon. Diesel prices are higher than gasoline prices throughout the projection because of stronger growth in demand for diesel than for motor gasoline.
- Retail prices for E85 (a blend of 70 to 85 percent ethanol and 30 to 15 percent gasoline by volume) are projected to shift from a volumetric basis to an energy-equivalent basis relative to motor gasoline, in order to meet the renewable fuels standard (RFS) legislated in Public Law 110-140, the Energy Independence and Security Act of 2007 (EISA2007). In 2022, the retail price of gasoline is $3.41 per gallon while the price of E85 is $2.63 per gallon, reflecting the higher energy content of gasoline versus E85 and delivering a similar cost for the two fuels per mile traveled.

Natural Gas

- The price of natural gas at the wellhead is lower in the *AEO2010* reference case than in the updated *AEO2009* reference case due to a more rapid

Figure 2. Change in conventional liquids production by top non-OPEC producers, 2008-2035 (thousand barrels per day)



ramping up of shale gas production, particularly after 2015. *AEO2010* assumes a larger resource base for natural gas, based on a reevaluation of shale gas and other resources, and a more rapid rate for bringing new resources into production, based on observations of the industry's current capability.

- In the *AEO2010* reference case (as in the updated *AEO2009* reference case), natural gas prices increase in the short term from the low prices observed in 2009 that resulted from the sharp economic downturn. After 2012, prices continue to rise in the *AEO2010* reference case, but more slowly, as additional resources are brought into production to meet demand growth. Natural gas wellhead prices reach $8.06 per thousand cubic feet (2008 dollars) in 2035.

Coal

- Coal prices are expected to moderate through 2029 from their recent high levels because of a continuing shift to lower cost production west of the Mississippi River; however, they remain slightly above the price projections in the updated *AEO2009* reference case through 2025. In the *AEO2010* reference case, the share of total coal production from west of the Mississippi River, on a Btu basis, grows from 50 percent in 2008 to 60 percent in 2029 and remains at that level through 2035.
- In the *AEO2010* reference case, average real minemouth coal prices (in 2008 dollars) fall from $1.55 per million Btu ($31.26 per short ton) in 2008 to $1.41 per million Btu ($27.37 per short ton) in 2029, then begin rising slightly to $1.44 per million Btu ($28.10 per short ton) in 2035 as demand increases and the share of lower cost western production remains steady at 60 percent.

Electricity

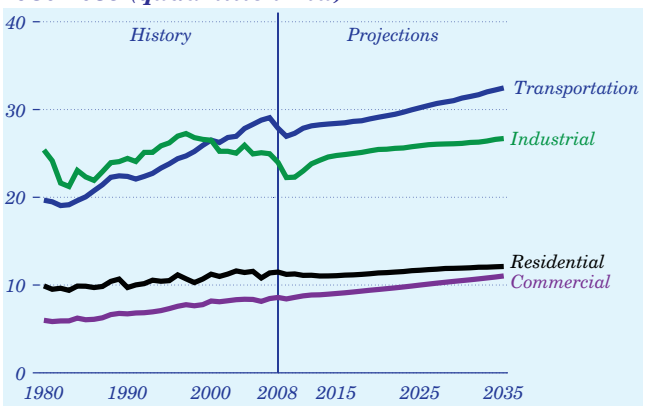
- Following the recent rapid decline in natural gas prices, real average delivered electricity prices in the *AEO2010* reference case fall sharply from 9.8 cents per kilowatthour in 2008 to 8.6 cents per kilowatthour in 2011 and remain below 9.0 cents per kilowatthour through 2020. Electricity prices tend to reflect trends in fuel prices—particularly natural gas prices, because natural-gas-fired plants often are the marginal generators. There can be lags in the timing of price impacts, however, because fuel price contracts may affect the fuel costs passed through to electricity consumers.
- Throughout the projection, electricity prices are linked to natural gas prices. Once natural gas prices begin to rise steadily, electricity prices also begin to increase, reaching an average of 10.2 cents per kilowatthour in 2035. Over the longer term, real electricity prices rise as demand grows and the prices of delivered fuels increase, leading to higher production costs.
- Relatively lower costs for fuel through most of the projection period lead to lower electricity prices in the *AEO2010* reference case than in the updated *AEO2009* reference case. Electricity prices in 2030 (in 2008 dollars) are 9.7 cents per kilowatthour in the *AEO2010* reference case compared with 10.3 cents per kilowatthour in the updated *AEO2009* reference case.

Energy Consumption by Sector

Residential

- Residential delivered energy consumption in the *AEO2010* reference case grows from 11.3 quadrillion Btu in 2008 to 11.9 quadrillion Btu in 2030, 0.3 quadrillion Btu less than in the updated *AEO2009* reference case (Figure 3). Contributing to the lower level of residential energy use is the recent adoption of regional standards for heating and cooling equipment, which require a 90-percent efficiency rating for natural gas furnaces in the northern tier of the country.
- Recently enacted efficiency standards for residential lighting products and incandescent lighting in EISA2007 significantly reduce electricity demand for lighting in the residential sector.
- Shipments of ground-source (geothermal) heat pumps to the residential market increased 40 percent in 2008, as tax credits specified in the Energy

Figure 3. Delivered energy consumption by sector, 1980-2035 (quadrillion Btu)



Improvement and Extension Act of 2008 (EIEA-2008) and greater consumer awareness have fostered significant growth in this emerging technology. The stock of ground-source geothermal heat pumps reaches 2.25 million units in 2030 in the *AEO2010* reference case, 44 percent more than projected in the updated *AEO2009* reference case. Even with the relatively large increase in the number of ground-source heat pump installations, the 2.25 million units represent only 2.2 percent of the heating market for single-family homes in 2030.

Commercial

- Despite lower energy prices after 2015, efficiency gains lead to slower growth in commercial energy consumption in the *AEO2010* reference case than in the updated *AEO2009* reference case. Delivered commercial energy consumption grows from 8.6 quadrillion Btu in 2008 to 10.5 quadrillion Btu in 2030, about 147 trillion Btu less than in the updated *AEO2009* reference case.
- New lighting and refrigeration standards and Federal and State efficiency programs help offset increasing demand for electricity to power electronic equipment, holding growth in commercial electricity use to 1.3 percent per year from 2008 to 2035—the same as growth in commercial floorspace.
- Higher near-term electricity prices combine with the 30-percent Federal investment tax credit to foster increased adoption of commercial photovoltaic systems and small wind turbines in the *AEO2010* reference case relative to the updated *AEO2009* reference case.

Industrial

- Slightly more than one-third of delivered energy consumption in the United States occurs in the industrial sector. The largest users of energy in this sector are the bulk chemical, refining, mining, and paper industries. Those four industries together account for more than 60 percent of total industrial delivered energy consumption. Although the largest current user of energy is the bulk chemicals industry, the refining industry, which also uses energy for coal-to-liquids (CTL), natural gas-to-liquids (GTL), and biofuel production, becomes the largest energy-consuming industry starting in 2028 in the *AEO2010* reference case.
- Collectively, the energy-intensive manufacturing industries—bulk chemicals, refining, paper products, iron and steel, aluminum, food, glass, and cement—produce about one-fifth of the dollar value of industrial shipments while accounting for two-thirds of industrial delivered energy consumption. Strong growth in fuel use for refining results from higher industrial demand for lighter feedstocks, a shift by refineries from lighter to heavier crudes, and growth in biofuel production. As a result, the share of industrial energy use by the energy-intensive industries grows slightly, from 67 percent in 2008 to 70 percent in 2035, despite declines in energy consumption for several other industries.
- Industrial shipments increase 44 percent from 2008 to 2035 in the *AEO2010* reference case, while growth in the energy-intensive manufacturing industries, which drive total industrial energy consumption, is much slower (25 percent). As a result, industrial delivered energy consumption increases only 8 percent. Most significant is a decline of nearly 10 percent in shipments from the bulk chemical industry from 2008 to 2035, leading to a decline of nearly 7 percent in this industry's energy consumption, including feedstock usage.
- Energy consumption in the refining industry—including petroleum, biofuels, and CTL—drives the growth in total industrial delivered energy consumption. While total shipments from the refining industry are largely unchanged from those in the updated *AEO2009* reference case projections, the industry becomes more energy-intensive as a result of growth in energy-intensive biofuels and CTL production.

Transportation

- Delivered energy consumption in the transportation sector grows to 31.3 quadrillion Btu in 2030 (only slightly higher than the 31.2 quadrillion Btu in the updated *AEO2009* reference case) and 32.5 quadrillion Btu in 2035 in the *AEO2010* reference case.
- Energy consumption for LDVs grows to 17.2 quadrillion Btu in 2030, 0.7 quadrillion Btu higher than in the updated *AEO2009* reference case, and to 17.7 quadrillion Btu in 2035 in the *AEO2010* reference case. Lower fuel prices in *AEO2010* and slightly higher total real disposable personal income combine to increase total vehicle miles traveled in 2030 relative to the updated

AEO2009 reference case, offsetting the impact of slightly higher efficiency for new LDVs resulting from revised CAFE standards.

- Energy demand for heavy trucks increases to 6.3 quadrillion Btu (3.2 million barrels per day) in 2030—compared with 6.6 quadrillion Btu in the updated *AEO2009* reference case—and 6.8 quadrillion Btu (3.5 million barrels per day) in 2035 in the *AEO2010* reference case. Fuel use by heavy trucks is lower in the *AEO2010* reference case as a result of the incorporation of updated historical data, which includes a decrease in heavy truck travel.
- *AEO2010* assumes the adoption of CAFE standards jointly proposed by the EPA and NHTSA for LDVs in model years 2012 through 2016. The proposed fuel economy standards for model year 2016 then modestly increase through the 2020 model year to meet the requirements of EISA2007. CAFE standards beyond 2020 are similar to those used in the updated *AEO2009* reference case. To attain the mandated fuel economy levels, the *AEO2010* reference case includes a rapid increase in sales of unconventional vehicle technologies,[3] such as flex-fuel, hybrid, and diesel vehicles, as well as slower growth in sales of new light trucks. Sales of hybrid vehicles, including plug-in hybrid electric vehicles (PHEVs), increase from 2.6 percent of new LDV sales in 2008 to 24.6 percent in 2035. PHEV sales grow rapidly as a result of the EIEA2008 tax credits, increasing to about 90,000 vehicles annually in 2015. In 2035, PHEVs account for 2.6 percent of new LDV sales and 1.7 percent of the total LDV stock.

Energy Consumption by Primary Fuel

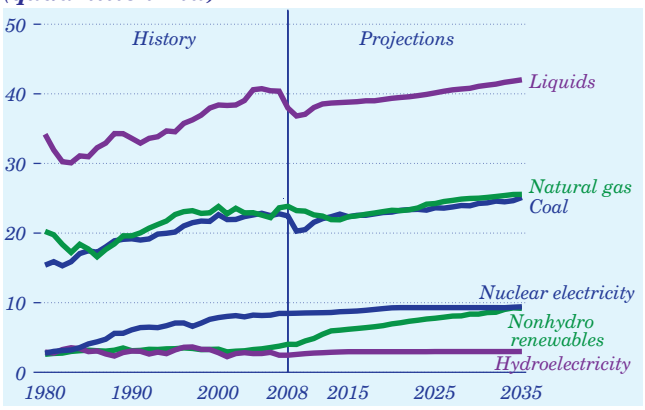
- The fossil fuel share of energy consumption falls from 84 percent of total U.S. energy demand in 2008 to 78 percent in 2035, reflecting the impact of the new CAFE, ARRA, EIEA2008, EISA2007, and State provisions.
- Biofuel consumption accounts for most of the growth in total U.S. liquids consumption, as consumption of petroleum-based liquids is essentially flat.
- Rapid growth in the consumption of renewable fuels results mainly from the implementation of the Federal RFS for transportation fuels and State renewable portfolio standard (RPS) programs for electricity generation.
- Increased renewable energy consumption in the electric power sector, excluding hydropower, accounts for 41 percent of the growth in electricity generation from 2008 to 2035.

Total primary energy consumption in the *AEO2010* reference case grows 14.4 percent, from 100.1 quadrillion Btu in 2008 to 114.5 quadrillion Btu in 2035. Among the most important factors leading to lower total energy demand in the *AEO2010* reference case than was projected in the updated *AEO2009* reference case are greater use of more efficient appliances and vehicles in response to CAFE, EISA2007, and EIEA2008 requirements.

Total U.S. consumption of liquid fuels, including both fossil liquids and biofuels, grows from 38.4 quadrillion Btu (19.5 million barrels per day) in 2008 to 42.0 quadrillion Btu (22.1 million barrels per day) in 2035 in the *AEO2010* reference case (Figure 4). Biofuel consumption accounts for most of the growth, as consumption of petroleum-based liquids is essentially flat. The transportation sector dominates demand for liquid fuels, and its share (as measured by energy content) grows from 71 percent of total liquids consumption in 2008 to 75 percent in 2035.

In the *AEO2010* reference case, natural gas consumption falls to 21.3 trillion cubic feet in 2014 before increasing gradually to 24.3 trillion cubic feet in 2030, 0.8 trillion cubic feet higher than projected in the updated *AEO2009* reference case, as a result of lower natural gas prices (especially when compared with oil prices) in the *AEO2010* reference case. Natural gas consumption reaches 24.9 trillion cubic feet in 2035 in the *AEO2010* reference case.

Figure 4. Energy consumption by fuel, 1980-2035 (quadrillion Btu)



[3]Vehicles that can use alternative fuels or employ electric motors and advanced electricity storage, advanced engine controls, or other new technologies.

Total coal consumption increases from 22.4 quadrillion Btu (1,122 million short tons) in 2008 to 25.6 quadrillion Btu (1,319 million short tons) in 2035 in the *AEO2010* reference case. Coal consumption, mostly for electric power generation, grows gradually throughout the projection period, as existing plants are used more intensively, and new plants, which are already under construction, are completed and enter service. Coal consumption in the electric power sector in 2030 in the *AEO2010* reference case is more than 1 quadrillion Btu lower than in the updated *AEO2009* reference case, however, as a result of higher levels of natural gas use for electric power generation due to relatively lower natural gas prices in the *AEO2010* reference case.

The moderate increase in coal consumption from 2008 to 2035 also reflects coal use at CTL plants, a new industry projected to start up over the coming years, stimulated by rising oil prices and assuming current policies. In 2035, CTL accounts for approximately 1 quadrillion Btu of coal use, despite concerns about potential GHG regulations.

Total consumption of marketed renewable fuels grows 2.8 percent per year in the *AEO2010* reference case. Marketed renewable fuels include wood, municipal waste, and biomass in the end-use sectors; hydroelectricity, geothermal, municipal waste, biomass, solar, and wind for generation in the electric power sector; and ethanol for gasoline blending and biomass-based diesel in the transportation sector, of which 3.9 quadrillion Btu is included with liquids fuel consumption in 2035.

Although the situation is uncertain, the current state of the industry and EIA's present view of the projected rates of technology development and market penetration of cellulosic biofuel technologies suggest that available quantities of cellulosic biofuels will be insufficient to meet the new RFS targets for cellulosic biofuels before 2022, triggering both waivers and a modification of applicable volumes, as provided in Section 211(o) of the Clean Air Act as amended in EISA2007. The modification of volumes reduces the overall target in 2022 from 36.0 to 25.8 billion gallons in the *AEO2010* reference case.[4]

Excluding hydroelectricity, renewable energy consumption in the electric power sector grows from 1.2 quadrillion Btu in 2008 to 4.3 quadrillion Btu in 2035. The projected consumption of nonhydroelectric renewable energy in the *AEO2010* reference case is predominantly a result of an expansion of Federal tax credits for renewable generation and capacity, as well as State RPS programs that require specific and generally increasing shares of electricity sales to be supplied by renewable resources, such as wind, solar, geothermal, and, in some States, biomass or hydropower. Rising fossil fuel prices also contribute to the growth in consumption of renewables in the later years of the projection. The largest sources of growth in renewable energy use in the *AEO2010* reference case are biomass and wind, both of which benefit from concerns about the possible enactment of future GHG regulations that dampen investment in carbon-intensive technologies.

Energy Intensity

- The energy intensity of the U.S. economy, measured as primary energy use (in thousand Btu) per dollar of GDP (in 2000 dollars), declines 40 percent from 2008 to 2035 in the *AEO2010* reference case as the result of a continued shift from energy-intensive manufacturing to services, rising energy prices, and the adoption of policies that promote energy efficiency.
- The reference case reflects observed historical relationships between energy prices and energy conservation. To the extent that consumer preferences change, the improvement in energy intensity or energy consumption per capita could be greater or smaller.

Since 1992, the energy intensity of the U.S. economy has declined an average of 1.9 percent per year, in large part because the economic output of the service sectors, which use relatively less energy per dollar of output, has grown at a pace 2.5 times that of the industrial sector (in constant dollar terms). As a result, the share of total shipments accounted for by the industrial sectors fell from 28 percent in 1992 to 22 percent in 2008. In the *AEO2010* reference case, the industrial share of total shipments continues to decline, to 18 percent in 2035 (Figure 5).

Population is a key determinant of energy consumption, influencing demand for travel, housing, consumer goods, and services. The U.S. population increases 28 percent from 2008 to 2035 in the *AEO2010* reference case, and energy consumption grows

[4]The accounting of RFS volumes is based on ethanol-equivalent gallons and not necessarily on actual physical volumes. Other RFS-qualifying fuels are assigned an "equivalence value multiplier," which largely reflects the differential between each fuel's energy content and the energy content of ethanol. The volumes of individual qualifying fuels are discussed on a physical volume basis and, therefore, do not sum to the total RFS volume cited.

14 percent over the same period. Energy consumption per capita declines 0.4 percent per year from 2008 to 2030 in the *AEO2010* reference case, similar to the decline in the updated *AEO2009* reference case.

With rising energy prices and growing concern about the environment, interest in energy conservation has increased. Although additional energy conservation is induced by higher energy prices in the *AEO2010* reference case, no further policy-induced conservation measures are assumed beyond those in existing legislation and regulation, nor does the reference case assume behavioral changes beyond those observed in the past.

Energy Production and Imports

Net imports of energy meet a major, but declining, share of total U.S. energy demand in the *AEO2010* reference case (Figure 6). The projected growth in energy imports is moderated by increased use of biofuels (much of which are produced domestically), demand reductions resulting from new efficiency standards, rapid improvement in the efficiency of appliances, and higher energy prices. Higher fuel prices also spur domestic energy production across all fuels, further tempering import growth. The net import share of total U.S. energy consumption in 2035 is 20 percent, compared with 26 percent in 2008. (The share was 29 percent in 2007, but it has dropped considerably during the current recession.)

Liquids

- U.S. dependence on imported liquids, measured as a share of total U.S. liquids use, is expected to continue declining over the projection period, from the high-water mark of 60 percent, attained in 2005 and 2006, to 45 percent in 2035.
- Cumulatively, lower 48 oil production in the *AEO2010* reference case is approximately the same as in the updated *AEO2009* reference case, but the pattern differs in that more oil is produced earlier in *AEO2010* and less is produced later. In the *AEO2010* reference case, crude oil production increases from 5 million barrels per day in 2008 to 6.3 million barrels per day in 2027 and remains at just over 6 million barrels per day through 2035 (Figure 7). Production increases are expected from the deep waters of the Gulf of Mexico and from onshore enhanced oil recovery (EOR) projects.
- Offshore oil production in *AEO2010* is lower than in *AEO2009* throughout most of the projection period, because prices for natural gas co-produced with crude oil in associated fields are lower and because of expected delays in near-term projects (based on a reevaluation of the history of development in current fields).

Although world oil prices in the *AEO2010* reference case are lower than in the updated *AEO2009* reference case, they remain high enough to have the same impact on the initiation of oil shale production as in the *AEO2009* reference case. In both projections, oil shale production is initiated in 2023 and grows rapidly thereafter, assuming current policies. The long-term potential for oil shale production is one of the more uncertain areas of the projection for domestic oil production because production costs are relatively high and improvements in extraction technologies are expected to be needed, and also because of uncertainty about potential changes in controlling legislation.

Figure 5. Output in industrial and service sectors, 1990-2035 (trillion 2000 dollars)

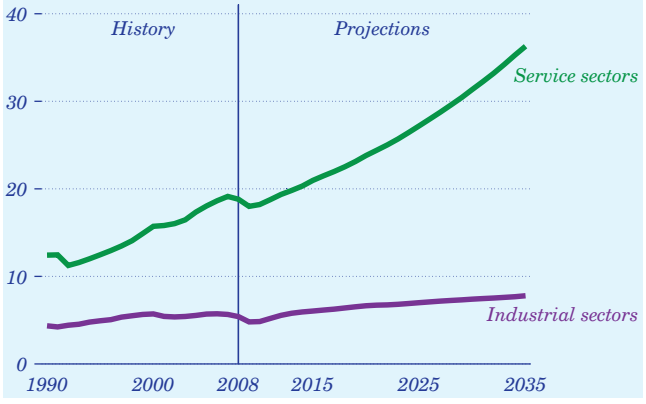
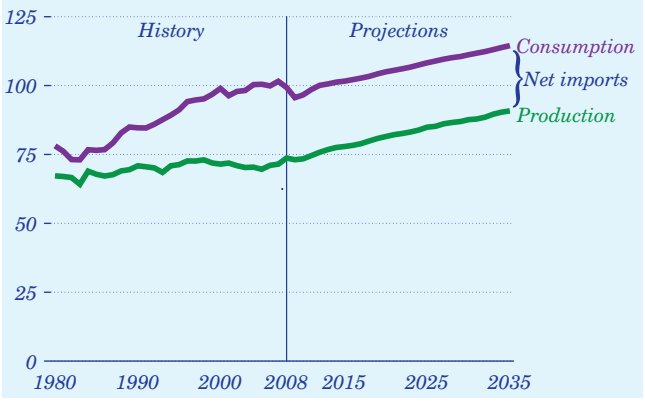


Figure 6. Total energy production and consumption, 1980-2035 (quadrillion Btu)

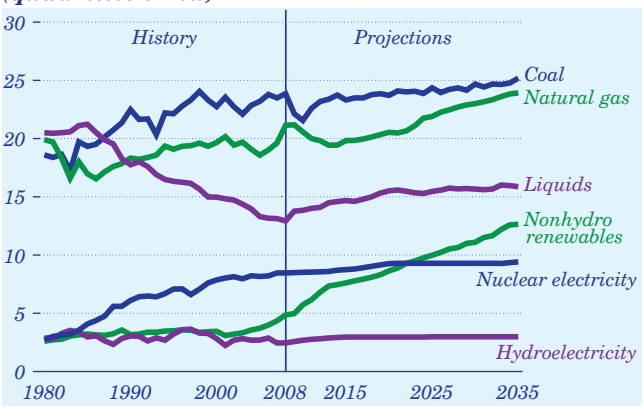


Natural Gas

- A larger resource base of shale gas results in higher shale gas production overall and a higher rate of development in the *AEO2010* reference case than in the updated *AEO2009* reference case. As a result, production from gas shale plays in 2030 is 50 percent higher in the *AEO2010* reference case, than in the updated *AEO2009* reference case.
- Increased production from gas shale plays takes production shares from other higher-cost sources—particularly, offshore production. Lower natural gas prices induced by growth in gas shales make offshore production less economical and slows its development.
- Net pipeline imports are considerably higher in the *AEO2010* reference case than projected in the updated *AEO2009* reference case. Although Canada's conventional natural gas production continues to decline, its unconventional production increases more rapidly than in *AEO2009*, reflecting the penetration of shale gas extraction technologies beyond U.S. borders.

Cumulative lower 48 natural gas production in the *AEO2010* reference case is slightly higher than in the updated *AEO2009* reference case as a result of greater supply availability, particularly from gas shale plays. In the updated *AEO2009* reference case, technically recoverable shale gas resources were estimated at 267 trillion feet; in the *AEO2010* reference case they are estimated at 347 trillion cubic feet. Given the rapid development in recent plays, including the Marcellus and Haynesville, it is assumed that newer shale gas plays can be brought into production faster than assumed in the updated *AEO2009* reference case. As a result, shale gas production grows at a much faster pace.

Figure 7. Energy production by fuel, 1980-2035 (quadrillion Btu)



An Alaska natural gas pipeline is expected to be completed in 2023 in the *AEO2010* reference case, 1 year later than in the updated *AEO2009* reference case. The later timing is a result of lower natural gas wellhead prices. Of course, there are many factors that could alter the timeline for the opening of the Alaskan natural gas pipeline, and this is a major uncertainty in the natural gas supply projection.

Total net pipeline imports of natural gas from Canada and Mexico decline from 2.7 trillion cubic feet in 2008 to 0.9 trillion cubic feet in 2030 in the *AEO2010* reference case, as compared with net exports of 0.4 trillion cubic feet in 2030 in the updated *AEO2009* reference case. Net pipeline imports continue to fall in the *AEO2010* reference case, reaching 0.6 trillion cubic feet in 2035. The much higher level of net pipeline imports in *AEO2010* results largely from projected increases in production of shale gas in Canada. The assumed Canadian shale gas resource base is approximately 100 trillion cubic feet higher in the *AEO2010* reference case than in the updated *AEO2009* reference case. The largest increase in production occurs toward the end of the *AEO2010* projection period.

Total U.S. net imports of LNG in the *AEO2010* reference case peak slightly later than in the updated *AEO2009* reference case, based on a revised worldwide outlook for liquefaction supply. Because of delays in liquefaction projects, LNG imports peak at 1.5 trillion cubic feet in 2021 in the *AEO2010* reference case, as compared with a peak of 1.4 trillion cubic feet in 2018 in the updated *AEO2009* reference case.

Coal

- Although coal remains the most important fuel for U.S. electricity generation, its share of total electricity generation is slightly lower in the *AEO2010* reference case than in the updated *AEO2009* reference case, and total coal-fired generation also is lower. As a consequence, total coal production is slightly lower in the *AEO2010* reference case than in the updated *AEO2009* reference case.

As U.S. coal use grows in the *AEO2010* reference case, domestic coal production increases at an average rate of 0.2 percent per year, from 23.9 quadrillion Btu (1,172 million short tons) in 2008 to 25.2 quadrillion Btu (1,285 million short tons) in 2035. Production from mines west of the Mississippi River trends upward over the entire projection period. Following substantial declines in output in 2009 and 2010, coal production east of the Mississippi River remains

relatively constant from 2010 through 2035. On a Btu basis, 60 percent of domestic coal production originates from States west of the Mississippi River in 2035, up from 50 percent in 2008.

Typically, trends in U.S. coal production are linked to its use for electricity generation, which currently accounts for 92 percent of total coal consumption. Coal consumption in the electric power sector in the *AEO2010* reference case (22.2 quadrillion Btu in 2030) is less than in the updated *AEO2009* reference case (23.4 quadrillion Btu in 2030). For the most part, the reduced outlook for coal consumption in the electricity sector is the result of increased generation from natural gas and renewable energy in the *AEO2010* reference case.

Another emerging market for coal is CTL plants. In the *AEO2010* reference case, coal use at CTL plants grows from 0.5 quadrillion Btu (32 million short tons) in 2020 to 1.0 quadrillion Btu (68 million short tons) in 2035.

Electricity Generation

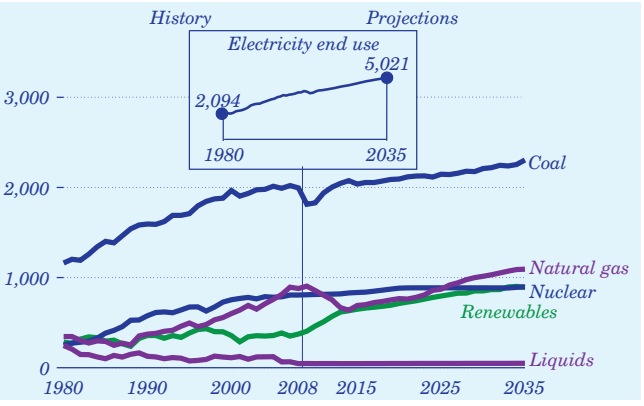
- Total electricity consumption, including both purchases from electric power producers and on-site generation, increases at an average annual rate of 1.0 percent from 2008 to 2035 in the *AEO2010* reference case.
- Although the mix of investments in new power plants includes fewer coal-fired plants than other fuel technologies, coal remains the dominant energy source for electricity generation (Figure 8) because of continued reliance on existing coal-fired plants and the addition of some new ones in the absence of an explicit Federal policy to reduce GHG emissions.
- Natural gas plays a larger role in the *AEO2010* reference case than in earlier *AEO*s because growing concerns about GHG emissions make it more attractive than coal and because new natural-gas-fired plants are much cheaper to build than new renewable or nuclear plants.
- Generation from renewable resources increases in response to the extension of key Federal tax credits and the loan guarantee program in ARRA, which greatly increase renewable generation relative to the projections in earlier outlooks. Additional growth is also supported by State requirements for renewable generation.

Total electricity consumption, including both purchases from electric power producers and on-site generation, grows from 3,873 billion kilowatthours in 2008 to 5,021 billion kilowatthours in 2035 in the *AEO2010* reference case, increasing at an average annual rate of 1.0 percent. The growth rate in the *AEO2010* projection is the same as in the updated *AEO2009* reference case.

A total of 24 gigawatts of coal-fired generating capacity are added from 2008 to 2030 in the *AEO2010* reference case, less than the 32 gigawatts added in the updated *AEO2009* reference case. Concerns about GHG emissions continue to slow the expansion of coal-fired capacity in the *AEO2010* reference case, even under current laws and policies. Lower projected fuel prices for new natural-gas-fired plants also affect the relative economics of coal-fired capacity. Total coal-fired generating capacity grows to 337 gigawatts in 2035 in the *AEO2010* reference case. Compared with the updated *AEO2009* reference case, electricity generation from natural gas in 2030 is 4 percent higher in the *AEO2010* reference case. Generation from natural gas continues to grow through 2035.

Nuclear generating capacity in the *AEO2010* reference case increases from 100.6 gigawatts in 2008 to 112.9 gigawatts in 2035. The increase includes 8.4 gigawatts of capacity at new plants and 4.0 gigawatts from uprates at existing plants. There are no projected nuclear plant retirements through 2035 in the *AEO2010* reference case because it is assumed that plant owners will apply for, and be granted, license extensions beyond the current 20-year extensions of operating licenses (that originally were granted for a 40-year period) as long as it is economical to continue the operation of existing plants. Clearly, the future of existing nuclear plants is a major uncertainty in the *AEO2010* projections, as the possibility of license extensions beyond 60 years is likely to be significantly

Figure 8. Electricity generation by fuel, 1980-2035 (billion kilowatthours)



affected by information developed over the next 2 decades.

Electricity generation from nuclear power plants grows from 806 billion kilowatthours in 2008 to 898 billion kilowatthours in 2035 in the *AEO2010* reference case, accounting for about 17 percent of total generation in 2035 compared with 20 percent in 2008. Higher construction costs for new nuclear plants, along with lower projected natural gas prices, make new nuclear capacity slightly less attractive than was projected in the updated *AEO2009* reference case.

Generation from renewable resources grows in response to the extension of key Federal tax credits and the loan guarantee program in ARRA, which greatly increases renewable generation relative to the projections in earlier outlooks. Additional growth is also supported by the many State requirements for renewable generation. The share of generation coming from renewable fuels grows from 9 percent in 2008 to 17 percent in 2035. In the *AEO2010* reference case, Federal subsidies for renewable generation are assumed to expire as enacted. Their extension could have a large impact on renewable generation.

Energy-Related Carbon Dioxide Emissions

- Total U.S. primary energy-related emissions of carbon dioxide (CO_2) increase 8.7 percent in the *AEO2010* reference case, from 5,814 million metric tons in 2008 to 6,320 million metric tons in 2035, or an average of 0.3 percent per year (Figure 9).
- Emissions per capita fall an average of 0.6 percent per year, as demand growth for electricity and transportation fuels is moderated by higher energy prices, efficiency standards, State RPS requirements, and Federal CAFE standards.

In the *AEO2010* reference case, total primary energy-related CO_2 emissions increase 6 percent from 2008 to 2030, matching the percentage growth projected in the updated *AEO2009* reference case. Following a decline from 2008 to 2009 as a result of the current economic recession, CO_2 emissions return to their 2008 level in 2019 and then gradually rise to 6,320 million metric tons in 2035.

Energy-related CO_2 emissions reflect the quantities of fossil fuels consumed and, because of their different carbon contents, the mix of coal, petroleum, natural gas, and other fuels consumed. Given the high carbon content of coal and its use currently to generate more than one-half of the U.S. electricity supply, prospects for CO_2 emissions depend in part on growth in electricity demand. Electricity sales growth in the *AEO2010* reference case slows as a result of a variety of regulatory and socioeconomic factors, including appliance and building efficiency standards, higher energy prices, housing patterns, and economic activity. With slower electricity demand growth and increased use of renewables for electricity generation influenced by RPS laws in many States, electricity-related CO_2 emissions grow only 0.4 percent per year from 2008 to 2035. Growth in CO_2 emissions from transportation activity also slows in comparison with recent experience, as Federal CAFE standards increase the efficiency of the vehicle fleet, and higher fuel prices moderate growth in travel.

Taken together, all these factors tend to slow the growth in primary energy consumption and CO_2 emissions. As a result, energy-related emissions of CO_2 grow 9 percent from 2008 to 2035—lower than the 14-percent increase in total energy use. Over the same period the economy becomes less carbon-intensive, as CO_2 emissions per dollar of GDP decline 40 percent.

Figure 9. U.S. primary energy-related carbon dioxide emissions by sector and fuel, 2008 and 2035 (million metric tons)

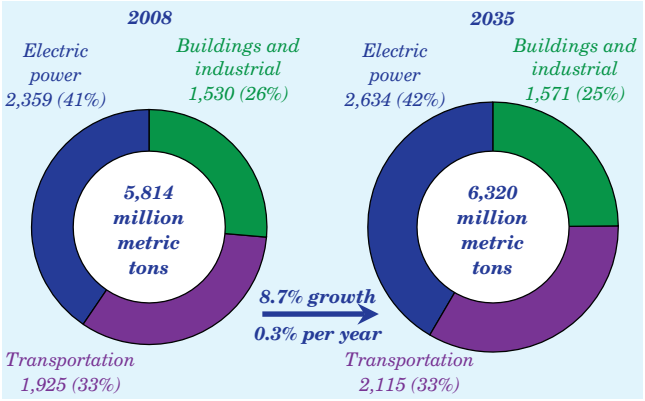


Table 1. Comparison of projections in the *AEO2010* and Updated *AEO2009* reference cases, 2008-2035

Energy and economic factors	2008	2020		2030		2035
		AEO2010	*AEO2009*	*AEO2010*	*AEO2009*	*AEO2010*
Primary energy production (quadrillion Btu)						
Petroleum	13.08	15.51	15.01	15.68	18.00	15.87
Dry natural gas	21.14	20.54	20.13	23.00	23.67	23.92
Coal	23.86	23.71	24.56	24.68	25.42	25.19
Nuclear power	8.46	9.26	9.14	9.29	9.29	9.41
Hydropower	2.46	2.96	2.95	2.98	2.96	2.99
Biomass	3.97	5.63	6.19	7.93	8.58	9.27
Other renewable energy	1.17	3.01	2.97	3.17	3.08	3.36
Other	0.10	0.89	0.93	0.92	1.01	0.81
Total	**74.23**	**81.51**	**81.88**	**87.63**	**92.02**	**90.83**
Net imports (quadrillion Btu)						
Petroleum	24.06	20.83	20.35	21.23	17.90	21.30
Natural gas	3.04	2.66	1.92	1.91	0.42	1.53
Coal/other (- indicates export)	-1.11	-0.37	0.11	0.08	0.47	0.53
Total	**25.99**	**23.11**	**22.37**	**23.22**	**18.78**	**23.36**
Consumption (quadrillion Btu)						
Liquid fuels	38.35	39.36	38.67	41.08	40.30	42.02
Natural gas	23.91	23.27	22.13	25.01	24.15	25.56
Coal	22.41	23.01	24.36	24.25	25.42	25.11
Nuclear power	8.46	9.26	9.14	9.29	9.29	9.41
Hydropower	2.46	2.96	2.95	2.98	2.96	2.99
Biomass	3.10	3.93	4.28	5.19	5.60	5.83
Other renewable energy	1.17	3.01	2.97	3.17	3.08	3.36
Net electricity imports	0.24	0.20	0.18	0.20	0.16	0.22
Total	**100.09**	**105.00**	**104.67**	**111.18**	**110.96**	**114.51**
Liquid fuels (million barrels per day)						
Domestic crude oil production	4.96	6.13	5.79	6.20	7.14	6.27
Other domestic production	3.38	4.58	4.58	5.26	5.35	5.73
Net imports	11.19	9.72	9.51	9.91	8.38	10.00
Consumption	19.53	20.56	20.05	21.48	20.92	22.06
Natural gas (trillion cubic feet)						
Production	20.62	20.04	19.65	22.44	23.09	23.34
Net imports	2.95	2.57	1.85	1.84	0.38	1.46
Consumption	23.25	22.63	21.53	24.33	23.50	24.86
Coal (million short tons)						
Production	1,172	1,183	1,223	1,260	1,272	1,285
Net imports	-49	-15	7	2	22	20
Consumption	1,122	1,183	1,240	1,276	1,305	1,319
Prices (2008 dollars)						
Imported low-sulfur, light crude oil (dollars per barrel)	99.57	108.28	119.36	123.50	133.80	133.22
Imported crude oil (dollars per barrel)	92.61	98.14	117.02	111.49	127.09	121.37
Domestic natural gas at wellhead (dollars per thousand cubic feet)	8.07	6.03	6.94	7.31	8.19	8.06
Domestic coal at minemouth (dollars per short ton)	31.26	30.01	27.99	27.43	28.48	28.10
Average electricity price (cents per kilowatthour)	9.8	9.0	9.5	9.7	10.3	10.2
Economic indicators						
Real gross domestic product (billion 2000 dollars)	11,652	15,416	15,398	19,883	19,875	22,362
GDP chain-type price index (2000=1.000)	1.225	1.497	1.521	1.849	1.896	2.059
Real disposable personal income (billion 2000 dollars)	8,753	11,967	11,903	16,069	16,014	18,168
Value of manufacturing shipments (billion 2000 dollars)	4,014	5,006	5,019	5,680	5,631	6,010
Primary energy intensity (thousand Btu per 2000 dollar of GDP)	**8.59**	**6.81**	**6.80**	**5.59**	**5.58**	**5.12**
Energy-related carbon dioxide emissions (million metric tons)	**5,814**	**5,852**	**5,905**	**6,176**	**6,207**	**6,320**

Notes: Quantities reported in quadrillion Btu are derived from historical volumes and assumed thermal conversion factors. Other production includes liquid hydrogen, methanol, and some inputs to refineries. Net imports of petroleum include crude oil, petroleum products, unfinished oils, alcohols, ethers, and blending components. Other net imports include coal coke and electricity. Coal consumption includes waste coal consumed in the electric power and industrial sectors, which is not included in coal production.

Sources: AEO2010 National Energy Modeling System, run AEO2010R.D111809A; and AEO2009 National Energy Modeling System, run STIMULUS.D041409A.