AN OUTLOOK FOR ENERGY EFFICIENCY IN U.S. ENERGY MARKETS

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Overview

The paper presents the latest U.S. energy outlook for the period 1995 - 2015 by the U.S. Department of Energy, Energy Information Administration. The Outlook is characterized by continued technological improvements in all sectors under conditions of current federal policies and regulations. Weather-related and geopolitically created shocks in energy prices and investment patterns are not reflected since they are virtually impossible to predict.

Major Technology Assumptions of the Forecast

Building Sector Assumptions. The buildings sector includes both residential and commercial structures. Both the National Appliance Energy Conservation Act of 1987 (NAECA), the Energy Policy Act of 1992 (EPACT), and the Climate Change Action Plan (CCAP) contain provisions which impact future buildings sector energy use. The provisions with the most significant effect are minimum equipment efficiency standards. These standards require that new heating, cooling, and other specified energy-using equipment meet minimum energy efficiency levels which change over time. The manufacture of equipment that does not meet the standards is prohibited.

Residential Assumptions. The NAECA minimum standards [1] for the major types of equipment in the residential sector are:

- Heat pumps—a 10.0 minimum seasonal energy efficiency ratio for 1992
- Room air conditioners—an 8.6 energy efficiency ratio in 1990
- Gas/oil furnaces—a 0.78 annual fuel utilization efficiency in 1992
- Refrigerators—a standard of 976 kilowatthours per year in 1990, decreasing to 691 kilowatthours per year in 1993
- Electric water heaters—a 0.88 energy factor in 1990
- Natural gas water heaters—a 0.54 energy factor in 1990.

Improvements to existing building shells are based on both energy prices and assumed annual efficiency increases. New building shell efficiencies relative to existing construction vary by main heating fuel and assumed annual increases. The effects of shell improvements are modeled differentially for heating and cooling. For space heating, existing and new shells improve by 11 percent and 29 percent, respectively, by 2015 relative to the 1993 stock average. For space cooling, the corresponding increases are 10 percent and 24 percent for existing and new buildings. Building codes relevant to CCAP are represented by an increase in the shell integrity of new construction over time.

Other CCAP programs which could have a major impact on residential energy consumption are the Environmental Protection Agency's (EPA) Green Programs. These programs, which are cooperative efforts between the EPA and home builders and energy appliance manufacturers, encourage the development and production of highly energy-efficient housing and equipment. One of the best known examples of these programs is the "golden carrot refrigerator," a very efficient design that is projected to be widely available by 1998 and to consume less than two-thirds of the energy specified in the 1993 NAECA standard. At fully funded levels, residential CCAP programs are estimated by program sponsors to reduce carbon emissions by nearly 9 million metric tons by the year 2000. For the reference case, carbon reductions are estimated to be 4.3 million metric tons, primarily because of differences in the estimated penetration of energy-saving technologies.

Commercial Assumptions. Minimum equipment efficiency standards for the commercial sector are mandated in the EPACT legislation [2]. Minimum standards for representative equipment types are:

- Central air-conditioning heat pumps—a 9.7 seasonal energy efficiency rating (January 1994)
- Gas-fired forced-air furnaces—a 0.8 annual fuel utilization efficiency standard (January 1994)
- Fluorescent lamps—a 75.0 lumens per watt lighting efficacy standard for 4-foot F40T12 lamps (November 1995) and a 80.0 lumens per watt efficiency standard for 8-foot F96T12 lamps (May 1994).

Improvements to existing building shells are based on assumed annual efficiency increases. New building shell efficiencies relative to existing construction vary for each of the 11 building types. The effects of shell improvements are modeled differentially for heating and cooling. For space heating, existing and new shells improve by 5 percent and 8 percent, respectively, by 2015 relative to the 1992 averages.

The CCAP programs recognized in the *AEO97* reference case include the expansion of the EPA Green Lights and Energy Star Buildings programs and improvements to building shells from advanced insulation methods and technologies. The EPA green programs are designed to facilitate cost-effective retrofitting of equipment by providing participants with information and analysis as well as participation recognition. Retrofitting behavior is captured in the commercial module via discount parameters for controlling cost-based equipment retrofit decisions for various market segments. To model programs such as Green Lights, which target particular end uses, the *AEO97* version of the commercial module includes end-use specific segmentation of discount rates. At fully funded levels, commercial CCAP programs are estimated by program sponsors to reduce carbon emissions by nearly 6 million metric tons by the year 2000, primarily because of differences in the estimated penetration of energy-saving technologies.

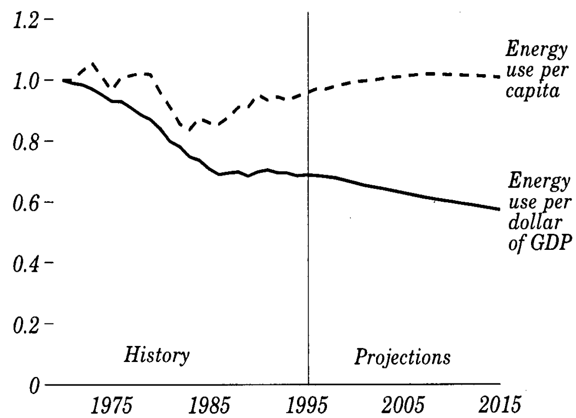

Figure 1. Energy use per capita and per dollar of gross domestic product, 1970-2015(index, 1970 = 1)

Industrial Sector Assumptions. Compared to the building sector, there are relatively few regulations which target industrial sector energy use. The electric motor standards in EPACT require a 10-percent increase in efficiency above 1992 efficiency levels for motors sold after 1997 [3]. These standards have been incorporated into the Industrial Demand Module through the analysis of process efficiencies for new industrial processes. These standards are expected to lead to significant improvements in efficiency since it has been estimated that electric motors account for about 60 percent of industrial process electricity use.

Climate Change Action Plan. Several programs included in the CCAP target the industrial sector. Note that the potential impacts of the Climate Wise Program are also included in the CCAP impacts. The intent of these programs is to reduce greenhouse gas emissions by lowering industrial energy consumption. The program offices estimated that full implementation of these programs would reduce industrial electricity consumption by 29 billion kilowatthours and non-electric consumption by 383 trillion Btu by 2000. However, since the energy savings associated with the voluntary programs in the CCAP are, to a large extent, already contained in the *AEO97* baseline, total CCAP energy savings were reduced. Consequently, CCAP reduces electricity consumption by 16 billion kilowatthours and non-electric energy consumption by 90 trillion Btu. The non-electric energy is assumed to be steam coal.

For 2010, the program offices estimated electricity savings of 81 billion kilowatthours and fossil fuel savings of 650 trillion Btu. For the reason cited above, these estimates were revised to 47 billion kilowatthours for electricity and 190 trillion Btu for fossil fuels. In this situation, carbon emissions would be reduced by about 10 million metric tons (2 percent) in 2010.

Transportation Sector Assumptions. The transportation sector accounts for the two-thirds of the Nation's oil use and has been subject to regulations for many years. The Corporate Average Fuel Economy (CAFE) standards, which mandate average miles-per-gallon standards for manufacturers, continue to be widely debated. The projections appearing in this report assume that there will be no further increase in the CAFE standards from the current 27.5 miles per gallon standard. This assumption is consistent with the overall policy that only current legislation is assumed. Furthermore, compliance with the CAFE standards is assumed in all years.

EPACT requires that centrally-fueled automobile fleet operators—Federal, State, and local governments, and fuel providers (e.g., gas and electric utilities)—purchase a minimum fraction of alternative-fuel vehicles [4]. Federal fleet purchases of alternative-fuel vehicles must reach 50 percent of their total vehicle purchases by 1998 and 75 percent by 1999. Purchases of alternative-fuel vehicles by State governments must realize 25 percent of total purchases by 1998 and 75 percent by 2000. Private fuel-provider companies are required to purchase 50 percent alternative-fuel vehicles in 1997, increasing to 90 percent by 1999. Fuel provider exemptions for electric utilities are assumed to follow the electric utility provisions beginning in 1998 at 30 percent and reaching 90 percent by 2001. It is assumed that the municipal and private business fleet mandates begin in 2002 at 20 percent and scale up to 70 percent by 2005.

In addition to these requirements, the State of California has delayed the Low Emission Vehicle Program, which now requires that 10 percent of all new vehicles sold by 2003 meet the “zero emissions requirements.” At present, only electric-dedicated vehicles meet these requirements. Originally, Massachusetts and New York adopted this program. The projections currently assume that only California and Massachusetts have formally delayed the Low Emission Vehicle Program.

The projections assume that these regulations represent minimum requirements for alternative-fuel vehicle sales; consumers are allowed to purchase more of these vehicles, should vehicle cost, fuel efficiency, range, and performance characteristics make them desirable. In fact, the projections indicate that more than the minimum will be purchased, as shown in Figure 48.

Projections for both vehicle-miles traveled [5] and ton-miles traveled [6] are calculated endogenously and are based on the assumption that modal shares, for example, personal automobile travel versus mass transit, remain stable over the forecast and track recent historical patterns. Other important factors affecting the forecast of vehicle-miles traveled are personal disposable income per capita; the ratio of miles driven by females to males in the total driving population, which increases from 56 percent in 1990 to 80 percent by 2015; and the aging of the largest segment of the age distribution of the population, which will slow the growth in vehicle-miles traveled.

Climate Change Action Plan. There are four CCAP programs that focus on transportation energy use: (7) reform Federal subsidy for employer-provided parking; (8) adopt a transportation system efficiency strategy; (9) promote telecommuting; and (10) develop fuel economy labels for tires. The combined assumed effect of the Federal subsidy, system efficiency, and telecommuting policies in the *AEO97* reference case is a 1.1-percent reduction in vehicle-miles traveled (194 trillion Btu). The fuel economy tire labeling program improved new fuel efficiency by 4 percent among vehicles that switched to low rolling resistance tires, and resulted in a reduction in fuel consumption of 40 trillion Btu.

Energy Efficiency and Demand-Side Management. Improvements in energy efficiency induced by growing energy prices, new appliance standards, and utility demand-side management programs are represented in the end-use demand models. Appliance choice decisions are a function of the relative costs and performance characteristics of a menu of technology options. Utilities have reported plans to spend more than $2.4 billion per year by 1999.

Representation of Utility Climate Challenge Participation Agreements. As a result of the Climate Challenge Program, many utilities have announced efforts to voluntarily reduce their greenhouse gas emissions between now and 2000. These efforts cover a wide variety of programs, including increasing demand-side management (DSM) investments, repowering (fuel-switching) fossil plants, restarting nuclear plants that have been out-of-service, planting trees, and purchasing emission offsets from international sources. To the degree possible, each one of the participation agreements was examined to determine if the commitments made were addressed in the normal reference case assumptions or whether they were addressable in NEMS. Programs like tree planting and emission offset purchasing are not addressable in NEMS. With regard to the other programs, they are, for the most part, captured in NEMS. For example, utilities annually report to EIA their plans (over the next 10 years) to bring a plant back on line, repower a plant, life extend a plant, cancel a previously planned plant, build a new plant, or switch fuel at a plant. These data are inputs to NEMS. Thus, programs that would affect these areas are reflected in NEMS input data. However, because many of the agreements do not identify the specific plants where action is planned, it is not possible to determine which of the specified actions, together with their greenhouse gas emissions savings, should be attributed to the Climate Challenge Program and which are the result of normal business operations.

Prices

The *Annual Energy Outlook 1997* (*AEO97*[1]) projects lower prices for all energy fuels than were projected in *AEO96* [2](Figure 1). Average world crude oil prices in *AEO97* are projected to be about $21 a barrel (in 1995 dollars) in 2015, $5 lower than the *AEO96* price of $26 a barrel. The lower prices reflect expectations that oil production from the Organization of Petroleum Exporting Countries (OPEC) will expand and that technology advances will sustain non-OPEC production. It is assumed that Iraqi oil production will not resume until 1998 and then will increase gradually to full capacity in 2000.

The *AEO97* average wellhead price of naturalgas in 2015 is $2.13 per thousand cubic feet, compared with $2.63 in *AEO96*, primarily as the result of a reevaluation of the impacts of technological progress on oil and natural gas discovery. In *AEO96*, technological programs was assumed to slow the decline in finding rates—reserves discovered per new well.

In *AEO97*, technological progress arrests and even reverses declining finding rates in some regions.

As a result, natural gas production is increased, with less drilling activity and at lower cost, particularly in offshore regions, where technological progress has a greater impact on the development of relatively immature fields. In addition, competition within the industry and projections of lower interest rates reduce the costs of transmission and distribution, offsetting the projected increase in wellhead prices, so that the average delivered price of natural gas declines between 1995 and 2015 at an average annual rate of 0.2 percent.

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[1] Energy Information Administration, *Annual Energy Outlook 1997*, DOE/EIA-0383(97) (Washington, DC, December 1996).

[2] Energy Information Administration, *Annual Energy Outlook 1996*, DOE/EIA-0383(96) (Washington, DC, January 1996).

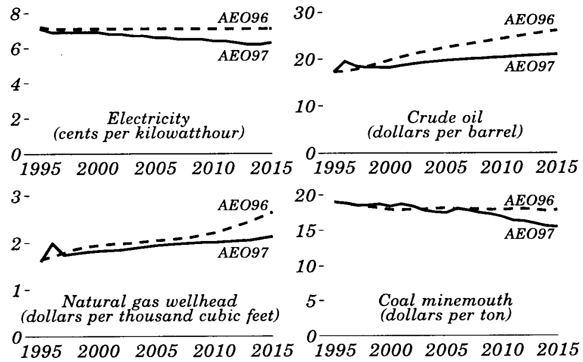

Figure 2. Fuel price projections, 1995-2015: AEO96 and AEO97 compared (1995 dollars)

Coal minemouth prices are projected to decline in the forecast as a result of increasing productivity, a shift to western production, and competitive pressures on labor costs. In *AEO97*, the average minemouth price of coal is projected to be $15.46 per ton in 2015, compared with $17.75 in *AEO96*. Lower coal transportation rates—leading to higher production from western mines, where production costs are lower than in the East—are the primary reason for the lower minemouth prices.

Average electricity prices also decline through 2015 and are lower than in *AEO96*. The average price in 2015 is projected to be 6.3 cents per kilowatthour, compared with 7.1 cents in *AEO96*, as a result of lower projected fossil fuel prices and anticipated industry restructuring. Increased competition in the electricity industry is assumed to lead to lower operating and maintenance costs, lower general and administrative costs, early retirement of inefficient units, and other cost reductions. *AEO97* reflects the evolving trend of competition within electricity markets but does not include the full impacts of restructuring and deregulation. Although the projections include the recent actions taken by the Federal Energy Regulatory Commission on open access, specific actions to be taken by State public utility commissions and their timing are not yet known and have not been incorporated.

Energy Efficiency

Energy intensity, measured as energy use per dollar of GDP, has generally declined since 1970, particularly during periods of rapid increases in energy prices (Figure 6). In the 1970s and early 1980s, energy intensity declined at an average rate of nearly 2 percent a year as the economy shifted to less energy-intensive industries and increasingly efficient technologies. In the late 1980s and into the projection period, moderate price increases and the growth of more energy-intensive industries lead to a slower projected decline - a yearly average of 0.9 percent - from 1995 to 2015.

Energy use per person, which also declined from 1970 through the mid-1980s, rose in the mid-1980s as energy prices dropped. Per capita energy use is expected to remain nearly stable through 2015 and below the high in the early 1970s, as efficiency gains offset higher demand for energy services.

AEO97 incorporates the efficiency standards for new energy-using equipment in buildings and for motors mandated through 1994 by the National Appliance Energy Conservation Act of 1987 and the Energy Policy Act of 1992. Additional improvements in the efficiency of energy-using technologies beyond the standards are likely. Several alternative cases in *AEO97* examine the impact of the penetration of more energy-efficient technologies in the end-use sectors beyond that projected in the reference case.

Carbon Emissions

Carbon emissions from energy use are projected to increase by 1.2 percent a year through 2015, reaching 1,799 million metric tons (Figure 7), compared with the *AEO96* projection of 1,735 million metric tons. The higher emissions projections are the result of higher total energy consumption and lower penetration of renewable energy sources.

Higher projected economic growth in *AEO97* and lower use of renewables contribute to higher carbon emissions in the industrial sector. Emissions are also higher in the transportation sector, as stronger economic growth and lower fuel prices boost personal and freight travel and fuel consumption. Emissions in the residential and commercial sectors are only slightly higher.

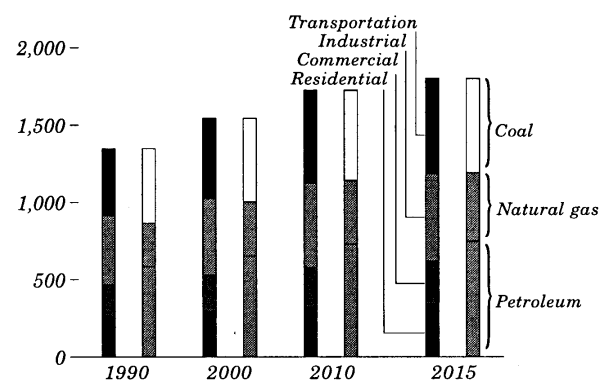

Figure 3. U.S. carbon emissions by sector and fuel, 1990-2015 (million metric tons)

Over the forecast horizon, 40 percent of the increase in emissions results from the transportation sector, where increases in travel are projected for all modes. The industrial sector accounts for 28 percent of the increase. The sectoral values in Figure 7 include emissions from the generation of electricity used in each sector. Although part of the growth in emissions from electricity generation results from the replacement of nuclear power by fossil-fired generation, the increased use of natural gas relative to coal moderates the growth in emissions.

The Climate Change Action Plan (CCAP) was developed to stabilize greenhouse gas emissions in 2000 at 1990 levels. In 1990, carbon emissions from energy use were estimated to be about 1,340 million metric tons. *AEO97* analyzes the impacts of CCAP provisions, including Climate Challenge and Climate Wise, which foster voluntary reductions in emissions by electric utilities and industry. The first report on voluntary programs, *Voluntary Reporting of Greenhouse Gases 1995*, was released in July 1996 [*1*]. That report documents the Climate Wise and Climate Challenge commitments.

Emissions grew more rapidly than expected in the early 1990s, partly due to lower than expected growth in energy prices, which is projected to continue through 2015. That trend, combined with funding reductions for some CCAP programs, leads to higher projected emissions than were estimated at the time CCAP was formulated. The impacts of additional efforts that may be undertaken to curtail emissions are not analyzed in these projections. Further discussion of carbon emissions, as well as other emissions, begins on page 72 of *AEO97*.

Energy Intensity and Technological Progress

In a recent currently unpublished analysis performed at EIA, a series of sensitivity analysis related to the availability of technologies and their impact on energy intensity were investigated. Two sets of market and technology assumptions were defined for each energy sector to illustrate uncertainty in these markets. *This analysis did not attempt to evaluate the energy programs of the Federal Government or their programmatic goals. There is no relationship between the assumptions in the cases analyzed and the funding levels of the U.S. research and development programs.*

In the sensitivity study, the series of *AEO97* slow technology assumptions were combined to form an integrated slow technological progress case. The more optimistic group of sensitivity assumptions were also combined to form an integrated rapid technological progress case. The slow technological progress case examined fuel and technology choices when the availability or adoption of new technologies was assumed to occur at a slower rate than the *AEO97* Reference Case in all energy markets. The technological menu was limited to those technologies that are expected to be commercially available in 1997. The rapid technological progress case examined fuel and technology choices when the availability or adoption of new technologies was assumed to occur at a faster rate than the *AEO97* Reference Case. Although advanced cost and performance characteristics of technologies were represented in this study, the study did not attempt to analyze the potentially best technologies achievable through research, and it did not incorporate all possible new technologies or the greatest possible improvements in new technologies.

The goals of this analysis were: (a) to analyze the potential role of technological progress on energy supply, consumption, and prices in U.S. energy markets; and (b) to assess how "success" on one side of the supply or demand equation may reduce the potential benefits on the other side.

In addition to testing the sensitivity to the technological menu available, sensitivity cases were also run for the residential and commercial markets that varied the "hurdle rates" -- the willingness to purchase higher efficiency equipment with higher capital cost. The sensitivity cases tested the relative impact of changes in the menus of technologies relative to changes in the willingness of consumers to purchase greater efficiency at higher cost. "Hurdle rates" in the residential and commercial markets can be thought of as the sum of two components: a cost-of-money component and a non-financial component that reflects all other factors that influence consumer choices. Two cases were run relative to the Reference Case residential and commercial sector hurdle rates. The first case assumed that the non-financial components of hurdle rates were reduced to 50 percent of their Reference Case values. The second group of cases assumed that the non-financial portion was reduced to 0 percent. The financial portion of the hurdle rate was assumed to be 15 percent for residential and consumer customers in all cases.

In sectors where technologies were explicitly represented (residential, commercial, transportation and utilities), costs for advanced technologies (the rapid cases) were generally reduced by approximately similar percentages (35 percent) over a fifteen year period. For coal, oil and gas supply, technology, wage and productivity parameters for the low and high technology cases were changed by about one standard deviations from the expected values of the Reference Case.

Observations and Conclusions

Two of the major insights of this study include:

- Under the assumptions of this study, it appears that programs that increase the willingness of consumers to purchase highly efficient *existing* equipment can be more effective in reducing energy intensity than making available the menu of advanced technologies identified in this study, all else being equal.
- Under the variety of advanced technology assumptions of this study, including the assumption that non-financial hurdle rates of the residential and commercial energy markets are reduced to zero, and assuming current laws, policies programs, and equipment retirement patterns, the annual rate of decline of the ratio of primary energy to GDP appears to be bounded by about -1.25 percent when all non-financial impediments are removed and the financial hurdle rate is

assumed to be 15 percent in the residential and commercial markets.

A more complete discussion, graphics and data are published in [10].

References

[1] Lawrence Berkeley Laboratory, *U.S. Residential Appliance Energy Efficiency: Present Status and Future Direction*.

[2] National Energy Policy Act of 1992, P.L. 102-486, Title I, Subtitle C, Sections 122 and 124.

[3] National Energy Policy Act of 1992, P.L. 102-486, Title II, Subtitle C, Section 342.

[4] National Energy Policy Act of 1992, P.L. 102-486, Title III, Section 303, and Title V, Sections 501 and 507.

[5] Vehicle-miles traveled are the miles traveled yearly by light-duty vehicles.

[6] Ton-miles traveled are the miles traveled and their corresponding tonnage for freight modes, such as trucks, rail, air, and shipping.

[7] Energy Information Administration, *Annual Energy Outlook 1997*, DOE/EIA-0383(97) (Washington, DC, December 1996).

[8] Energy Information Administration, *Annual Energy Outlook 1996*, DOE/EIA-0383(96) (Washington, DC, January 1996).

[9] Energy Information Administration, Voluntary Reporting of Greenhouse Gases, 1995, DOE/EIA-0608(95), (Washington, D.C., July 1996).

[10] Energy Information Administration, *Issues in Midterm Analysis and Forecasting 1997*, "Sensitivity of Energy Intensity in U.S. Energy Markets to Technological Change", (Washington, D.C., *expected July 1997*).

Table 1. Summary of results for five cases

Sensitivity Factors	1995	2015				
		Reference	Low Economic Growth	High Economic Growth	Low World Oil Price	High World Oil Price
Consumption (quadrillion Btu)						
Petroleum Products	34.92	43.26	40.33	46.11	45.66	41.65
Natural Gas	22.18	30.97	29.12	32.81	30.04	31.84
Coal	19.95	23.76	22.41	26.41	23.51	23.92
Nuclear Power	7.19	4.79	4.79	4.79	4.79	4.79
Renewable Energy	6.30	7.71	7.23	8.18	7.56	7.78
Other	0.39	0.37	0.36	0.38	0.37	0.37
Total Consumption	**90.93**	**110.87**	**104.23**	**118.67**	**111.93**	**110.35**
Prices (1995 dollars)						
World Oil Price						
(dollars per barrel)	17.26	20.98	19.78	22.21	13.99	28.23
Domestic Natural Gas at Wellhead						
(dollars per thousand cubic feet)	1.61	2.13	1.83	2.49	2.12	2.16
Domestic Coal at Minemouth						
(dollars per short ton)	18.83	15.46	15.32	15.90	14.82	16.24
Average Electricity Price						
(cents per kilowatthour)	7.1	6.3	6.0	6.5	6.2	6.3
Economic Indicators						
Real Gross Domestic Product						
(billion 1992 dollars)	6,739	9,880	8,982	10,766	9,919	9,836
(annual change, 1995-2015)	--	1.9%	1.4%	2.4%	2.0%	1.9%
Real Disposable Personal Income						
(billion 1987 dollars)	4,047	6,109	5,614	6,585	6,137	6,075
(annual change, 1995-2015)	--	2.1%	1.7%	2.5%	2.1%	2.1%
Index of Manufacturing Gross Output						
(index, 1987=1.00)	1.246	1.904	1.709	2.102	1.913	1.893
(annual change, 1995-2015)	--	2.1%	1.6%	2.7%	2.2%	2.1%
Energy Intensity						
(thousand Btu per 1992 dollar of GDP)	13.50	11.23	11.62	11.03	11.30	11.23
(annual change, 1995-2015)	--	-0.9%	-0.7%	-1.0%	-0.9%	-0.9%
Carbon Emissions (million metric tons)	1,424	1,799	1,689	1,941	1,821	1,790

Notes: Assumptions underlying the alternative cases are defined in the Economic Activity and International Oil Markets sections, beginning on page 32. Quantities are derived from historical volumes and assumed thermal conversion factors. Other production includes liquid hydrogen, methanol, supplemental natural gas, 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. Some refinery inputs appear as petroleum product consumption. Other consumption includes net electricity imports, liquid hydrogen, and methanol.

Source: Tables A1, A8, A19, A20, B1, B8, B19, B20, C1, C8, C19, and C20.