

The outlook for U.S. energy markets to 2030

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Abstract

This paper summarizes the reference case outlook for U.S. energy markets to 2030³, released by the Energy Information Administration in March 2008. The Energy Independence and Security Act of 2007 (*EISA2007*), enacted in December 2007, is a critical part of the latest outlook and its impacts on projected energy consumption, energy prices, and carbon dioxide emissions are highlighted.

³ The reference case is updated annually, typically in the February to March time frame. The *AEO2008* reference case did not anticipate the economic downturn of 2008-2009 nor new legislation.

1. Introduction

The Energy Information Administration (EIA) published an “early release” version of the Annual Energy Outlook 2008 (*AEO2008*) reference case [1] in the beginning of December 2007. About 2 weeks later, the Energy Independence and Security Act of 2007 (*EISA2007*) [2] was enacted. The provisions in *EISA2007* are expected to have a major impact on U.S. energy markets, particularly liquid fuels consumption and carbon dioxide emissions. Given the year-long life of *AEO2008* and its use as a baseline for analyses of upcoming policy proposals, EIA decided to update the reference case to reflect the provisions of *EISA2007*. This paper summarizes the updated *AEO2008* reference case, released in March 2008, and describes the estimated impacts that *EISA2007* had on the latest U.S. energy outlook.

Although current U.S. energy-environmental laws, regulations, and policies are almost certain to change and new ones are likely to be enacted over the next 25 years, the specific changes, timing, and implementation of those changes are impossible to predict. Sensitivity cases are used to explore some of the key uncertainties. The *AEO2008* reference case typically assumes that current laws, regulations, and policies affecting the U.S. energy sector remain unchanged throughout the projection period. This approach provides a clear basis for analyzing the impact of potential new policies and legislation.

The *AEO2008* reference case projections are not statements of what will happen but of what might happen, given the assumptions and methodologies used.⁴ The projections can be viewed as business-as-usual trend estimates under current laws and regulations, given known or estimated historical trends regarding technologies and consumer preferences. Many of the events that shape energy markets are unpredictable, including severe weather, political changes, strikes, new laws and regulations, and technological breakthroughs. In addition, other important factors that influence world-wide energy markets cannot be foreseen with certainty: Future technological, demographic, and resource developments; changes in consumer preferences and decision-making;

⁴ Because energy markets are complex, models of energy markets are necessarily simplified representations of the energy market. Projections are highly dependent on the data, methodologies, model structures, and assumptions used in their development. Behavioural characteristics are indicative of current real-world tendencies that reflect preferences and other market conditions.

global energy prices; U.S. and worldwide economic growth; and future public policy decisions, both in the United States and in other countries. Many key uncertainties in the *AEO2008* projections are addressed through sensitivity case analysis. At best, all projections, including this one, should serve as an adjunct to, not a substitute for, a complete and focused analysis of public policy initiatives. The readers are encouraged to review the complete description of the cases described in *AEO2008*.

2. Important recent changes to the “early release” reference case of *AEO2008*

2.1. EISA2007

The key legislative change since *AEO2007* that impacts the U.S. energy market outlook to 2030 is *EISA2007*, which was enacted in December 2007. EIA modelled three key categories of provisions of *EISA2007*: new Corporate Average Fuel Economy (CAFE) standards, new RFS standards, and new efficiency standards. As is usual, EIA does not model legislation that requires Federal funding which has not been appropriated. The major modelled provisions of *EISA2007* that will influence the U.S. energy outlook are:

CAFE provisions. *EISA2007* requires that all new light duty vehicles sold in the United States achieve an average automotive efficiency of 35 miles per gallon by 2020. These requirements are phased in beginning in 2010 and represent an over 32 percent efficiency improvement over current standards (26.4 versus 35). To achieve the overall target, new cars must achieve an average of about 42 miles per gallon and new light trucks and sport utility vehicles must achieve an efficiency of about 31 miles per gallon by 2020.

RFS provisions. The first renewable fuel standard in the United States was included in the Energy Policy Act of 2005 (EPAct 2005) [3]. That energy bill required the production and use of 7.5 billion ethanol equivalent gallons of renewable fuels by 2012. Renewable fuel production would then increase proportionately with the increase in gasoline usage thereafter. More than 9 billion gallons of corn-based ethanol production capacity has already been completed or under is construction and scheduled for completion by 2010. *EISA2007* built on this requirement by mandating 36 billion ethanol

equivalent gallons of renewable motor transport fuels by 2022 [4].⁵ While the targets are described in terms of gallons, the specific targets are defined in terms of renewable fuel credits of ethanol equivalent. Since biodiesel contains approximately 1.5 times the energy content of one gallon of ethanol, biodiesel is assigned 1.5 renewable credits for each gallon of renewable diesel produced. Of that amount, 21 billion gallons must⁶ be from advanced biofuels, essentially from any biofuel other than cornstarch (that is, cellulosic ethanol, “biomass-to-liquids” (BTL), other biodiesel, and ethanol from sugar cane) that achieves fifty percent less than baseline lifecycle GHG emissions of gasoline or diesel sold as transportation fuel. Further, 16 billion gallons of the advanced biofuels must be cellulose-based (ethanol or diesel) and 1 billion gallons must be biomass-based diesel (e.g., soybean or coconut palm oil).

The law provides for the annual reduction of the target for cellulosic-based biofuels if the needed capacity to meet the target has not been built. After 2015, if the target cannot be met by at least 50 percent in any one year or by at least 20 percent in any 2 consecutive years, the target path may be permanently reduced. There is no restriction on meeting these targets with imports. The greatest challenge placed by *EISA2007* on the U.S. market is meeting the liquid production target from cellulosic materials, particularly between 2010 and 2020.

End-use efficiency standards. Both EPAct and EISA address energy efficiency as a means of reducing GHG emissions. The bills contain a variety of provisions aimed at increasing energy efficiency. EPAct [5] includes energy conservation standards for a number of industrial items and commercial equipment, including air conditioning and heating equipment, refrigerators, freezers, ice makers and clothes washers. *EISA2007* expands on these measures by creating energy efficiency requirements for products including household electrical appliances, electric motors, lamps and light bulbs, and homes and buildings [6]. Only those provisions that specify both efficiency levels and effective dates in the standards are included in *AEO2008*.

⁵ Corn-based ethanol credits are limited to a maximum of 15 billion gallons.

⁶ The goals of the legislation for each type of fuel in the renewable fuel standard are mandated subject to several production feasibility tests. While the distributors and blenders must take the volumes if produced, nothing in the law requires producers to manufacture the targets specified by EISA. Even if all of the different sources of production capacity specified in the law are constructed, the actual volumes sold are likely to be less than 36 billion gallons because each gallon of biodiesel is 1.5 credits and at least 1 billion gallons of biodiesel (1.5 billion renewable fuel credits) must be produced.

The end-use provisions with the greatest energy reduction impacts are associated with lighting. For example, electricity consumption by incandescent lamps must be reduced by 28 percent in 2012 and be reduced by 65 percent in 2020. Other standards impose standards on the efficiency of fluorescent lamps, incandescent reflector lamps, and ballast efficiency for metal halide lamp fixtures beginning in 2009.

2.2. Other non-EISA Updates to the early release of *AEO2008*

In addition to including the major *EISA2007* provisions noted above relative to the December 2007 release version, the final release of the *AEO2008* reference case in March 2008 changed in other critical ways.

Macroeconomic updates. The projected gross domestic product (GDP) growth rate between 2006 and 2030 was reduced from 2.6 percent year in the December 2007 release to 2.4 percent year for the March 2008 release. The economic growth rate in *AEO2007* [7] was 2.8 percent per year.

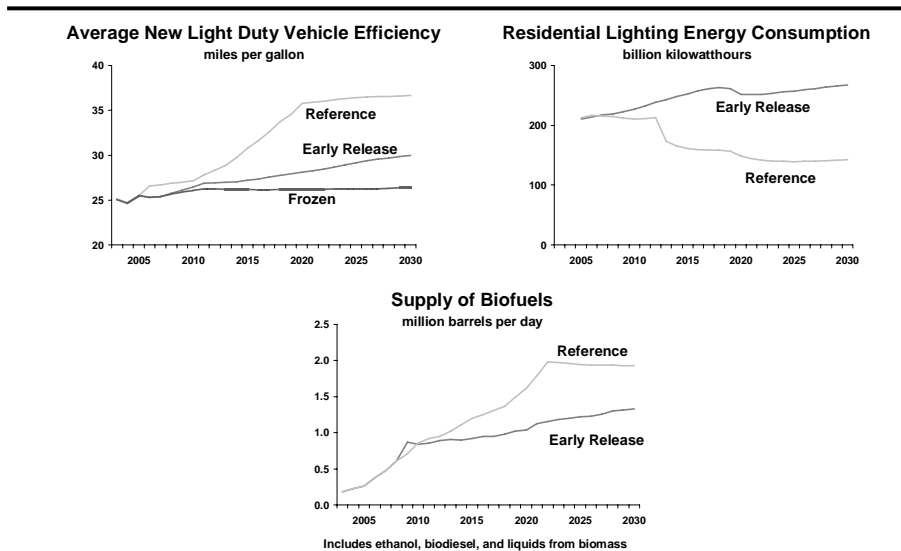
Historical revisions for most industrial categories.

Other miscellaneous changes. Changes included: updates to the latest Short Term Energy Outlook, revisions to weather data, and revision light duty vehicle sales from National Highway Transportation Safety Administration.

2.3. Impacts of the changes made between the December 2007 and March 2008 versions of the *AEO2008* reference case

Two sets of NEMS simulations were made to determine the impact of each of the above “groups” (that is, *EISA2007* changes and the “other changes”) on the energy market. One set was based on adding each group of change to the early release reference case (December 2007) and the other set was based on subtracting (removing) each group from the *AEO2008* reference case. Figure 1 summarizes the impacts of *EISA2007* on average light duty vehicle efficiency, residential electricity consumption for lighting, and the supply of biofuels.

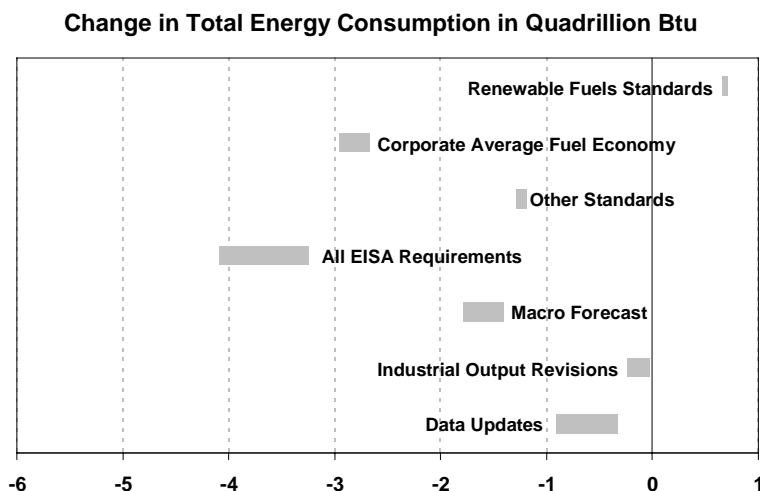
Figure 1. Energy Independence and Security Act of 2007



Annual Energy Outlook 2008

Some of these changes have a larger effect when modelled together than when modelled independently, while others had the opposite impact. In this case, most of the changes had an offsetting effect. For example, when the macroeconomic growth projections are lower, as they are in the *AEO2008* reference case, the impact of adding the new CAFE standard on petroleum motor fuel consumption is smaller than the case that adds the new CAFE standards to the original higher macroeconomic growth assumption because slower macroeconomic growth results in fewer car sales, fewer cars on the road, and fewer vehicle miles travelled and a lower initial consumption path. Figure 2 summarizes the range of impacts of *EISA2007* and other changes made between the December 2007 early release and the final *AEO2008* reference case.

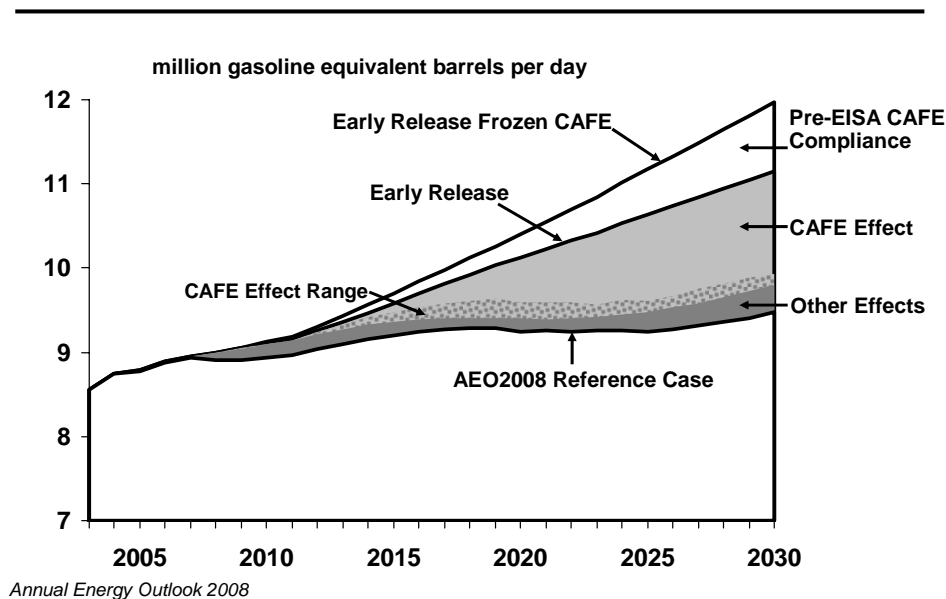
Figure 2. Range of Effects of the Energy Bill on Total Energy Consumption, 2030



Annual Energy Outlook 2008

Total primary energy consumption in 2030. *EISA2007* reduces primary energy consumption between 3.2 and 4.1 quadrillion Btu. This is between 56 percent and 71 percent of the reduction in total primary energy consumption of 5.8 quadrillion Btu that occurs between the early release reference case (December 2007 version) and the *AEO2008* reference case. By this measure, the largest reductions are attributable to the revised CAFE standards and the energy efficiency standards (EES). The RFS provisions increase primary energy consumption somewhat because the biofuels are mostly processed in the US, whereas, they displace petroleum products, some of which are imported. Figure 3 illustrates light duty vehicle (LDV) consumption and its response to the various changes between the two reference cases. The top line is a frozen efficiency scenario. It assumes that LDV efficiency does not exceed the previous CAFE standards of 26.4 miles per gallon. The revised CAFE standard reduces light duty vehicle consumption by about 1.2 to 1.4 million gasoline-equivalent barrels per day, between 12 and 13 percent. If measured against a frozen-efficiency standard, the EISA CAFE standard reduces light duty vehicle gasoline-equivalent barrels per day by between 2.1 and 2.2 million barrels per day, about 18 percent.

Figure 3. Light Duty Vehicle Consumption



The macro, industrial, and data changes comprise the remainder of the differences between the early release reference case and the *AEO2008* reference case. The largest of these changes is attributable to the macroeconomic assumption changes that were made. The industrial output revisions, results in a decrease in liquefied petroleum gasses used in feedstocks and an increase in electricity consumption in both the electric power and cogeneration sectors.

Cumulative carbon dioxide emissions, 2008-2030. The reduction in carbon dioxide emissions closely follows the reductions in primary energy consumption. Cumulative carbon dioxide emissions are 5.4 billion metric tons lower (cumulative 3.5 percent, 2008—2030) in the *AEO2008* reference case than in the early release reference case. An even a larger part of the overall reductions in carbon dioxide emissions can be attributed to *EISA2007* than in the reduction in primary energy consumption because the RFS, which did not reduce primary energy consumption, replaced petroleum with biofuels. Between 75 percent and 92 percent of all the in carbon dioxide emission reductions can be attributed to *EISA2007*.

Net petroleum - imports, 2030. Between 70 percent and 74 percent of the reduction in net petroleum imports in 2030 can be attributed to *EISA2007*. The reductions are associated with the higher CAFE standards and the renewable fuels standards. The higher CAFE standard reduces petroleum imports on almost a one-for-one basis; that is, for every barrel of fuel saved there is nearly a one barrel reduction in petroleum imports. There is a similar decrease due to the renewable fuels standard, but there is some increase in biofuel imports and some additional energy consumed domestically in the production of biofuels.

Light Duty Vehicle gasoline-equivalent fuel consumption, 2030. Similar to the reduction in net petroleum imports, most of the reduction in light duty vehicle fuel consumption is attributable to the higher CAFE standard and the renewable fuels standard. For both net petroleum imports and light duty vehicle fuel consumption there are some minor reductions caused by reduced macroeconomic activity and data updates in the *AEO2008* reference case compared to the early release reference case.

Total electricity use, 2030. Most of the reduction in electricity use - between 74 percent and 84 percent - can be attributed to the energy efficiency standards of *EISA2007* with much of the remainder due to the change in economic growth.

3. Economic growth

The *AEO2008* reference case reflects reduced expectations for U.S. economic growth. Gross domestic product (GDP) is projected to grow at an average annual rate of 2.4 percent from 2006 to 2030—0.4 percentage points slower than the rate projected in the *AEO2007* reference case over the same period. The main factor contributing to the slower rate of GDP growth is a lower estimate of growth in labour productivity. For example, non-farm business labour productivity was projected to grow by 1.9 percent per year in the *AEO2008* reference case, compared with 2.3 percent per year in *AEO2007*. Total industrial shipments are projected to grow by 1.3 percent per year in the *AEO2008* reference case, as compared with 2.0 percent per year in *AEO2007*.

4. Energy prices

Table 1 summarizes aggregate energy production, consumption and prices in the *AEO2008* reference case.

4.1. Crude oil supply and prices

World crude oil prices⁷ for the alternative oil price scenarios are based on a separate analysis of global oil markets and the factors that influence them. Consequently, the crude oil prices are largely an exogenous input to the *AEO2008* reference case projection. In developing its oil price outlook, EIA explicitly considered four factors: (1) growth in world liquids consumption; (2) the outlook for conventional oil production in countries outside the Organization of the Petroleum Exporting Countries (OPEC); (3) growth in unconventional liquids production; and (4) OPEC behaviour. With the forces driving demand outside the United States as strong as, or stronger than, previously expected but with global supply projections somewhat weaker, oil prices in *AEO2008* are higher than projected in *AEO2007*. One of the most critical and uncertain factors in the crude oil price projection appears to be the willingness and ability of OPEC to expand productive capacity to maintain a 40 percent market share of crude oil production. All else being equal, OPEC decisions to retain a smaller market share than 40 percent would send crude oil prices higher while a higher market share would send prices lower. The geopolitical factors make the OPEC uncertainty the dominant factor.

The *AEO2008* reference case projects a gradual decline from current levels to \$57 per barrel (2006 dollars) in 2016 (\$68 per barrel in nominal dollars), as expected expansion of investment in exploration and development brings new supplies to world markets. After 2016, real prices are expected to rise, as demand continues to grow and higher cost supplies are brought to market. In 2030, the average real price of crude oil is projected to be \$70 per barrel in 2006 dollars, or about \$113 per barrel in nominal dollars. Alternative *AEO2008* cases address higher and lower world crude oil prices.

⁷ For the purposes of *AEO2008*, the world oil price is meant to approximate the world oil price for imported low sulphur light crude oil and is defined as the price of light, low-sulphur crude oil delivered in Cushing, Oklahoma, in 2006 dollars per 42-gallon barrel.

Table 1. Total Energy Supply and Disposition Summary							
(quadrillion Btu, unless otherwise noted)							
	2006	2010	2015	2020	2025	2030	Annual Growth Rate 2006-2030
<u>Production (Quadrillion Btu)</u>							
Crude Oil and Lease Condensate	10.80	12.76	13.25	13.40	12.99	12.04	0.5%
Natural Gas Plant Liquids	2.36	2.27	2.29	2.31	2.17	2.11	-0.5%
Dry Natural Gas	19.04	19.85	20.08	20.24	20.17	20.00	0.2%
Coal	23.79	23.97	24.48	25.20	26.85	28.63	0.8%
Nuclear Power	8.21	8.31	8.41	9.05	9.50	9.57	0.6%
Hydropower	2.89	2.92	2.99	3.00	3.00	3.00	0.2%
Biomass	2.94	4.05	5.12	6.42	8.00	8.12	4.3%
Other Renewable Energy	0.88	1.51	1.75	2.00	2.25	2.45	4.4%
Other	0.50	0.54	0.58	0.58	0.61	0.64	1.1%
<i>Total</i>	<i>71.41</i>	<i>76.17</i>	<i>78.96</i>	<i>82.21</i>	<i>85.53</i>	<i>86.56</i>	<i>0.8%</i>
<u>Net Imports (Quadrillion Btu)</u>							
Liquids	26.70	23.93	24.23	24.03	24.49	26.52	0.0%
Natural Gas	4.29	4.80	5.12	4.68	4.63	4.64	0.3%
<u>Consumption (Quadrillion Btu)</u>							
Liquid Fuels and Other Petroleum	40.06	40.46	41.80	42.24	42.78	43.99	0.4%
Natural Gas	22.30	23.93	24.35	24.01	23.66	23.39	0.2%
Coal	22.50	23.03	24.19	25.87	27.75	29.90	1.2%
Nuclear Power	8.21	8.31	8.41	9.05	9.50	9.57	0.6%
Hydropower	2.89	2.92	2.99	3.00	3.00	3.00	0.2%
Biomass	2.50	3.01	3.60	4.50	5.42	5.51	3.3%
Other Renewable Energy	0.88	1.51	1.75	2.00	2.25	2.45	4.4%
Other	0.19	0.18	0.17	0.17	0.18	0.20	0.3%
<i>Total</i>	<i>99.52</i>	<i>103.34</i>	<i>107.26</i>	<i>110.85</i>	<i>114.54</i>	<i>118.01</i>	<i>0.7%</i>

							Annual Growth Rate 2006- 2030
	2006	2010	2015	2020	2025	2030	
Prices (2006 dollars per unit)							
Petroleum (dollars per barrel)							
Low Sulphur Light Price	66.02	74.03	59.85	59.70	64.49	70.45	0.3%
Natural Gas (dollars per million Btu)							
Price at Henry Hub	6.73	6.90	5.87	5.95	6.39	7.22	0.3%
Wellhead Price	6.24	6.16	5.21	5.29	5.69	6.45	0.1%
Coal (dollars per million Btu)							
Mine-mouth Price	1.21	1.28	1.17	1.14	1.16	1.19	-0.1%
Average Delivered Price	1.78	1.93	1.80	1.77	1.78	1.82	0.1%
Average Electricity (cents per kwhr)							
	8.9	9.2	8.5	8.6	8.7	8.8	0.0%

In the *AEO2008* reference case projection, OPEC countries are assumed to increase production at a rate that keeps their market share of world liquids production at approximately 40 percent through 2030. Recent pronouncements by OPEC that they no longer intend to expand productive capacity in the next 2-5 years, as previously announced, suggests that the *AEO2008* reference case projection of crude oil prices are too low, at least for the next 5 to 10 years.

Further, recent strong economic growth worldwide, transitory shortages of experienced personnel, equipment, and construction materials in the oil industry, and political instability in some major producing regions, also provide pressure to keep crude oil prices in the next 5 years or more above EIA's estimate of the long-run equilibrium price.

The *AEO2008* reference case also projects significant long-term potential for supply from non-OPEC producers. In several resource-rich regions—including Canada, Brazil, Azerbaijan, and Kazakhstan—high oil prices, expanded infrastructure, new exploration and drilling technologies permit additional non-OPEC oil production. Also, with the increasingly economic viability of Canada's oil sands enhanced by higher world oil prices and advances in production technology, oil sands production is expected to reach 4 million barrels per day in 2030.

4.2. Natural gas supply and prices

The price of natural gas also is higher in the *AEO2008* reference case than in *AEO2007* reference case. The real wellhead price of natural gas (in 2006 dollars) is projected to decline from current levels through 2016, as new supplies enter the market. After some price fluctuations through 2021, real natural gas prices are projected to rise to \$6.63 per thousand cubic feet in 2030 (\$10.64 per thousand cubic feet in nominal dollars). The higher prices in the *AEO2008* reference case reflect an increase in production costs associated with recent trends that were discussed in *AEO2007*, but were not reflected fully in the *AEO2007* reference case.⁸ The higher natural gas prices also are supported by higher oil prices.

4.3. Coal supply and prices

The United States has large coal resources. Mine-mouth coal prices in the *AEO2008* reference case, both nationally and regionally, are generally similar to those projected in the *AEO2007* reference case. By region, the largest price difference is for Wyoming's Powder River Basin, where the projected average mine-mouth price in 2030 is 12.1 percent above the *AEO2007* projection, at \$0.66 (2006 dollars) per million British thermal units (Btu), reflecting a less optimistic outlook for improvements in coal mining productivity.

Average real mine-mouth coal prices (in 2006 dollars) are projected to fall from \$1.21 per million Btu (\$24.63 per short ton) in 2006 to \$1.14 per million Btu (\$22.45 per short ton) in 2018 in the *AEO2008* reference case, as prices moderate following a substantial run-up over the past few years. After 2020, coal prices rise as demand increases, reaching \$1.19 per million Btu (\$23.32 per short ton) in 2030. The 2020 and 2030 price projections are 2.6 percent and 0.9 percent higher, respectively, than those in the *AEO2007* reference case. Without adjustment for inflation, the average mine-mouth price of coal in the *AEO2008* reference case is \$1.91 per million Btu (\$37.42 per ton) in 2030.

⁸ Annual Energy Outlook 2007, DOE/EIA-0383(2007) (Washington, DC, February 2007), "Impact of Rising Construction and Equipment Costs on Energy Industries," pp. 36-41.

4.4. Delivered fuel prices to consumers

AEO2008 projects higher prices for most energy fuels delivered to consumers compared to the *AEO2007* reference case. In 2030, the average delivered price of natural gas (in 2006 dollars) is more than \$1 per million Btu higher in the *AEO2008* reference case than was projected in *AEO2007*. In part, the higher delivered prices result from higher prices paid to fossil fuel producers at the wellhead or mine-mouth; but they also result from updates made to assumptions about the costs to transport, distribute, and refine the fuels to make them more consistent with recent trends. For example, as a result of declining use per customer and the growing cost of bringing supplies from new regions to market, margins between the delivered and wellhead prices of natural gas are higher than previously projected. Factors contributing to higher margins for liquid fuels include continued growth in the use of heavier and more sourer crude oil, growing demand for cleaner products, and the rising cost of refinery safety and emissions abatement.

Increases in diesel fuel prices in recent years have led railroads to implement fuel adjustment surcharges on coal shipments, which are incorporated in the *AEO2008* reference case. The average real delivered price of coal to power plants (in 2006 dollars) is projected to increase from \$1.69 per million Btu (\$33.85 per short ton) in 2006 to \$1.78 per million Btu (\$35.03 per short ton) in 2030, 2.3 percent higher than in the *AEO2007* reference case. In nominal dollars, the average delivered price of coal to power plants is projected to reach \$2.86 per million Btu (\$56.22 per short ton) in 2030. Electricity prices follow trends in the delivered prices of fuels to power plants in the reference case. From a peak of 9.3 cents per kwhr (2006 dollars) in 2009, average delivered electricity prices decline to 8.5 cents per kwhr in 2015 and then increase to 8.8 cents per kwhr in 2030. In the *AEO2007* reference case, with slightly lower expectations for delivered fuel prices and construction costs for all new technologies, electricity prices reached 8.3 cents per kwhr (2006 dollars) in 2030. In nominal dollars, the average delivered electricity price in the *AEO2008* reference case reaches 14.1 cents per kwhr in 2030.

5. Energy consumption

Total consumption of liquid fuels, including both fossil liquids and biofuels, grows from 20.7 million barrels per day in 2006 to 22.8 million barrels per day in 2030 in the *AEO2008* reference case, less than the *AEO2007* reference case projection of 26.9 million barrels per day in 2030. Liquid fuels consumption is lower in all sectors in *AEO2008* than in the *AEO2007* reference case, as a result of incorporation of the new LDV CAFE standard specified in *EISA2007*, slower economic growth, and higher delivered prices for liquid fuels. Much of the difference is in the transportation sector. Table 2 summarizes energy consumption by sector.

5.1. Natural gas consumption

In *AEO2008*, natural gas consumption increases from 21.7 trillion cubic feet in 2006 to 23.8 trillion cubic feet in 2016, then declines to 22.7 trillion cubic in 2030. The projection for natural gas consumption in the *AEO2008* reference case is sharply lower than in *AEO2007*, where consumption grew to 26.1 trillion cubic feet in 2030. Consumption is lower in all sectors in *AEO2008*, and particularly in the industrial and electricity power sectors. Industrial natural gas use is 1.7 trillion cubic feet lower in 2030 in the *AEO2008* reference case (8.1 trillion cubic feet, compared with 9.8 trillion cubic feet in *AEO2007*), as a result of higher delivered prices for natural gas, lower economic growth, and a reassessment of natural gas use in the energy-intensive industries. In *AEO2008*, electricity generation accounts for 5.0 trillion cubic feet of natural gas use in 2030, compared with the *AEO2007* projection of 5.9 trillion cubic feet. The lower level of consumption in *AEO2008* results from higher natural gas prices and slower growth in electricity demand.

5.2. Coal consumption

Total coal consumption increases from 22.5 quadrillion Btu (1,114 million short tons) in 2006 to 29.9 quadrillion Btu (1,545 million short tons) in 2030 in the *AEO2008* reference case. As in the *AEO2007* reference case, coal consumption is projected to grow at a faster rate toward the end of the projection period, particularly after 2020, as coal use for new coal-fired generating capacity grows rapidly. In the *AEO2008* reference case, coal consumption in the electric power sector increases from 23.7 quadrillion

Btu in 2020 to 27.5 quadrillion Btu in 2030, and coal use at coal-to-liquids (CTL) plants is projected to increase from 0.6 quadrillion Btu in 2020 to 1.0 quadrillion Btu in 2030. The projected increase of coal use for CTL plants is lower than in previous AEOs as a result of *EISA2007* because investment dollars that previously would have gone into CTL capacity expansion are now partially diverted to biomass-to-liquids (BTL) capacity to meet the RFS requirements.

5.3. Renewable fuel consumption

The *AEO2008* reference case projects substantially greater use of renewable energy than was projected in *AEO2007*. Total consumption of marketed renewable fuels—including ethanol for gasoline blending, biodiesel⁹, and diesel from biomass¹⁰ grows by 3.0 percent per year in the reference case, from 6.8 quadrillion Btu in 2006 to 13.7 quadrillion Btu in 2030. About 45 percent of the demand for renewables in 2030 is for grid-related electricity generation, including combined heat and power.

Table 2. Energy Consumption by Sector and Source

(quadrillion Btu, unless otherwise noted)						
	2006	2010	2015	2020	2025	2030
Residential/Commercial						
Liquid Fuels	1.93	1.95	2.00	2.01	1.99	1.97
Natural Gas	7.42	7.99	8.46	8.77	8.98	9.11
Renewable Energy	0.54	0.57	0.55	0.53	0.52	0.51
Electricity	9.05	9.67	10.22	10.92	11.68	12.50
Delivered Energy	19.02	20.28	21.31	22.33	23.26	24.18
Industrial						
Liquid Fuels	9.92	9.67	9.60	9.27	9.15	9.25
Natural Gas Subtotal	7.85	8.37	8.43	8.39	8.44	8.35

⁹ Biodiesel is defined as the monoalkyl esters of fatty acids derived from plant or animal matter and suitable for use in a diesel engine.

¹⁰ Biomass-to-liquids (BTL) is defined as diesel fuel and other liquid hydrocarbons produced by a Fischer-Tropsch process using cellulosic biomass as feedstock.

Coal	1.92	1.93	1.92	2.11	2.14	2.26
Biofuels Heat and Co-products	0.30	0.67	1.00	1.49	2.28	2.31
Renewable Energy	1.69	1.66	1.75	1.83	1.93	2.02
Electricity	3.42	3.50	3.61	3.59	3.55	3.52
<i>Delivered Energy</i>	<i>25.10</i>	<i>25.82</i>	<i>26.31</i>	<i>26.70</i>	<i>27.50</i>	<i>27.70</i>
<u>Transportation</u>						
E85	0.00	0.00	0.18	0.97	1.42	1.34
Motor Gasoline	17.20	17.25	17.46	16.56	15.83	15.97
Jet Fuel	3.16	3.44	3.82	4.15	4.48	4.79
Distillate Fuel Oil	6.18	6.54	7.13	7.63	8.25	8.98
LPG & Resid & Other Petroleum	1.03	1.04	1.04	1.05	1.06	1.06
Natural Gas Fuel and Compressors	0.61	0.68	0.71	0.76	0.80	0.80
<i>Delivered Energy</i>	<i>28.20</i>	<i>28.98</i>	<i>30.37</i>	<i>31.15</i>	<i>31.86</i>	<i>32.98</i>
<u>Electric Power</u>						
Petroleum	0.64	0.56	0.57	0.59	0.61	0.63
Natural Gas	6.42	6.89	6.75	6.09	5.45	5.13
Steam Coal	20.48	21.01	22.18	23.67	25.51	27.55
Nuclear Power	8.21	8.31	8.41	9.05	9.50	9.57
Renewable Energy	3.74	4.53	5.05	5.64	5.94	6.13
Electricity Imports	0.06	0.05	0.04	0.04	0.05	0.08
<i>Total</i>	<i>39.68</i>	<i>41.46</i>	<i>43.12</i>	<i>45.21</i>	<i>47.19</i>	<i>49.21</i>
<u>Energy Use & Related Statistics</u>						
Total Delivered Energy Use	72.32	75.08	77.99	80.18	82.61	84.86
Ethanol Consumed in Transportation	0.47	1.05	1.34	1.82	2.06	2.01
Population (millions)	300.13	310.85	324.29	337.74	351.41	365.59
GDP (billion 2000 dollars)	11,319	12,453	14,199	15,984	17,951	20,219
CO ₂ (million metric tons)	5,890.3	6,010.6	6,226.2	6,384.1	6,570.6	6,851.0

The rapid growth in the use of renewable fuels for transportation in *AEO2008* reflects the *EISA2007* RFS, which sets a requirement for 21 billion gallons of advanced biofuels and 36 billion gallons of ethanol equivalent consumption by 2022. Included are requirements for 1 billion gallons of biodiesel and 16 billion gallons of cellulosic biofuels, both of

which count toward the advanced biofuels requirement. The remaining 4 billion gallons of advanced biofuels may come from any source other than corn starch. The difference between advanced biofuels and total renewable fuels may be met by corn ethanol. Diesel fuels derived from biomass feedstocks count for 1.5 times their physical volume in the calculation of credits toward the RFS requirements because diesel has a higher energy content per gallon than ethanol does.

Although the situation is very uncertain, the current state of the industry and EIA's present view of projected rates of technology development and market penetration of cellulosic biofuel technologies suggest that available quantities of cellulosic biofuels before 2022 will be insufficient to meet the new RFS targets for cellulosic biofuels, triggering both waivers and a modification of applicable volumes, as provided for in Section 211(o) of the Clean Air Act as amended by *EISA2007*. The modification of volumes reduces the overall target in 2022 from 36 billion gallons to 32.5 billion gallons in the *AEO2008* reference case. Ethanol use in the *AEO2008* reference case grows from 5.6 billion gallons in 2006 to 23.9 billion gallons in 2030—about 16 percent of total gasoline consumption by volume and about 65 percent more than was projected in *AEO2007*. Ethanol use for gasoline blending is projected to grow to 13.4 billion gallons and E85 consumption to 10.5 billion gallons in 2030. The ethanol supply is expected to be produced from both corn and cellulose feedstocks, with corn accounting for about 15.0 billion gallons and cellulose 6.9 billion gallons of ethanol production in 2030. Biodiesel use increases to 1.2 billion gallons in 2030, or about 1.5 percent of total diesel consumption by volume. In addition, consumption of BTL diesel grows to 4.5 billion gallons in 2030, or 5.3 percent of total diesel consumption by volume.

Excluding hydroelectricity, renewable energy consumption for electric power generation grows from 0.9 quadrillion Btu in 2006 to 3.2 quadrillion Btu in 2030, as compared with 2.1 quadrillion Btu in *AEO2007*. The higher level of non-hydroelectric renewable energy consumption in the *AEO2008* reference case reflects primarily a revised representation of State RPS programs, which require that specific and generally increasing shares of electricity sales be supplied by renewable resources, such as wind, solar, geothermal, and sometimes biomass or hydropower. Previous Annual Energy Outlooks placed more weight on the “escape clauses” incorporated in many State RPS programs when estimated consumer costs of the programs could be anticipated to increase significantly if the Federal

production tax credit (PTC) for qualifying renewable energy expired as provided for under current law. The new representation assumes that the State RPS goals will be met absent a clear contrary indication and results in significant additional growth of renewable generation from wind, biomass, and geothermal resources.

6. Energy intensity

Energy intensity, measured as primary energy use (in thousand Btu) per dollar of GDP (in 2000 dollars), is projected to decline by about one-third from 2006 to 2030 in the *AEO2008* reference case. Although energy use generally increases as the economy grows, continuing improvement in the energy efficiency of the U.S. economy and a shift to less energy-intensive activities are projected to keep the rate of energy consumption growth lower than the rate of GDP growth.

Since 1992, the energy intensity of the U.S. economy has declined on average by 2.0 percent per year, in part because the share of industrial shipments accounted for by the energy-intensive industries has fallen from 30 percent in 1992 to 21 percent in 2006. In the *AEO2008* reference case, the energy-intensive industries' share of total industrial shipments is projected to continue to decline, although at a slower rate, to 18 percent in 2030.

Population is a key determinant of energy consumption, influencing demand for travel, housing, consumer goods, and services. Since 1990, the population has increased by about 20 percent and energy consumption by a comparable 18 percent in the United States, with annual variations in energy use per capita resulting from variations in weather and economic factors. The age, income, and geographic distribution of the population also affect the growth of energy consumption. The aging of the population, a gradual shift from the U.S. North to the U.S. South, and rising per-capita income are expected to significantly influence future energy consumption trends. Overall, the U.S. population increases by 22 percent from 2006 to 2030 in the *AEO2008* reference case. Over the same period, energy consumption increases by 19 percent. The result is a decrease in energy consumption per capita at an annual rate of 0.1 percent per year from 2006 to 2030, a drop from the 0.3-percent yearly increase in the *AEO2007* reference case.

Recently, as energy prices have risen, the potential for more energy conservation has received increased attention. Although additional energy conservation is induced by higher energy prices in the *AEO2008* reference case and by the passage of *EISA2007*, no further policy-induced conservation measures are assumed beyond those in existing legislation and regulation, nor does the reference case assume behavioural changes beyond those observed in the past.

7. Energy production and imports

Net imports of energy are expected to continue meeting a major share of total U.S. energy demand. The increased use of biofuels resulting from *EISA2007*, much of which is domestically produced, and the reduction in demand for transportation fuels due to the new CAFE standards both serve to moderate growth in energy imports. Higher fuel prices over the projection period also spur increased domestic energy production and moderate energy demand growth, further tempering growth in imports. The projected net import share of total U.S. energy consumption in 2030 is 27 percent, a decline from the 30-percent share in 2006.

7.1. Liquids supply

The projection for U.S. crude oil production in the *AEO2008* reference case is higher than in the *AEO2007* reference case, primarily as a result of more production from the expansion of enhanced oil recovery (EOR) operations and, to a lesser extent, higher crude oil prices. U.S. crude oil production in the *AEO2008* reference case increases from 5.1 million barrels per day in 2006 to a peak of 6.3 million barrels per day in 2018, with production increases from the deep waters of the Gulf of Mexico and from onshore EOR projects. Domestic production subsequently declines to 5.6 million barrels per day in 2030, as increased production from new, smaller discoveries is inadequate to offset declines in production from large fields in Alaska and the Gulf of Mexico.

Total domestic liquids supply, including crude oil, natural gas plant liquids, refinery processing gains, and other refinery inputs (including ethanol, biodiesel, BTL, and liquids from coal) are generally projected to increase through 2022 in the *AEO2008* reference case, while imports of crude oil

and other petroleum products remain flat. Total domestic liquids supply grows from 8.2 million barrels per day in 2006 to 10.4 million barrels per day in 2030.

In the *AEO2008* reference case, the net import share of total liquids supplied, including crude oil and refined products, drops from 60 percent in 2006 to 51 percent in 2022 and then increases to 54 percent in 2030. Net imports of crude oil and net imports of petroleum products in 2030 are both about 2.0 million barrels per day lower in the *AEO2008* reference case than in the *AEO2007* reference case. The primary reasons for the difference between the *AEO2008* and *AEO2007* projections for net imports of liquid fuels are a lower level of total liquids consumption and a higher level of biofuels consumption in the transportation sector in the *AEO2008* reference case.

7.2. Natural gas supply

Total domestic production of natural gas (including supplemental natural gas) supplies increase from a projected level of 18.6 trillion cubic feet in 2006 to 20.0 trillion cubic feet in 2022 before declining to 19.5 trillion cubic feet in 2030 in the *AEO2008* reference case. The *AEO2008* reference case projections of natural gas production are lower than in the *AEO2007* reference case, which showed production increasing to 20.6 trillion cubic feet in 2030 because of higher costs associated with exploration and development and lower demand for natural gas in *AEO2008*. Onshore production of unconventional natural gas is expected to be a key contributor to the growth in U.S. supply, increasing from 8.5 trillion cubic feet in 2006 to a peak of 9.6 trillion cubic feet in 2018 and generally holding at about that level through 2030.

The Alaska natural gas pipeline is expected to be completed in 2020 (2 years later than in the *AEO2007* reference case, because of delays in the resolution of issues between Alaska's State government and industry participants). After the pipeline goes into operation, Alaska's total natural gas production in the *AEO2008* reference case is projected to increase to 2.0 trillion cubic feet in 2021 (from 0.4 trillion cubic feet in 2006) and then remain at that level through 2030.

Net pipeline imports of natural gas from Canada and Mexico fall from 2.9 trillion cubic feet in 2006 to 0.3 trillion cubic feet in 2030 in the *AEO2008*

reference case (compared with the *AEO2007* projection of 0.9 trillion cubic feet in 2030). The difference between the 2030 projections in *AEO2008* and *AEO2007* is largely the result of a higher level of exports to Mexico and lower demand in the United States.

Total net imports of liquefied natural gas (LNG) to the United States in the *AEO2008* reference case increase from 0.5 trillion cubic feet in 2006 to 2.8 trillion cubic feet in 2030, as compared with 4.5 trillion cubic feet in 2030 in *AEO2007*. The lower projection is attributable to two factors: higher costs throughout the LNG industry, especially in the area of liquefaction, and decreased U.S. natural gas consumption due to higher natural gas prices, slower economic growth, and expected greater competition for supplies in the global LNG market.

The future direction of the global LNG market is one of the key uncertainties in the *AEO2008* reference case. With many new international players entering LNG markets, the competition for available supplies is strong and the amounts available to the U.S. market may vary considerably from year to year as long as U.S. LNG imports are primarily based on spot market cargoes.

7.3. Coal supply

As domestic coal demand grows in the *AEO2008* reference case, U.S. coal production (excluding waste coal) increases at an average rate of 0.8 percent per year, from 23.8 quadrillion Btu (1,163 million short tons) in 2006 to 28.6 quadrillion Btu (1,455 million short tons) in 2030. Production from mines west of the Mississippi River provides the largest share of the incremental coal production. On a Btu basis, 59 percent of domestic coal production originates from States west of the Mississippi River in 2030, up from 49 percent in 2006.

Typically, trends in U.S. coal production are linked to its use for electricity generation, which currently accounts for 91 percent of total coal consumption. Coal consumption in the electric power sector in the *AEO2008* reference case, at 27.5 quadrillion Btu in 2030, is less than in the *AEO2007* reference case (31.1 quadrillion Btu in 2030). Slower growth in overall electricity demand, combined with more generation from nuclear and renewable energy, underlies the reduced outlook for electricity sector coal consumption. Another emerging market for coal is CTL. Coal use in

CTL plants grows from 0.6 quadrillion Btu (42 million short tons) in 2020 to 1.0 quadrillion Btu (64 million short tons) in 2030.

7.4. Electricity generation

Total electricity consumption, including both purchases from electric power producers and on-site generation, is projected to grow from 3,814 billion kwhr in 2006 to 4,972 billion kwhr in 2030, increasing at an average annual rate of 1.1 percent in the *AEO2008* reference case. In comparison, electricity consumption grew by annual rates of 4.2 percent, 2.6 percent, and 2.3 percent in the 1970s, 1980s, and 1990s, respectively. The growth rate of electricity generation in the *AEO2008* projection is lower than in the *AEO2007* reference case (1.5 percent per year). The reduced rate of growth in *AEO2008* results from slower economic growth, the imposition of new efficiency standards in *EISA2007*, and higher electricity prices.

In the *AEO2008* reference case, electricity generation from natural-gas-fired power plants increases sharply from 2006 to 2008 and then remains relatively stable for the next decade, growing by 3 percent from 2008 to 2016—less rapidly than in the *AEO2007* reference case. After 2016, however, generation from new coal, nuclear, and renewable plants displaces some natural-gas-fired generation. In the *AEO2008* reference case, 741 billion kwhr of electricity is generated from natural gas in 2030, 21 percent less than the 937 billion kwhr in 2030 in the *AEO2007* reference case.

In the *AEO2008* reference case, the natural gas share of electricity generation (including generation in the end-use sectors) remains between 20 percent and 21 percent through 2017 before falling to 14 percent in 2030. The coal share remains between 48 percent and 49 percent from 2006 through 2018 before increasing to 54 percent in 2030. Net additions to coal-fired generating capacity in the *AEO2008* reference case totals 100 GW from 2006 to 2030 (as compared with 151 GW in the *AEO2007* reference case), including 4 GW at CTL plants and 29 GW at integrated gasification combined-cycle plants. Given the assumed continuation of current energy and environmental policies in the reference case, the carbon capture and sequestration (CCS) technology does not come into use during the projection period.

Nuclear generating capacity in the *AEO2008* reference case increases from 100.2 GW in 2006 to 114.9 GW in 2030. The increase includes 17 GW of

capacity at newly built nuclear power plants (33 percent more than in the *AEO2007* reference case) and 2.7 GW expected from uprates of existing plants, partially offset by 4.5 GW of retirements.

Rules issued by the Internal Revenue Service in 2006 for the Energy Policy Act of 2005 (*EPACT2005*) production tax credit for new nuclear plants allow the credits to be shared out on a prorated basis to more than 6 GW of new capacity. In the *AEO2008* reference case the credits are shared out to 8 GW of new nuclear capacity and another 9 GW of capacity are built without credits.

Total electricity generation from nuclear power plants grows from 787 billion kwhr in 2006 to 917 billion kwhr in 2030 in the *AEO2008* reference case, accounting for about 18 percent of total generation in 2030. Additional nuclear capacity is built in some of the alternative *AEO2008* cases, particularly those that project higher demand for electricity or higher fossil fuel prices.

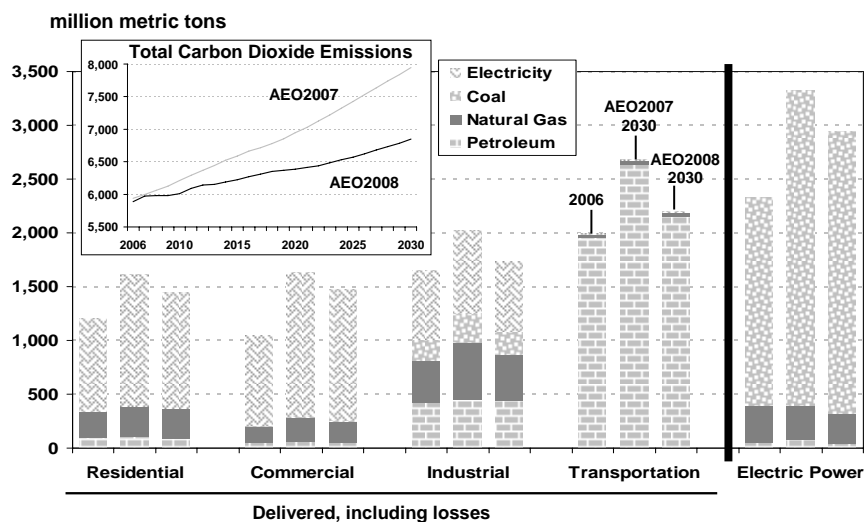
The use of renewable technologies for electricity generation is stimulated by improved technology, higher fossil fuel prices, and short-term extensions of the *EPACT2005* tax credits. The reference case also includes State RPS programs for which legislation is in place. Total renewable generation in the *AEO2008* reference case, including combined heat and power (CHP) and end-use generation, grows by 2.3 percent per year, from 385 billion kwhr in 2006 to 658 billion kwhr in 2030. The projection for renewable generation in the *AEO2008* reference case, which includes State and regional programs, is significantly higher than the *AEO2007* projection.

8. Energy-related emissions

Absent the application of CCS technology (which is not economic without changes in current policies that are not included in the reference case), CO₂ emissions from the combustion of fossil fuels are proportional to fuel consumption and carbon content, with coal having the highest carbon content, natural gas the lowest, and liquid fuels in between. In the *AEO2008* reference case, the coal share of total energy use increases from 23 percent in 2006 to 25 percent in 2030, while the share of natural gas falls from 22 percent to 20 percent, and the liquids share falls from 40 percent to 37 percent. The combined share of carbon-neutral renewable and nuclear energy grows from 15 percent in 2006 to 17 percent in 2030.

Taken together, projected growth in the absolute level of primary energy consumption and a shift toward a fuel mix with slightly lower average carbon content cause projected energy-related emissions of CO₂ to grow by 16 percent from 2006 to 2030—slightly lower than the projected 19-percent increase in total energy use. Over the same period, the economy becomes less carbon-intensive, because the 16-percent increase in CO₂ emissions is about one-fifth of the projected increase in GDP (79 percent), and emissions per capita decline by 5 percent. In the *AEO2008* reference case, projected energy-related CO₂ emissions grow from 5,890 million metric tons in 2006 to 6,851 million metric tons in 2030. By comparison, in the *AEO2007* reference case, energy-related CO₂ emissions were projected to grow by about 35 percent, to 7,950 million metric tons in 2030, reflecting both a higher projection of overall energy use and, to a lesser extent, a different mix of energy sources. Figure 4 displays the carbon emissions by sector rather than by fuel. As previously noted, the greatest carbon dioxide reductions occur in the transportation sector, due mostly to the improved efficiency imposed by the new CAFE standard, reduced economic activity which reduced demand for VMT, and the RFS which substituted renewable fuels for petroleum products.

Figure 4. Carbon Dioxide Emissions



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9. References

- [1] *Annual Energy Outlook 2008*, DOE/EIA-0383(2008), Washington, DC, June 2007, <http://www.eia.doe.gov/oiaf/aeo/index.html>
- [2] *Energy Independence and Security Act of 2007*, Pub. L. 110-140, 121 Stat. 1493 (2007) (codified at 42 U.S.C.17000, et seq.).
- [3] *Energy Policy Act of 2005*, Pub. L. 109-58, 119 Stat. 594 (2005) (codified at 42 U.S.C. 15801, et seq.)
- [4] *Energy Independence and Security Act of 2007* § 202(a)(2).
- [5] *Energy Policy Act of 2005* § 135-36.
- [6] *Energy Independence and Security Act of 2007* § 311, 313, 321, Title IV.
- [7] *Annual Energy Outlook 2007*, DOE/EIA-0383(2007), Washington, DC, February 2007.