Chapter 1
ENERGY DEMAND

Abstract

Demand for energy is growing steadily, and is likely to reach increasingly higher levels as populations and economies expand. During the last quarter-century, world energy demand increased by over half, and a similar increase is projected between now and 2030. However, future growth builds from today's much larger base, meaning that tomorrow's energy requirements are unprecedented in scale. This will pressure the global supply system and require increased emphasis on energy-use efficiency in transportation, residential, commercial, and industrial sectors.

This chapter examines how credible, integrated modeling efforts portray the future world energy situation, and identifies the implications of those projections. Subgroups examined a wide range of demand data from public and aggregated proprietary sources, making no attempt to produce a new, consensus projection. Expert teams assessed technologies that hold potential for critical efficiency gains; coal demand and supply trends; and how cultural, social, and economic conditions and other non-technical forces shape energy demand.

The outline of the Energy Demand chapter is as follows:

- Demand Study Observations
- Demand Summary
- Demand Data Evaluation
- Electric Generation Efficiency
- Coal Impact
- Industrial Efficiency
- Cultural/Social/Economic Trends
- Residential/Commercial Efficiency
- Demand Study Potential Policy Options
- Policy Recommendations.

The Demand Task Group organized its activities into six subgroups (Demand Data Evaluation, Electric Generation Efficiency, Coal Impact, Industrial Efficiency, Cultural/Social/Economic Trends, and Residential/Commercial Efficiency). The output of these efforts led to a series of observations and development of potential policy options. Detailed discussions of the work of each subgroup have been included in the report as topic papers. These topic papers are included on the CD distributed with the report (a list of all the topic papers can be found in Appendix E).

- The purpose of the Demand Data Evaluation subgroup was to summarize and compare the output from publicly available, integrated energy projections for the world, to understand the underlying basis of those projections, and to compare the results with other projections that were either non-integrated or available only as aggregated proprietary studies.
- The intent of the Electric Generation Efficiency subgroup was to understand the efficiency potential in the electric generation sector and estimate

the portion of that potential that is included in the available projections.

- The Coal Impact subgroup examined both the coal supply and demand trends. The primary goals were to compare the projected demand for coal in the outlooks examined with the potential future supply of coal on a worldwide and regional basis and to evaluate coal transportation factors.
- The focus of the Industrial Efficiency subgroup was to define the potential for energy-efficiency improvement in the industrial energy sector and to compare that potential to an estimate of the efficiency that is embedded in the outlooks examined for the study. This effort also investigated historical patterns of industrial feedstock use and how they changed over time.
- The Cultural/Social/Economic Trends subgroup undertook a broad area of investigation aimed at examining how non-technical factors affect energy demand, including how these factors have changed over time and how they might be expected to change in the future.
- The Residential/Commercial Efficiency subgroup looked at the potential for energy-efficiency improvement in the residential and commercial end-use sectors. Much of this effort focused on the potential to reduce energy losses in existing structures, the potential impact of appliance standards on energy use, and the potential impact of new building standards.
- Each of these subgroup efforts resulted in formation of observations associated with the respective areas. The Demand Task Group reviewed all of the observations and organized them into a list of those that appear to be the most significant.
- The next step in the process was to develop potential policy options, which were used as input into the study recommendations process after the Demand Task Group reduced the overall list to those it identified as most significant.

DEMAND STUDY OBSERVATIONS

The output of each of the demand subgroups provides a broad view of historical and projected worldwide and regional energy use. Many observations were derived from the subgroups' efforts. The list of observations were reduced to eighteen that the Demand Task Group deemed to be the most significant and broad based.[1] The rest of the observations can be found in the individual demand subgroup reports located in the topic papers.

1. **Income and population are prime drivers of energy demand.**

   The assumed rate of economic growth is a key variable in projections of global energy demand. Population growth and the size of a region's population are also important variables. Projected annual average global economic growth from 2000 to 2030 ranges from 3 percent to 4.4 percent in the publicly available integrated energy outlooks. From 1980 to 2000, global economic growth averaged 3.1 percent.

2. **There are varying views on the rate of global energy demand growth.**

   Projected annual average global energy demand growth from 2000 to 2030 ranges from 1.5 percent to 2.5 percent. Global energy demand growth averaged 1.7 percent from 1980 to 2000. High and low projections of economic growth result in high and low projections, respectively, of future energy growth. The difference in energy demand in 2030 between the high and low growth rates is 224 quadrillion Btu—equivalent to roughly half of global demand in 2005.

3. **There is a range of views on the rate of U.S. economic and energy demand growth.**

   Projections of annual average U.S. economic growth from 2000 to 2030 in the public energy outlooks range from 2.3 percent to 3.3 percent. The 1980 to 2000 average was 3.2 percent. Projected annual average U.S. energy demand growth ranges from 0.5 percent to 1.3 percent. The 1980 to 2000 average was 1.2 percent. The difference between the high and low energy demand growth rates from 2000 to 2030 is 37 quadrillion Btu—equivalent to 37 percent of 2005 total U.S. energy demand.

4. **In most cases, carbon dioxide emissions are closely related to projected energy use.**

   Projected global carbon dioxide emissions generally grow at roughly the same rate as projected

1 Unless otherwise noted, data referred to in this chapter and used in its figures and tables are from the Energy Information Administration's (EIA) *International Energy Outlook 2006* and the International Energy Agency's (IEA) *World Energy Outlook 2006*. These data were gathered by the NPC Survey of Global Energy Supply/Demand Outlooks.

energy demand, while growth in the United States is slightly slower than energy demand growth.

5. **Fossil fuels remain the largest source of energy.**

   In 2030, fossils fuels (oil, natural gas, and coal) are projected to account for between 83 and 87 percent of total world energy demand compared with 85 percent in 2000. The share for the United States ranges from 81 to 87 percent in 2030. The U.S. share in 2000 was 86 percent.

6. **The projections indicate that a large and, in many cases, growing share of energy use will be met by coal.**

   In all of the projections but one, annual average demand growth for coal is faster than in the past for both the United States and the world. Resources do not appear to be limiting the projected growth in coal use. However, use of coal will require infrastructure development, especially for transportation and unconventional uses such as coal to liquids.

7. **In most of the outlooks, world natural gas demand is projected to increase at a slower rate than in the past (1980 to 2000).**

   Natural gas demand growth is still faster than total energy demand from 2000 to 2030. The result is natural gas gaining in market share.

8. **Growth in U.S. natural gas demand is projected to be significantly slower than in the past (1980 to 2000), which results in a decline in its share of total U.S. energy.**

   Despite slower demand growth, absolute U.S. consumption of natural gas is projected to continue to grow.

9. **Projected world demand growth for oil is faster than in the past (1980-2000), but less than the projected overall increase in energy demand resulting in a declining market share for oil.**

   Annual average growth in world oil demand between 2000 and 2030 is projected to increase at an annual average rate ranging from 1.0 to 1.9 percent. From 1980 to 2000, annual growth in world oil demand averaged 0.9 percent. In most cases, U.S. oil demand growth equals or exceeds the 0.6 percent annual average growth rate from 1980 to 2000.

10. **Nuclear energy use is projected to contribute a declining share to world energy and U.S. energy consumption, but it grows in absolute terms.**

    Both world and U.S. projections show nuclear energy use growing slower than total energy demand, and losing its share of the energy mix.

11. **Transportation oil use is the largest component of oil demand growth in the world and the United States.**

    Transportation increases its share of world and U.S. oil use.

12. **The share of natural gas use in the major end-use sectors—residential/commercial, industrial, and electric generation—changes over time.**

    The publicly available projections show a declining share of world natural gas use in the residential and commercial sectors, essentially a constant share for industrial purposes, and an increasing share for electric generation. In the United States, the natural gas share remains essentially constant in the residential/commercial sector, while it declines in the industrial sector and grows for electric generation.

13. **Energy demand in Asia/Oceania is projected to grow at a faster rate than the global and U.S. averages.**

    Projected energy growth in the publicly available integrated projections indicates that Asia/Oceania's share of total world energy demand will increase by about 10 percent between 2000 and 2030. Over the same period, despite rising absolute consumption, the United States' share of total world energy use is projected to decline by about 2 percent.

14. **Energy use is projected to grow slower than economic activity in both the world and the United States, resulting in a projected decline in energy intensity.**

    World energy use is projected to grow slower than economic growth. This is a continuation of past trends. The United States is expected to exhibit a similar profile. Energy intensity (energy use per unit of gross domestic product, GDP) declines at a faster rate in Asia/Oceania than in North America.

15. **Global and U.S. energy consumption, per capita, is projected to increase.**

    With the exception of one case, in all the publicly available integrated projections, energy use per capita increases in the world, Asia, and the United States. From 1980 to 2000, energy use per capita was essentially constant in the United States, while it increased in Asia.

16. **U.S. per capita energy consumption is projected to remain higher than the world average.**

    In most publicly available projections, U.S. energy use per capita in 2030 is projected to be 4 times greater than the world average and 6 times greater than in Asia. In 2000, the U.S. to world ratio was 5 and U.S. to Asia ratio was 11.

17. **U.S. energy efficiency improvement, as measured by energy intensity, is projected to be equal to—or less than—the historical rate from 1980 to 2000.**

    Data limitations constrain insights into the amount of efficiency increase outside the United States that is built into the projections. However, the decrease in energy intensity suggests that there is an increase in energy efficiency underpinning many of the projections. U.S. new light duty vehicle miles per gallon (mpg) appears to be projected to increase at 0.6 percent per year. U.S. industrial efficiency is estimated to increase by 5 percent over the projection period. There is potential for further energy efficiency improvement in both of these sectors as well as in the residential/commercial sectors.

18. **Applying additional policy initiatives could change the energy, economic, and environmental outlook.**

    In a projection that assumed the enactment of several additional policies—the IEA Alternative Policy Case—total world energy demand growth from 2000 to 2030 was about 0.4 percent per year lower then in the IEA Reference Case. In the same Alternative Policy Case, growth in U.S. energy demand was 0.3 percent per year lower than in the Reference Case. Global carbon dioxide emissions are 6 billion metric tons lower (34 billion metric tons) in 2030 in the IEA Alternative Policy Case than in the IEA Reference Case (40 billion metric tons).

DEMAND SUMMARY

The NPC Demand Task Group reviewed, analyzed, and compared projections of world energy demand. These projection data were gathered by the NPC Survey of Global Energy Supply/Demand Outlooks and collected in the NPC data warehouse, a repository for data and information used in this study, which is discussed in the Methodology chapter. Publicly available demand data from the U.S. Department of Energy's Energy Information Administration and the International Energy Agency were the main focus of the analysis. Aggregated proprietary data and data from other, generally less complete, public outlooks were used primarily to establish whether the EIA and IEA outlooks provided a reasonable range of projections for analysis.

The three major input assumptions behind both the EIA and the IEA projections are economic growth, population, and energy policies. In general, the economic growth projections (2000 to 2030) for the world exceed past (1980 to 2000) growth. World population growth projections in all cases are essentially the same. Population growth rates are projected to be generally lower than historical growth rates.

The EIA projections generally include only those energy policies that are currently in effect and allow most policies to expire as currently enacted at their sunset dates. The IEA Reference Case, however, assumes the likely extension of public policies. The IEA Alternative Policy Case provides a significantly different energy policy approach, assuming not only existing energy policies and their logical extension, but also other policies that are under consideration around the world. Projected worldwide energy demand is shown in Figure 1-1, while projected U.S. energy demand is shown in Figure 1-2.

World demand for petroleum liquids is projected to grow from about 76 million barrels per day in 2000 to between 98 and 138 million barrels per day in 2030 (Figure 1-3). U.S. petroleum liquids demand is projected to grow from about 19 million barrels per day in 2000 to between 21 and 30 million barrels per day in 2030 (Figure 1-4).

World natural gas demand is projected to range from 356 to 581 billion cubic feet per day in 2030, compared with 243 billion cubic feet per day in 2000 (Figure 1-5). U.S. natural gas demand, which was 64 billion cubic feet per day in 2000, is projected to

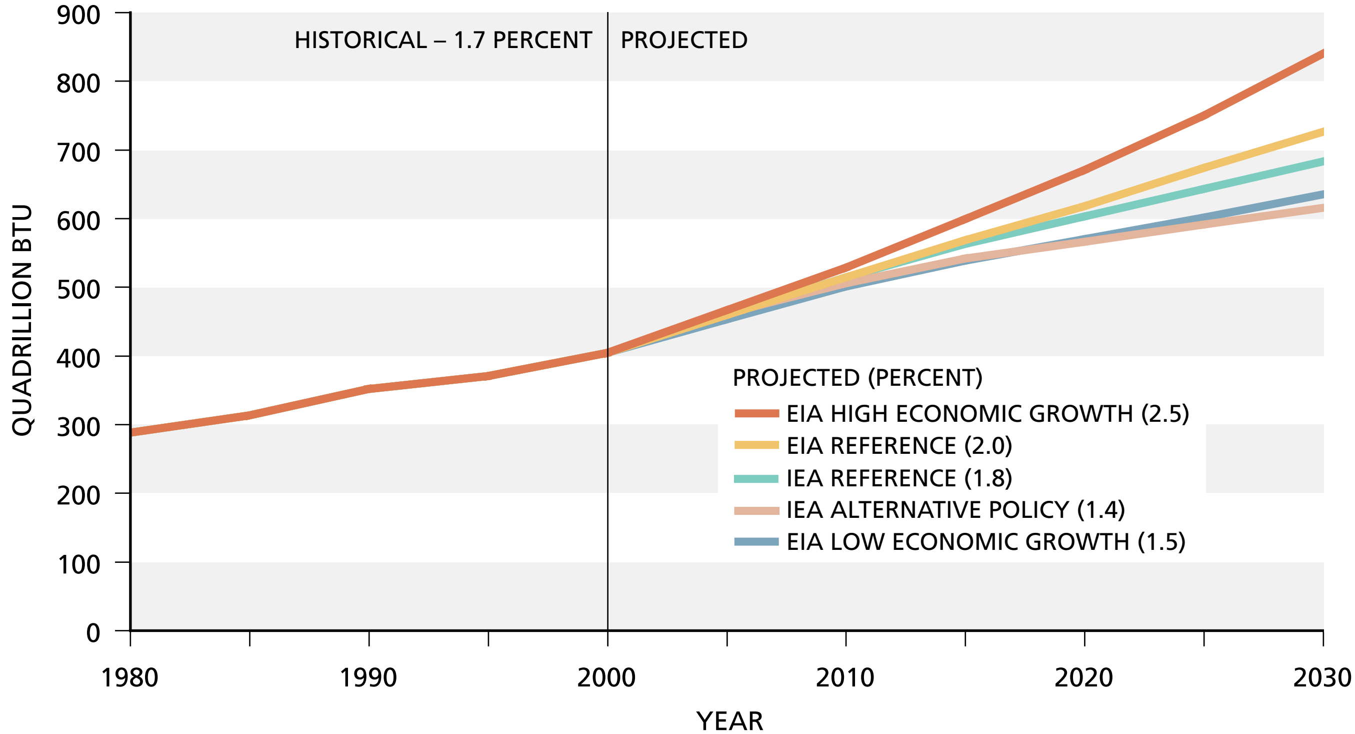


FIGURE 1-1. *World Energy Demand — Average Annual Growth Rates*

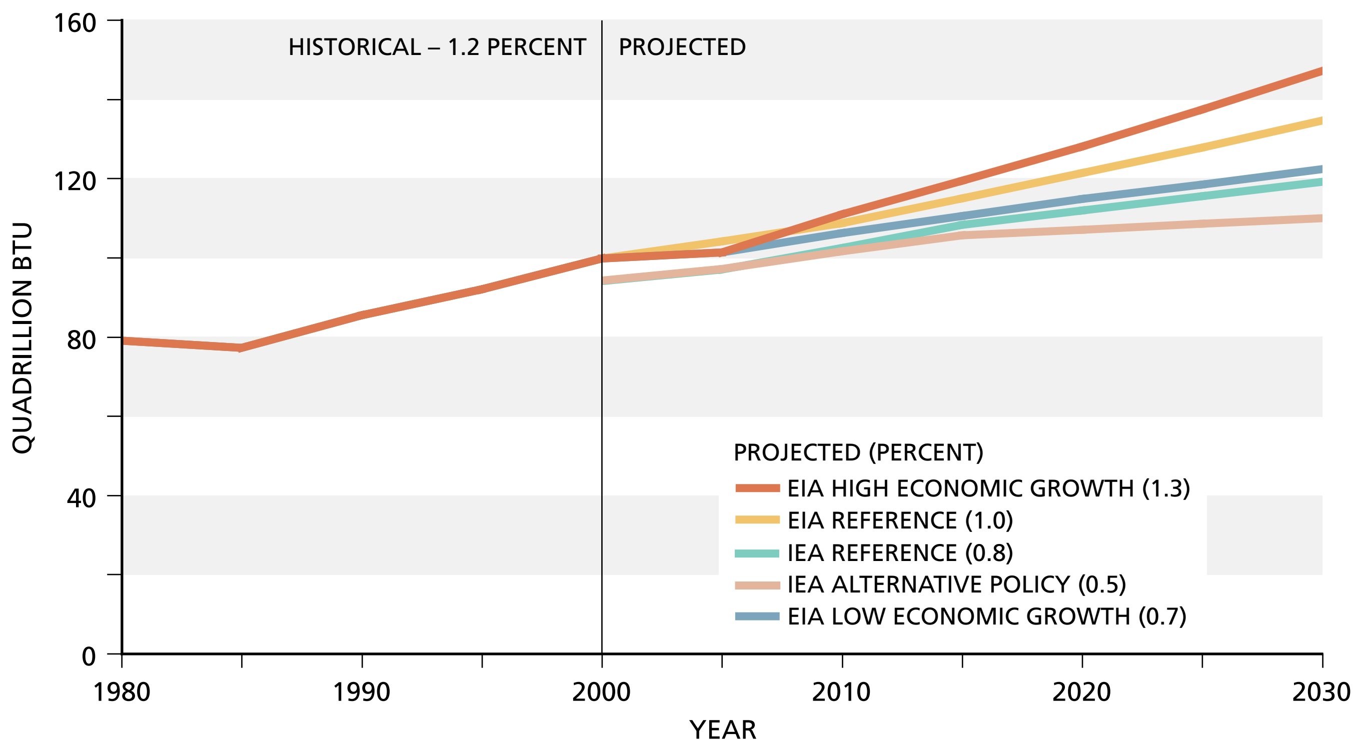


FIGURE 1-2. *U.S. Energy Demand — Average Annual Growth Rates*

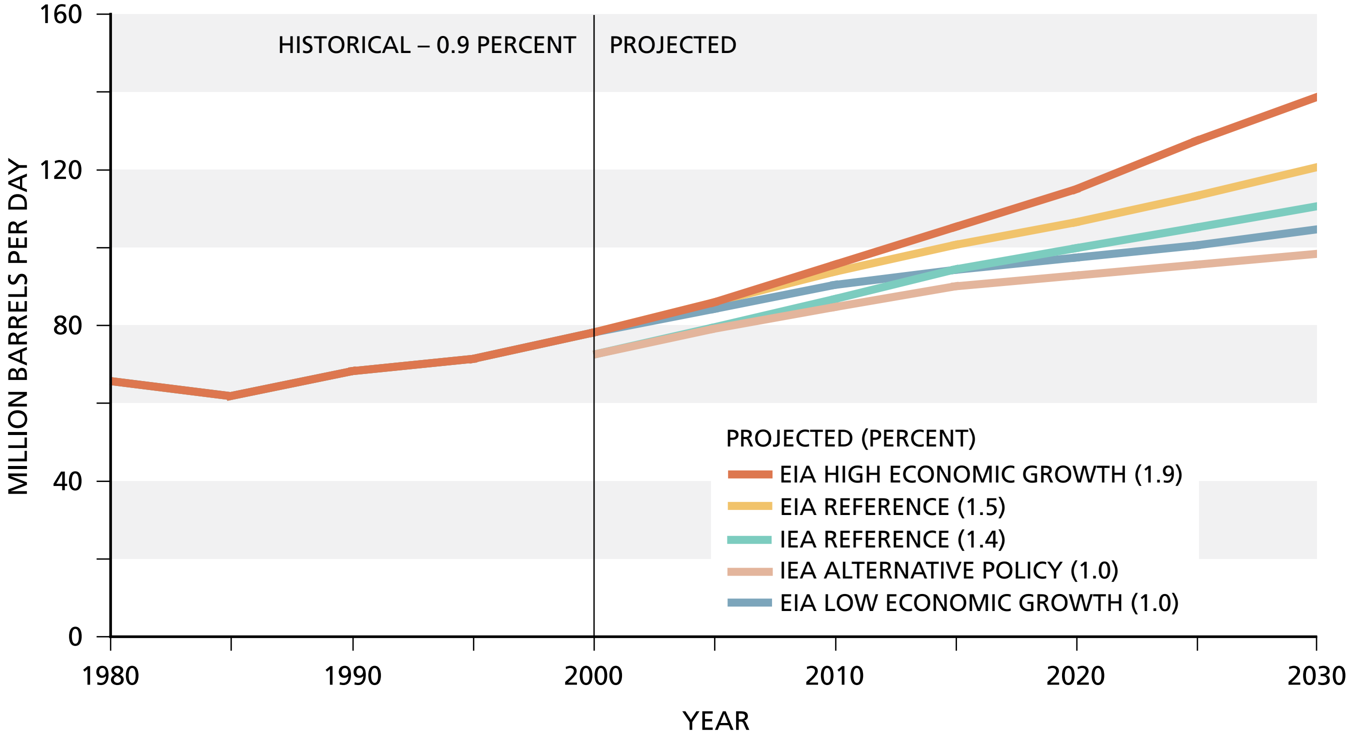


FIGURE 1-3. *World Petroleum Demand — Average Annual Growth Rates*

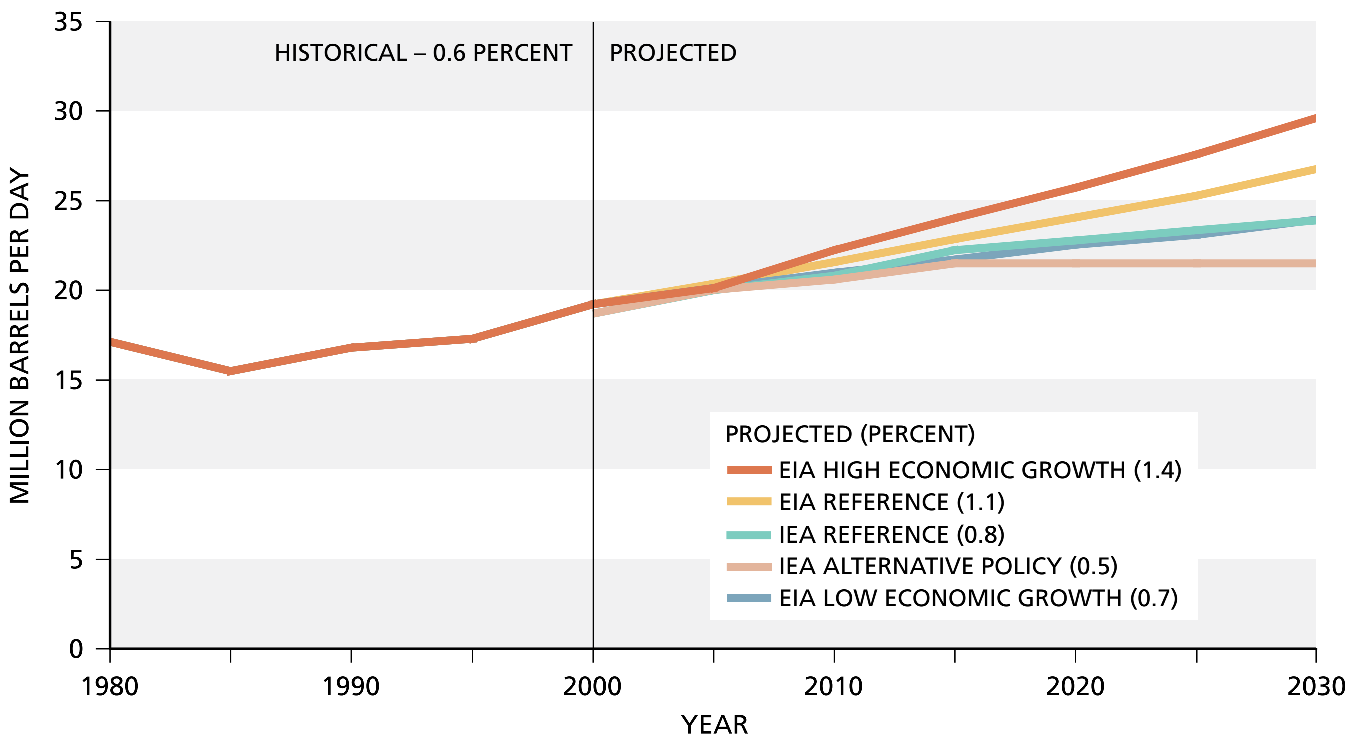


FIGURE 1-4. *U.S. Petroleum Demand — Average Annual Growth Rates*

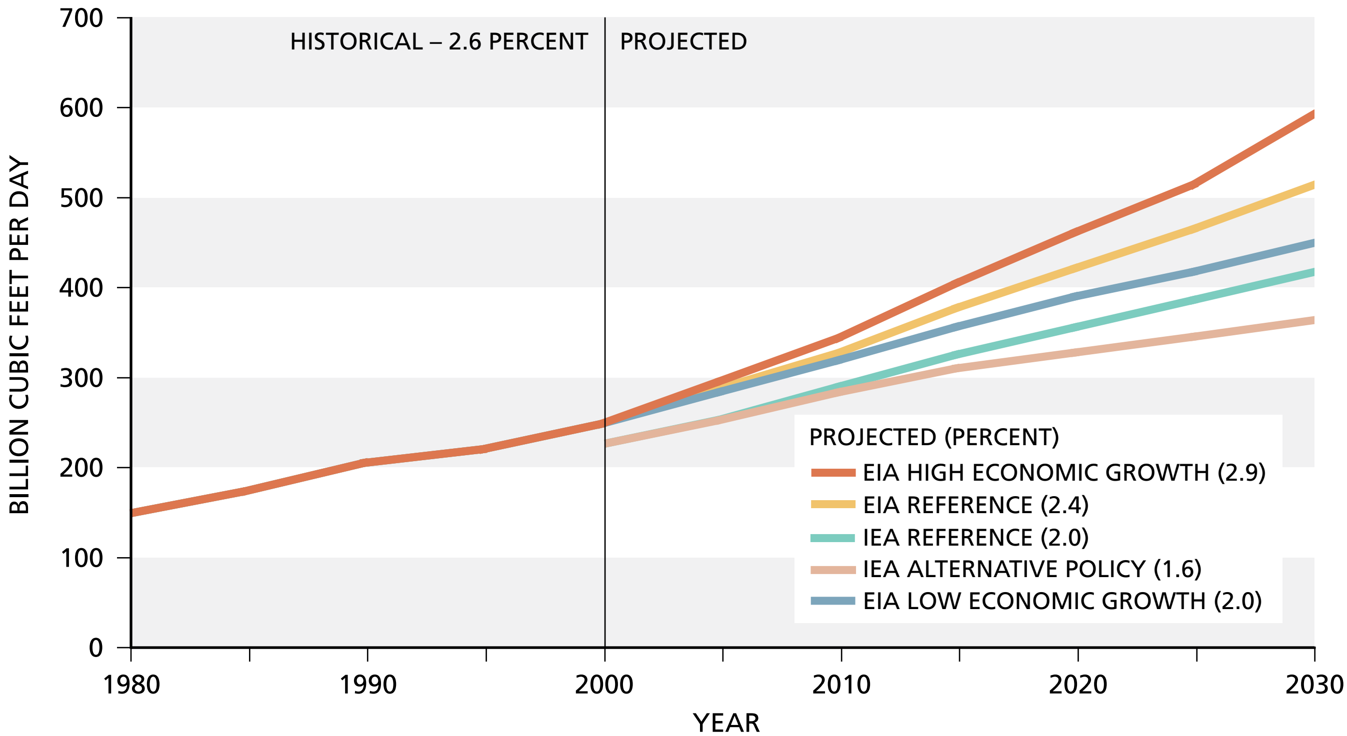


FIGURE 1-5. *World Natural Gas Demand — Average Annual Growth Rates*

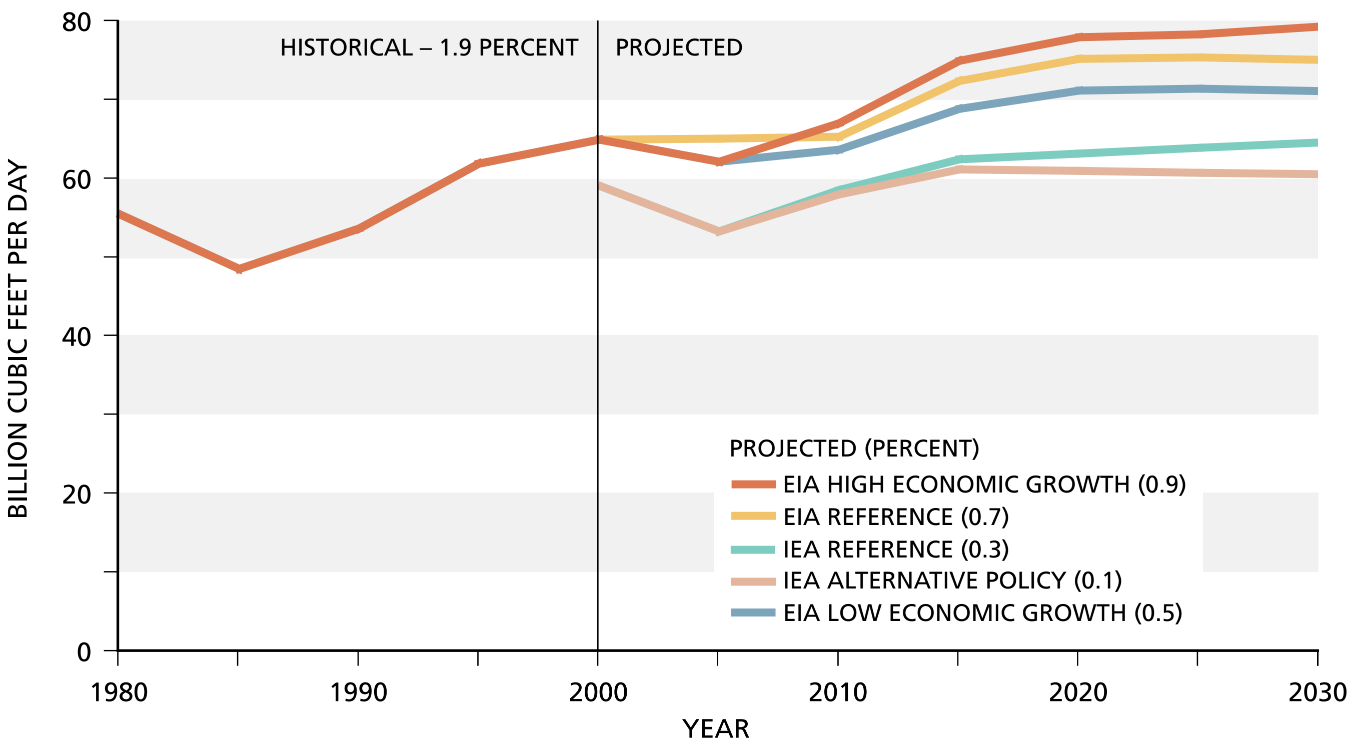


FIGURE 1-6. *U.S. Natural Gas Demand — Average Annual Growth Rates*

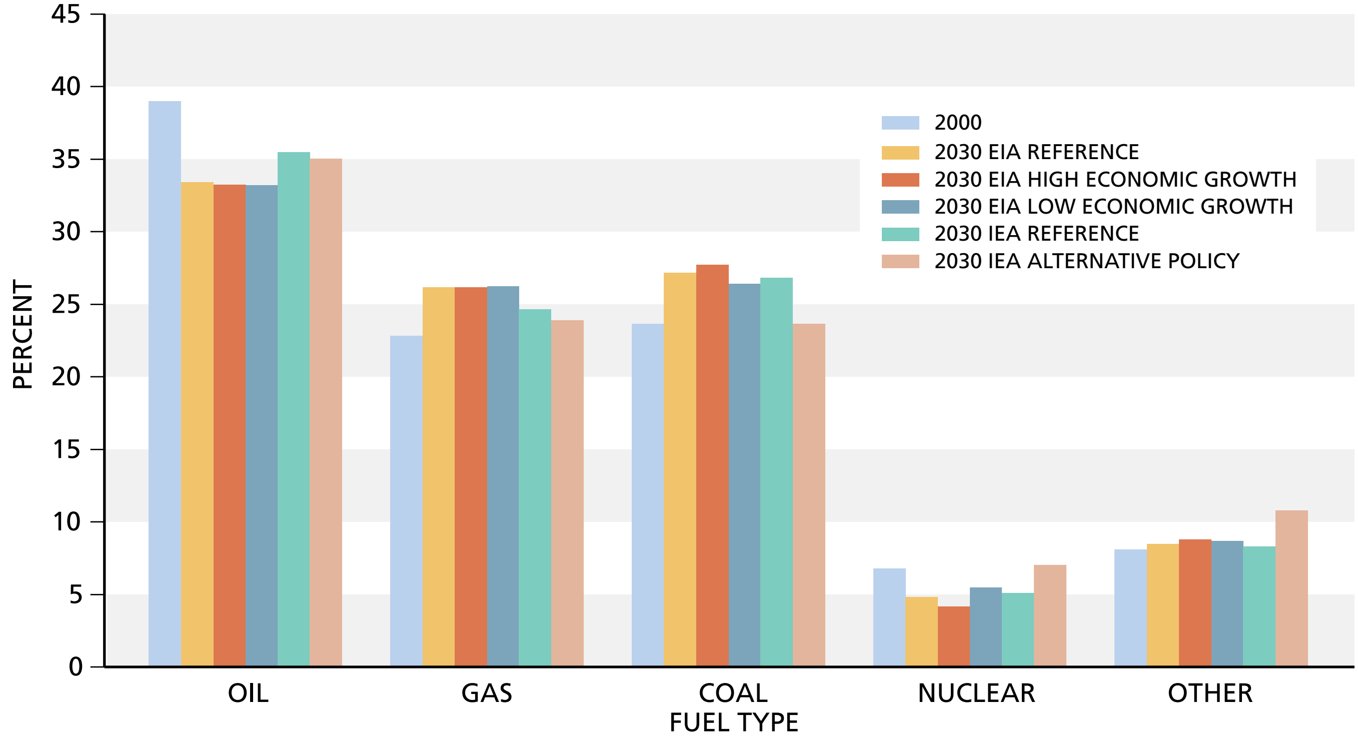


FIGURE 1-7. *World Energy Supply Shares*

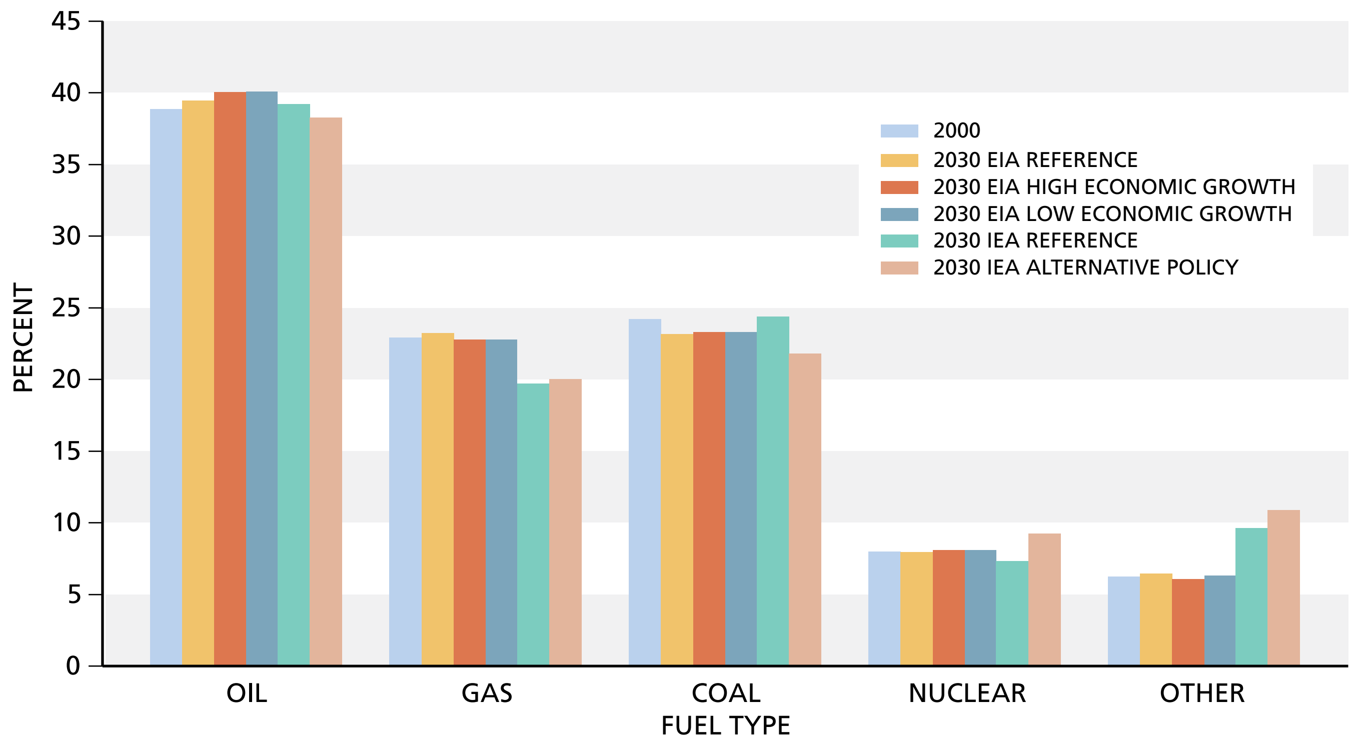


FIGURE 1-8. *U.S. Energy Supply Shares*

range from 59 to 78 billion cubic feet per day in 2030 (Figure 1-6).

On a world basis, oil use is generally expected to lose share, while share gain is expected in the United States. On the other hand, worldwide natural gas use share is projected to increase (Figure 1-7). In the United States, the projections indicate little change to a slight decline in natural gas use share (Figure 1-8).

Worldwide carbon dioxide emissions grow from 24 billion metric tons in 2000 and are projected to range from 34 to 51 billion metric tons in 2030 (Figure 1-9). In all cases, carbon dioxide emissions increase at about the same rate as energy demand. In 2030, projected carbon dioxide emissions in the United States range from 6.3 to 9 billion metric tons compared with 5.8 billion metric tons in 2000.

Regional shares of energy use are projected to change over time. The share of total worldwide energy consumed in North America, OECD Europe, and Non-OECD Europe & Eurasia is projected to fall in all of the cases, while the share in Asia/Oceania grows (Table 1-1). In general, the change in the oil share of total worldwide oil consumed by region parallels the change in the share of total energy consumption, with industrialized regions losing share and the Asia/Oceania oil share increasing significantly.

	2000 IEA	2030 IEA Ref. Case
North America	27%	21%
Central and South America	5%	5%
OECD Europe	18%	13%
Non-OECD Europe & Eurasia	10%	8%
Middle East	4%	6%
Asia/Oceania	31%	41%
Africa	5%	6%

TABLE 1-1. *Regional Energy Shares*

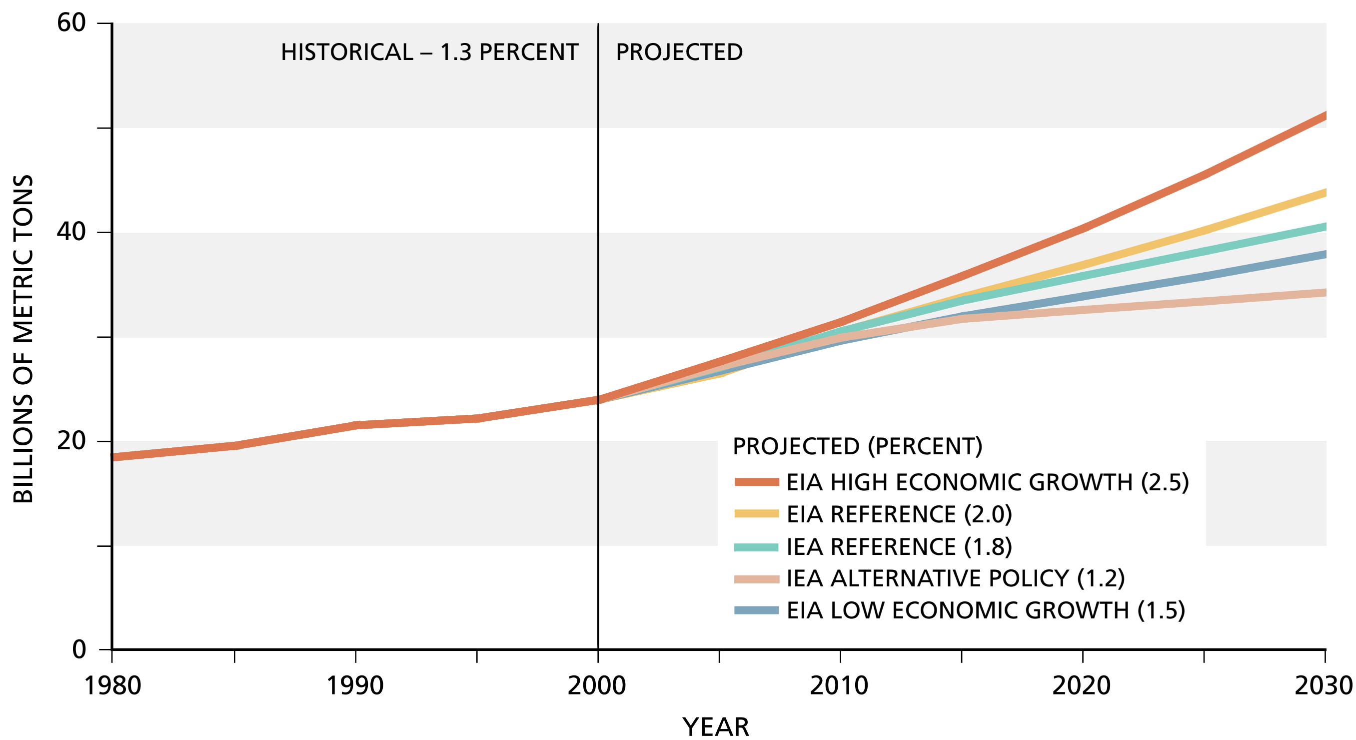


FIGURE 1-9. *World Carbon Dioxide Emissions — Average Annual Growth Rates*

Improvement in the efficiency of energy use is an important factor determining future energy use. The models used to project future energy use are complex, which makes it difficult to provide precise estimates of the efficiency improvement built into the projections. However, energy use intensity (energy use per unit of GDP) provides a useful proxy and is projected to decline in all regions.

Major Areas to Moderate Demand by Increasing Energy Efficiency

Vehicle Fuel Economy

The major use of liquid fuels in the United States is for transportation. The projections that were studied indicate that transportation will likely remain the primary use of liquid fuels in the United States. Among various transportation uses, light duty vehicle use (automobiles and light trucks) is the largest component. Significant potential exists for efficiency improvements, but most projections do not expect this potential to be fully realized. In most of the other transportation uses, the EIA Reference Case projection uses most or all of the potential for efficiency improvement now or expected to be available.

Technically, there appears to be a potential for improving the efficiency of new light duty vehicles (fuel used per unit travel) by about 50 percent using technology improvements in several areas: engine efficiency; body improvements; driveline changes; accessory modifications; and hybrid technology use. Some of the changes are likely to have costs associated with them as well as possible broader economic effects (see Technology chapter).

The NPC global oil and gas study has not been conducted in a way that provides for internally generated projections. However, it is possible to understand the potential size of an impact on U.S. light duty fuel consumption from incorporating an efficiency improvement of 50 percent in the U.S. new vehicle sales mix by 2030. By removing assumptions that relate to changes in the vehicle sales mix, increases in vehicle performance, increases in vehicle energy use created by added comfort and convenience options, and increases in miles driven per licensed driver, most of the factors that complicate direct understanding of a single factor like vehicle efficiency increase are set aside.

The 50 percent improvement in new vehicle efficiency that has been discussed thus far is not consistent with the general public understanding of light duty vehicle efficiency. The general measure used to indicate the fuel-use characteristic of a vehicle is miles traveled per gallon of fuel used (mpg). A 50 percent reduction in fuel used per mile of travel (efficiency) is, mathematically, equivalent to a doubling of—or a 100 percent increase in—mpg.

There are many ways to build a fuel use estimate of the impact of incorporating a new light duty vehicle efficiency improvement. Consequently, any estimate is, at best, an indication of magnitude and not a projected actual outcome. If it is assumed that the total 100 percent improvement in new vehicle fuel economy is implemented by the year 2030, the potential impact appears to lower light duty vehicle fuel consumption by 3 to 5 million barrels per day relative to a future with no improvement in new vehicle fuel economy. Factors such as rate of new vehicle technology penetration and new vehicle replacement in the on-road fleet have impacts on reduction in fuel use. New vehicle fuel economy improvement might vary from the rapid improvement rate in new vehicle fuel economy that occurred when the Corporate Average Fuel Economy program was instituted in the 1970s to a gradual incorporation of new vehicle efficiency over the period to 2030. Replacement of on-road light duty vehicles by new light duty vehicles has taken about 15 years. If the replacement period for light duty vehicles in the on-road fleet increases or decreases, the potential fuel use reduction decreases or increases.

Obviously there are many other factors that are likely to change with time. Consequently, the estimate of potential savings should not be applied to any specific future projection of U.S. light duty fuel demand, but should be used to indicate potential magnitude. The ultimate outcome will depend on the specifics of program design and implementation.

Consumption in the Residential and Commercial Sectors

There appears to be sizeable potential to reduce energy consumption in U.S. residential and commercial sectors. The EIA *Annual Energy Outlook 2007* (AEO 2007) reported the residential/commercial efficiency factors that are included in the projection. The factors shown in Table 1-2 are greatly influenced by the replacement of old, relatively inefficient

Category	Appliance	Efficiency Improvement
Appliance	Refrigerators	22%
	Freezers	8%
Space heating	Electric heat pumps	10%
	Natural gas heat pumps	14%
	Geothermal heat pumps	5%
	Natural gas furnaces	6%
	Distillate furnaces	2%
Space cooling	Electric heat pumps	20%
	Natural gas heat pumps	10%
	Geothermal heat pumps	6%
	Central air conditioners	22%
	Room air conditioners	7%
Water heaters	Electric	3%
	Natural gas	6%
	Distillate fuel oil	0%
	Liquefied petroleum gases	6%
Building shell efficiency	Space heating – Pre 1998 homes	7%
Note: Index includes size of structure in the calculation	Space cooling – Pre 1998 homes	2%
	Space heating – New construction	2%
	Space cooling – New construction	2%

Source: Energy Information Administration, *Annual Energy Outlook 2007,* table 21, http://www.eia.doe.gov/oiaf/aeo/supplement/sup_rci.xls.

TABLE 1-2. *Residential Stock Efficiency Improvements, 2007-2030*

equipment. Efficiency improvement in new equipment is expected to be less than the aggregated improvements in the table.

Studies for efficiency improvements are largely specific to regions, and often to energy types. A review of these studies suggests that anticipated energy use in the residential and commercial sectors could be reduced by roughly 15 to 20 percent through deployment of cost-effective energy-efficiency measures that use existing, commercially available technologies. Assuming that all these measures are put in place over the next decades and that all other factors such as level of services are held constant, U.S. residential/commercial energy consumption could be reduced by 7 to 9 quadrillion Btu. Technologies to accomplish savings of these magnitudes are indicated to be available in the marketplace. However, some of these measures have initial cost and retrofit issues associated with their use.

While significant efficiency improvements have been made over the last several decades in building shells, systems, and appliances, these have been offset in part by additional energy service demand requirements that have been imposed as a result of increased structure sizes and larger and multiple appliance use. As much as possible, programs to increase the efficiency in the U.S. residential/commercial sector need to avoid inclusion of measures that inadvertently encourage using energy services that decrease the effectiveness of energy-efficiency measures.

U.S. Industrial Sector Efficiency

The industrial sector is a price-responsive consumer of energy. U.S. energy-intensive industries and manufacturers rely on internationally competitive energy supplies to remain globally competitive. In recent years, U.S. natural gas prices have risen relative to those in the rest of the world. As a result, U.S. energy-intensive industries and manufacturers using natural gas as a fuel or feedstock have responded by increasing the efficiency of their operations and/or by shifting a greater proportion of their operations outside the United States.

Energy efficiency opportunities exist for reducing energy use by about 15 percent broadly across the industrial sector. Areas of opportunity include waste heat recovery, separations, and combined heat and power. While 40 percent of that opportunity could be implemented now, research, development, demonstration, and deployment are required before the rest can be implemented. If all of this efficiency could be put in place over the next 20 years, U.S. energy demand could be reduced by 4 to 7 quadrillion Btu compared with what it would be without the improvements.

Table 1-3 indicates some of the barriers to adopting industrial energy efficiency measures.

Research, development, and demonstration are needed to prove the technologies. However, focus on deployment of improved technologies and practices is particularly important because of the risk-averse character of manufacturing companies, the high capital cost of new equipment, the long life cycle of existing industrial equipment, access to unbiased information on technology performance, and lack of technically trained human resources. Addressing these issues will speed the diffusion of improved technologies and practices.

Making the federal research and development tax credit permanent, instead of legislatively renewing it every few years, is a way to encourage private investment in industrial energy-efficiency research, development, demonstration, and deployment.

U.S. Electric Power Generation Efficiency

U.S. electricity generation efficiencies indicated in both the EIA and IEA outlooks show improvements over time. The expected improvements come mainly

Energy Cost Environment	• Price volatility • Lack of transparency to end-users of the real cost of energy
Business Environment	• Technical and economic risk (uncertain return on investment) associated with efficiency projects • Initial capital costs influence decisions more than long-term energy costs • Lack of incentives for development and use of new technology • Lack of R&D investments in efficiency • Long service life of existing equipment
Regulatory Environment	• Election cycles and impact on R&D priorities • Uncertainty related to future regulation, particularly environmental, and power • Permitting hurdles for upgrading existing equipment
Education Environment	• Inadequate industry awareness of new technology • Lack of technical expertise

Sources: Energetics, Technology Roadmap: Energy Loss Reduction and Recovery in Industrial Energy Systems, 2004; Global Environmental Facility (GEF), Operation Program Number 5: Removal of Barriers to Energy Efficiency and Energy Conservation, 2003; Marilyn Brown, Market Failures and Barriers as a Basis for Clean Energy Policies, 2001; A.B. Jaffe, R.G. Newell, R.N. Stavins, "Energy-Efficient Technologies and Climate Change Policies: Issues and Evidence," Resources for the Future, Climate Issue Brief No. 19, 1999.

TABLE 1-3. *Barriers to Adopting Energy Efficiency Measures* from the replacement of retired plants with new plants that have better efficiencies. However, installation of environmental control systems will add internal energy requirements reducing the efficiency of a power generation plant.

There are a few changes that can be made to make an existing power generation plant more efficient. Studies suggest the potential to improve the efficiency of existing U.S. power plants by 2 to 6 percent. Existing electric generation plant efficiency improvements generally fall into the following categories.

- Improved operation and maintenance practices
- Replacement/upgrade of:
  - steam turbines
  - forced draft, primary air, and induced draft fans
  - condensers
  - air heaters
  - operating controls
  - soot blowers
  - burners.

If these efficiency improvements could be captured in the next decades, energy savings would equal about 1 quadrillion Btu.

Capturing Efficiency Potential

Current energy-efficiency polices will place downward pressure on future U.S. energy consumption. However, further energy reduction would be possible if additional energy-conservation-related policy is put in place.

In commercially oriented end-uses such as industrial, electric generation, and commercially oriented transportation, the market price mechanism creates an incentive for using economically available energy efficiency technology. Programs to assist in research, development, demonstration, and deployment of energy-efficient technology would bolster the market mechanism in these areas.

Energy conservation and efficiency use in areas where individual consumers are faced with complex choices that are not well understood, and where decisions are made by third parties who are not consuming and paying for the energy, are likely to benefit from prudent application of technically practical and economically rational policies. Areas such as light duty vehicle fuel use and residential and commercial energy use could potentially benefit from well developed and implemented energy conservation/efficiency policies.

DEMAND DATA EVALUATION

The Demand Data Evaluation Subgroup of the Demand Task Group reviewed, analyzed, and compared projection data collected in the NPC data warehouse, which is discussed in the Methodology chapter. Publicly available demand data from EIA and IEA were the main focus of the analysis. The aggregated proprietary data available in the NPC data warehouse were used primarily to establish whether the EIA and IEA projections provided a reasonable range of projection results. Other public projections, generally less complete than the EIA and IEA projections, were also used as a reasonableness check.

The three major input assumptions behind both the EIA and the IEA projections are economic growth, population, and effect of associated energy policies. In general, the economic growth projections (2000 to 2030) for the world exceed past (1980 to 2000) growth except for that used in the EIA Low Economic Growth Case (Figure 1-10). By region and country, the pattern is somewhat different. Economically developed regions (North America and OECD Europe), and both developing and economically emerging Asia are projected to grow more slowly than in the past. Countries in Africa, Central and South America, the Middle East, and Non-OECD Europe and Eurasia are projected to grow more rapidly than historically. The faster global economic growth is driven by the rapidly growing emerging Asian economies becoming a larger share of the global economy.

World population growth in all cases is essentially the same, drawn from United Nations or U.S. Census projections of population growth. Population growth rates are projected to be generally lower then historical growth rates.

The EIA, generally, only included those energy policies that are currently in effect and allows most policies to expire at their currently enacted sunset date. The IEA Reference Case, however, assumes the likely extension of public policies. The IEA Alternative

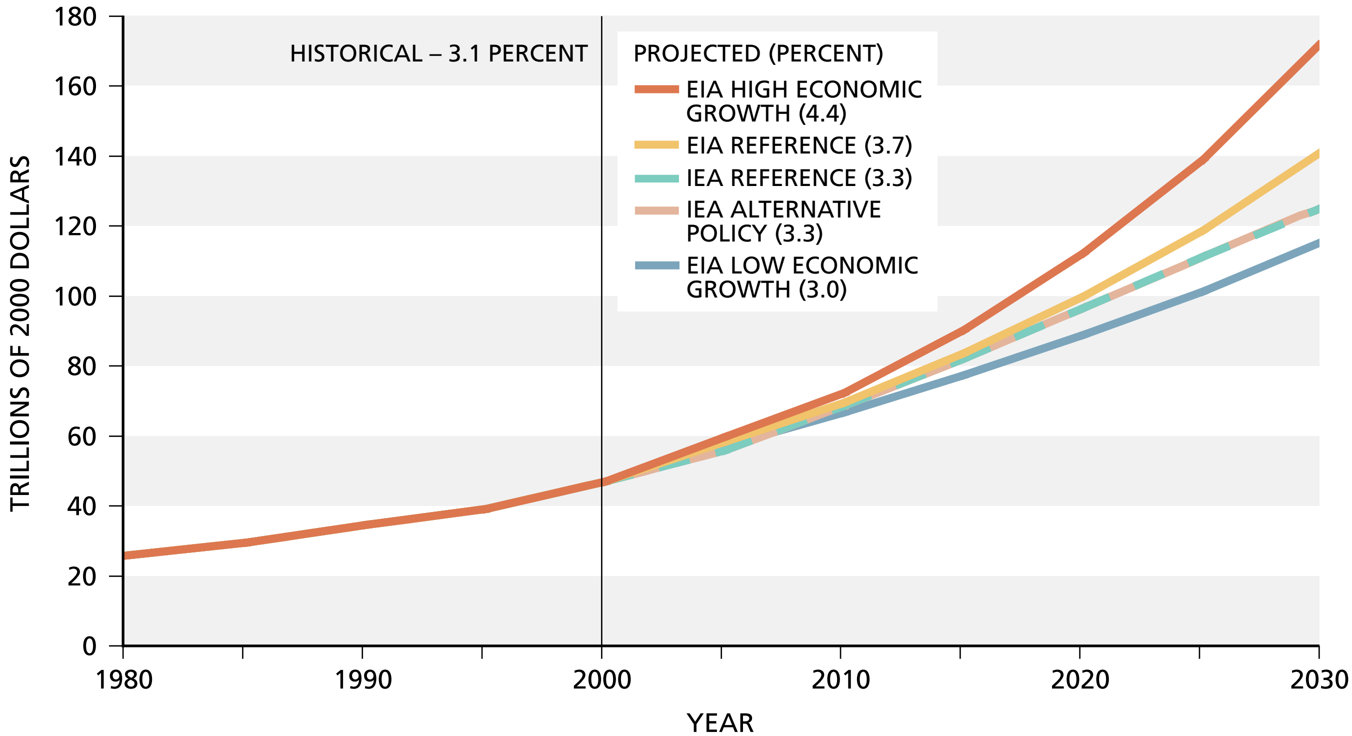


FIGURE 1-10. *World Economy — Average Annual Growth Rates*

Policy Case provides a significantly different energy policy approach, assuming not only existing energy policies and their logical extension, but also other policies now under consideration around the world. IEA used the same economic projections in its Reference Case and Alternative Policy Case.

Worldwide energy demand is projected to grow 1.4 to 2.5 percent per year, versus the historical growth rate of 1.7 percent per year (Figure 1-11). The projected U.S. energy demand growth of 0.5 to 1.3 percent per year was generally less than the historical rate of growth of 1.2 percent per year (Figure 1-12).

World demand for petroleum liquids is projected to grow at 1.0 to 1.9 percent per year versus the historical growth rate of 0.9 percent per year. In 2030, petroleum demand is projected to range from 98 to 138 million barrels per day, up from 76 million barrels per day in 2000 (Figure 1-13). Despite this growth, petroleum as a share of total energy declines in all cases. U.S. petroleum demand is projected to grow 0.5 to 1.4 percent per year versus 0.6 percent per year historically. In 2030, U.S. petroleum liquids demand is projected to range from 21 to 30 million barrels per day, compared to 19 million barrels per day in 2000 (Figure 1-14). The IEA Alternative Policy Case is the only public case in which growth in U.S. petroleum liquids demand is slower than in the past. This indicates that the policies assumed in this case could have a significant impact on the growth in petroleum liquids demand relative to the policies in place today.

According to the EIA projection for the United States, two-thirds of the volume and most of the projected growth in demand for petroleum liquids is in transportation services (Figure 1-15). That projected growth in transportation is led by increased demand by light duty vehicles (60 percent) (Figure 1-16). The key drivers of light duty vehicle growth are increased vehicle penetration and annual miles traveled per vehicle, which more than offset improvement in vehicle efficiency (miles per gallon).

The transportation sector provides the greatest potential for reducing oil consumption. The Technology Task Group, through its Transportation Efficiency subgroup, developed an estimate of transportation efficiency potential for five classes of transportation: light duty vehicles, heavy duty vehicles, air, marine, and rail (see Technology chapter).

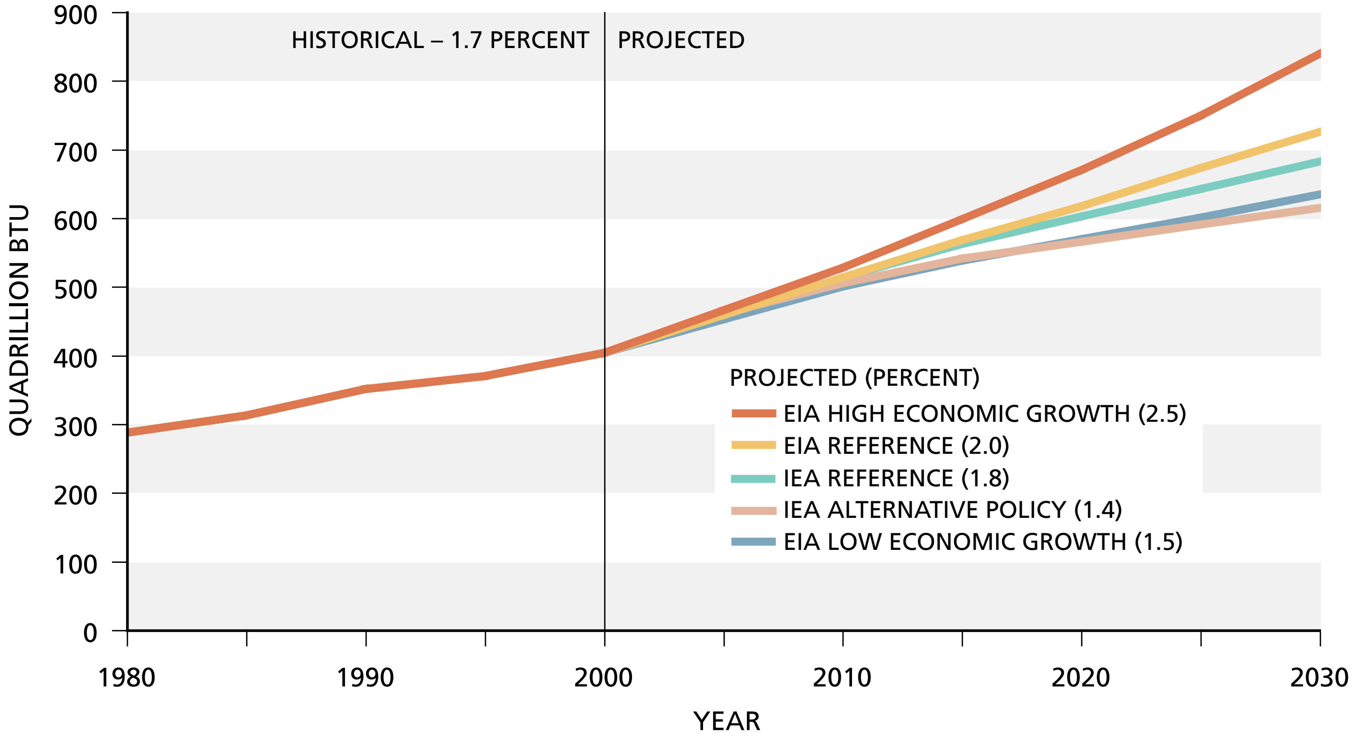


FIGURE 1-11. *World Energy Demand — Average Annual Growth Rates*

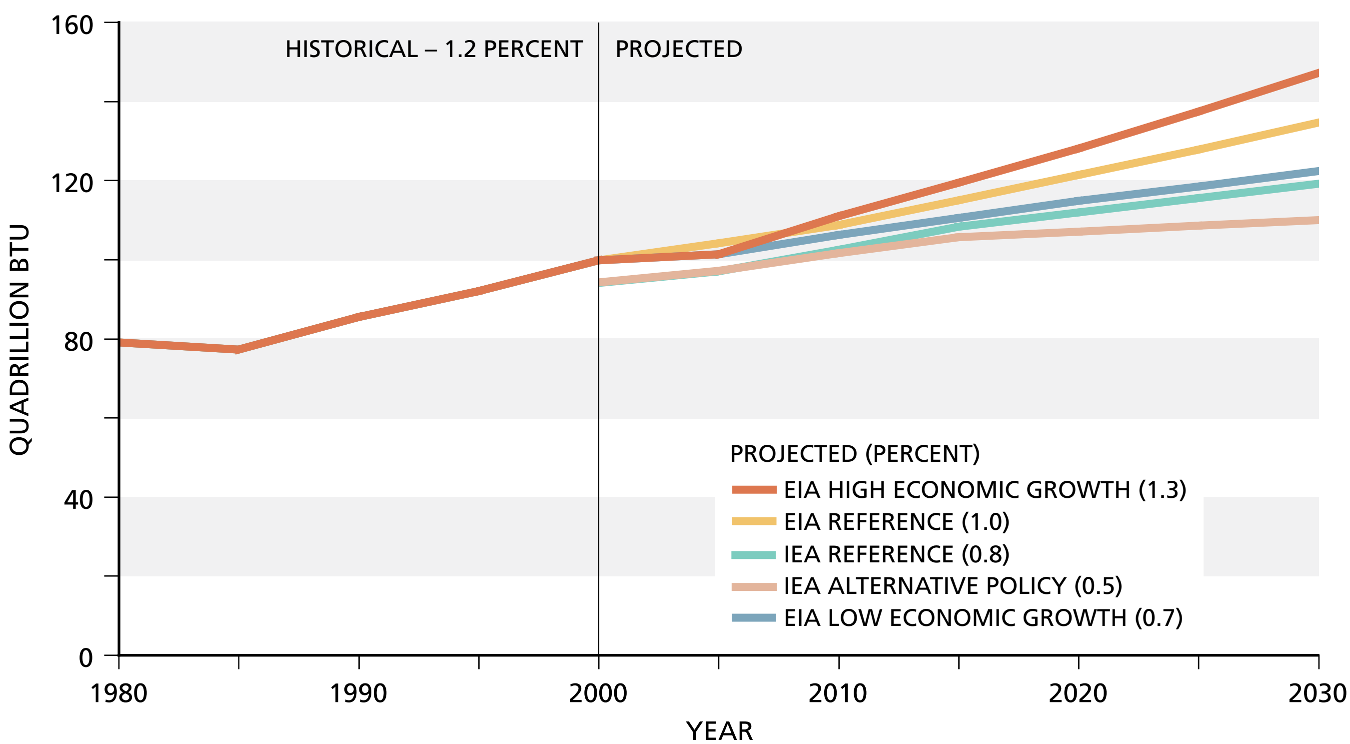


FIGURE 1-12. *U.S. Energy Demand — Average Annual Growth Rates*

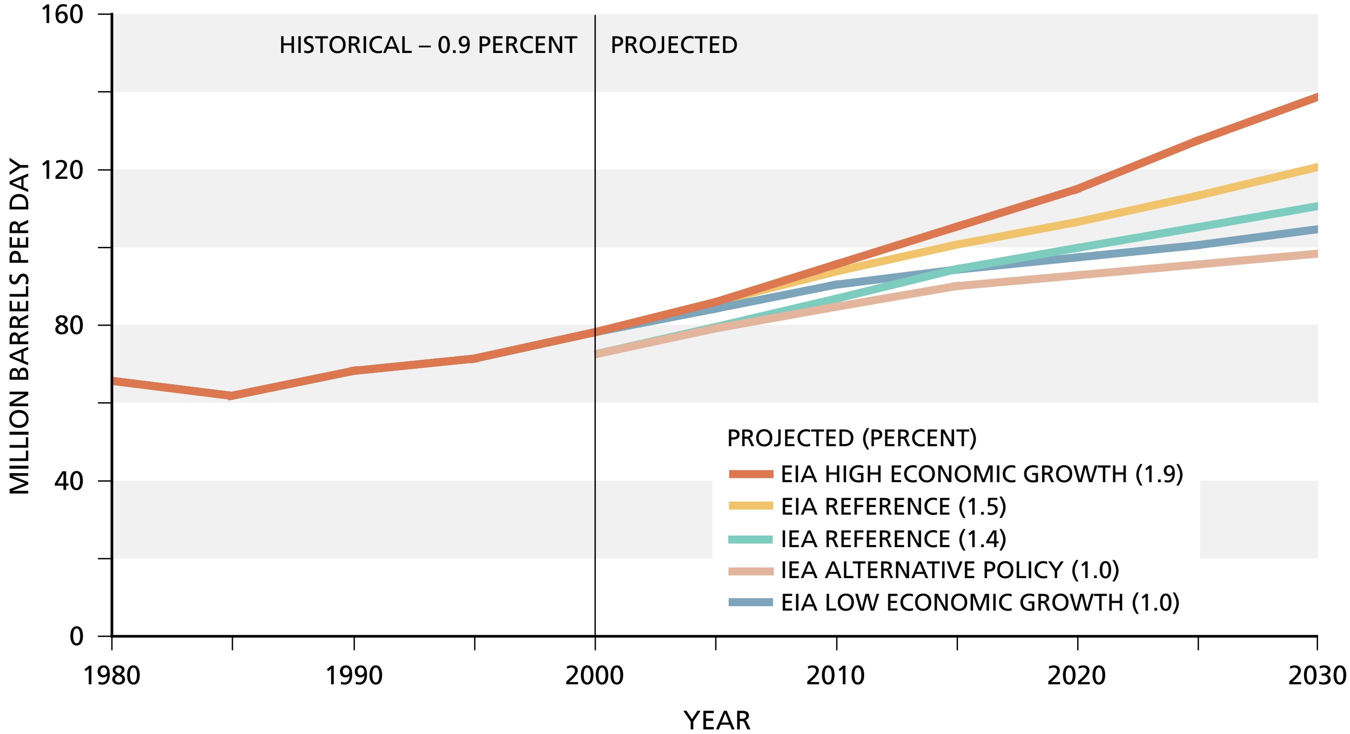


FIGURE 1-13. *World Petroleum Demand — Average Annual Growth Rates*

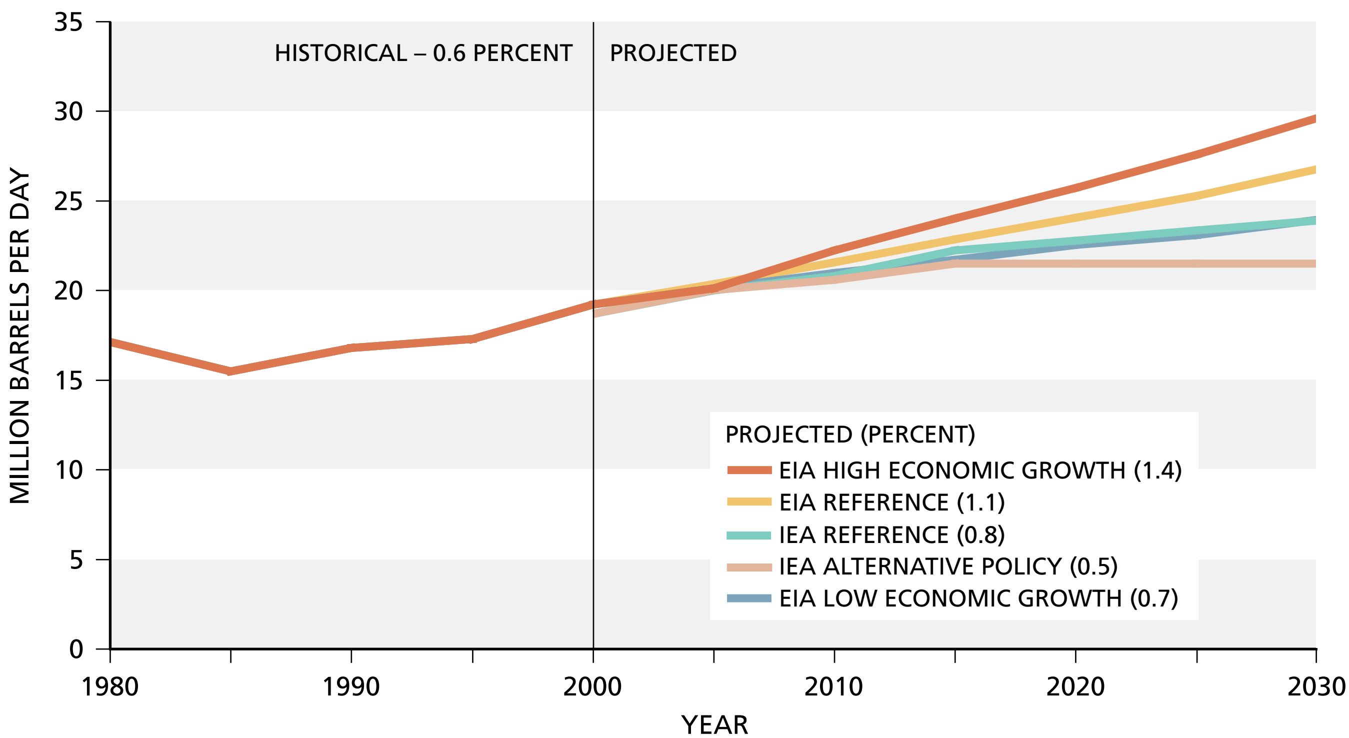


FIGURE 1-14. *U.S. Petroleum Demand — Average Annual Growth Rates*

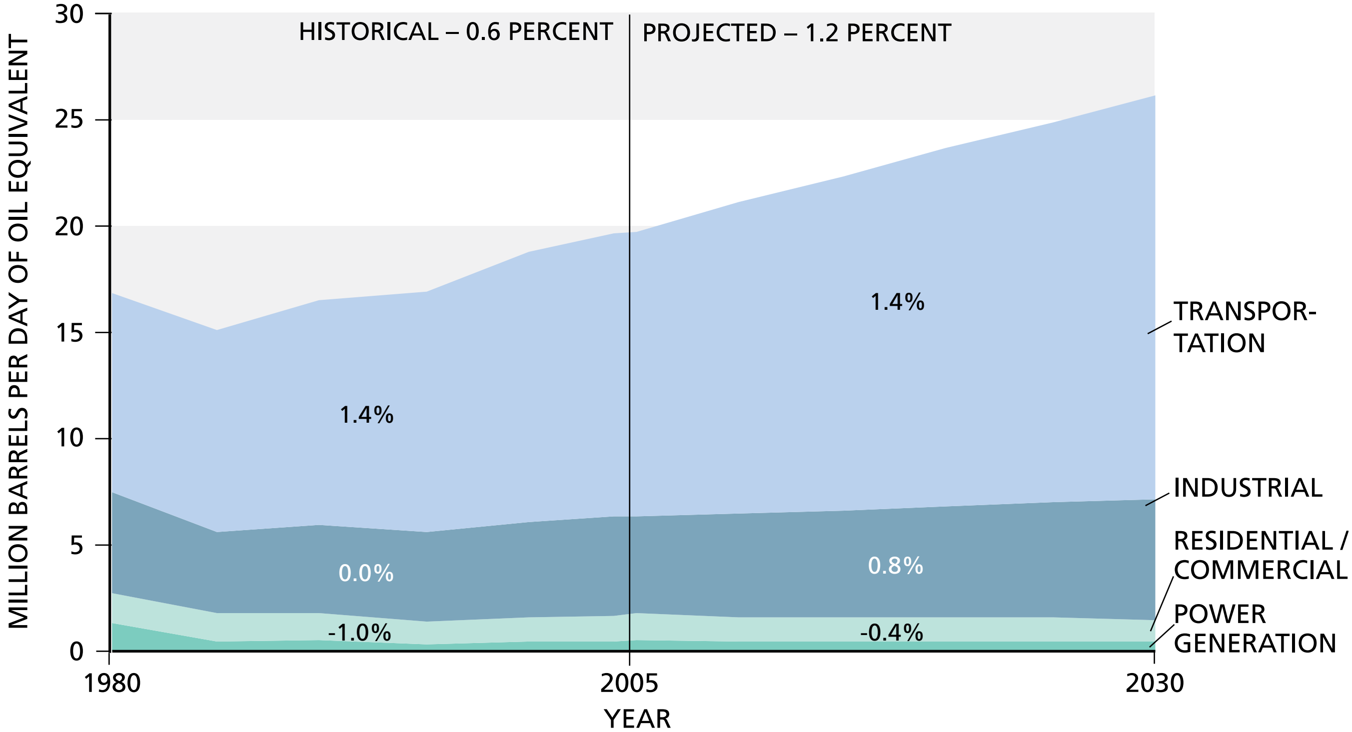


FIGURE 1-15. *U.S. Demand for Petroleum Liquids by Sector (EIA Reference Case) — Average Annual Growth Rates*

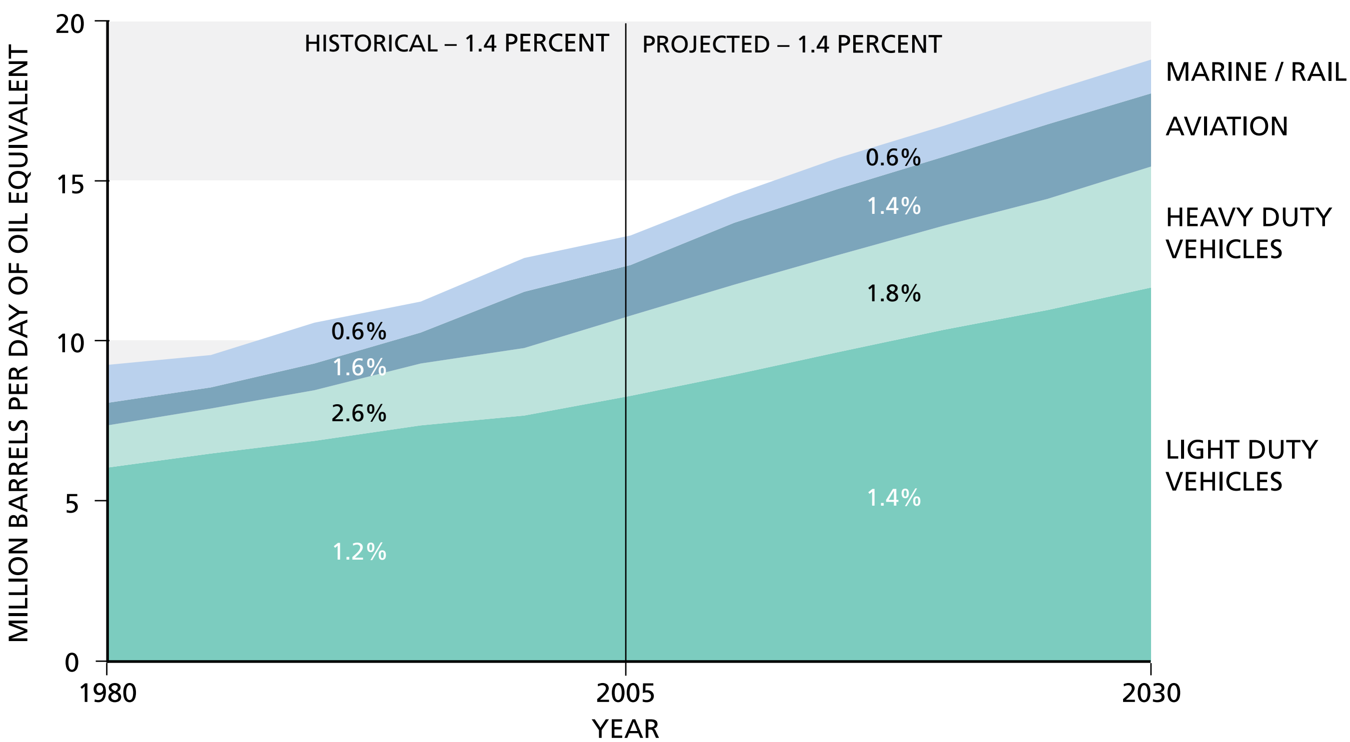


FIGURE 1-16. *U.S. Demand for Transportation Fuels by Transportation Mode (EIA Reference Case) — Average Annual Growth Rates*

The EIA Reference Case for the United States projects that in 2030 technology improvements will result in ~10 percent improvement in new light duty vehicle fuel consumption (Btu per mile) from 2005 levels. It is estimated that this includes technological improvements of ~30 percent at constant vehicle performance, and vehicle attribute changes that reduce this improvement by about half. Based on this study's analysis, technologies (drive-train and body improvements, and hybridization) exist, or are expected to be developed, that have the potential to reduce fuel consumption by 50 percent relative to 2005. This assumes constant vehicle performance, characteristics, and sales mix between light trucks and autos and entails higher vehicle cost.

Improvements beyond 50 percent will require breakthroughs in batteries or fuel cells, resulting in significantly higher vehicle costs and potentially significant infrastructure investments. The fuel efficiency improvement estimates beyond the initial 50 percent warrant careful scrutiny as other energy forms such as electricity and hydrogen are incorporated in the fuel mix. The conversion and transformation of primary fuels to secondary energy types may significantly decrease the overall energy efficiency of these advanced technologies.

Technologies exist to reduce new heavy-duty-truck fuel consumption by 15-20 percent in the United States by 2030, which is about equal to the EIA Reference Case assumption. These technologies (e.g., engine efficiency, rolling resistance, and aerodynamic improvements) will involve higher cost and require appropriate incentives. Operational improvements such as reduced idling and improved logistics can provide a benefit of 5 to 10 percent across the fleet during this period.

Advanced technology solutions, such as hybridization and fuel cells, offer fuel consumption reductions of an additional 25 percent, and applications would likely be initiated in local delivery, short-haul, medium-duty delivery trucks, and buses. As in the light duty vehicles, the conversion and transformation of primary fuels to secondary energy types may significantly decrease the overall energy efficiency of these advanced technologies.

Fuel consumption improvements for aircraft on the order of 25 percent are the basis for the EIA Reference Case. This is an aggressive projection and all of the known technologies appear to be included in the EIA estimates. New technologies will need to be discovered to achieve additional improvements in efficiency.

The EIA Reference Case is based on a 5 percent improvement in marine shipping fuel consumption by 2030. This improvement level is achievable with operational solutions and existing technologies. Improvements greater than 5 percent will require new hull designs and new propeller designs. Given the long life of ships (greater than 20 years), migration of these solutions into the fleet will not have a large impact until later in the study period. Operational changes, affecting the entire fleet, may be more significant sooner than technological improvements.

The EIA Reference Case assumes that fuel consumption will improve by 2.5 percent between 2005 and 2030 for rail use in the United States. Incremental improvements in engine design, aerodynamics, and use of hybrids have the potential to reduce new locomotive fuel consumption by up to 30 percent over 2005 technology. Rollout of new technology into the fleet is slow due to low turnover and will be difficult to achieve during the years considered in this study. More stringent emissions standards will tend to increase fuel consumption.

World natural gas demand is projected to grow 1.6 to 2.9 percent per year versus 2.6 percent per year historically (Figure 1-17). Despite the slowing of gas demand growth rates, gas is still projected to gain market share versus other energy sources in all cases. Natural gas demand grows in all regions. Gas demand ranges from 356 to 581 billion cubic feet per day in 2030, compared with world natural gas demand of 243 billion cubic feet per day in 2000. In all cases, the projected growth rate in U.S. natural gas demand is lower than the historical rate. U.S. natural gas demand ranges from 59 to 78 billion cubic feet per day in 2030, compared with 64 billion cubic feet per day in 2000 (Figure 1-18).

In contrast with projected U.S. oil demand, which is concentrated in the transportation sector (Figure 1-15), natural gas use in the United States is more evenly spread across three sectors: residential/commercial, industrial, and electric utility (Figure 1-19).

Worldwide, coal demand growth is projected to be faster in the future than in the past in all outlooks except for the Alternative Policy Case where the growth is slightly less than in the past. More than two-thirds

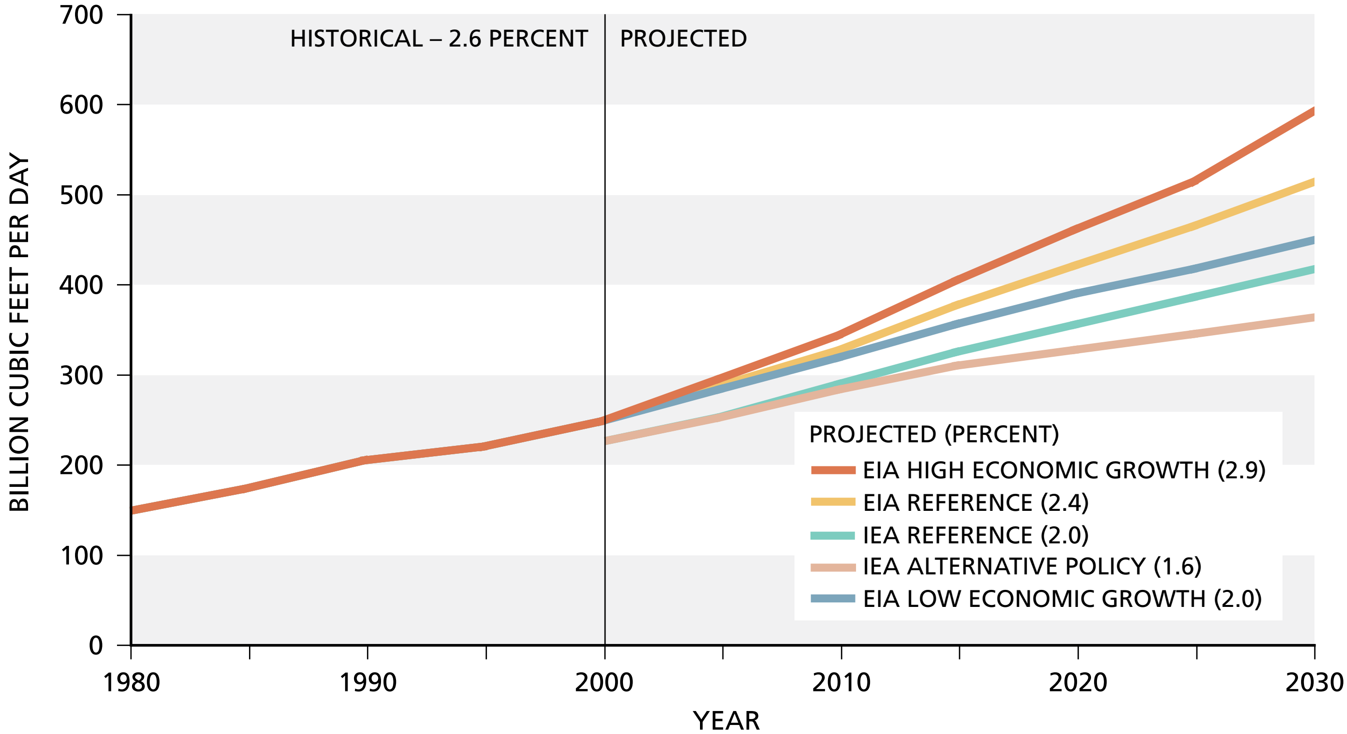


FIGURE 1-17. *World Natural Gas Demand — Average Annual Growth Rates*

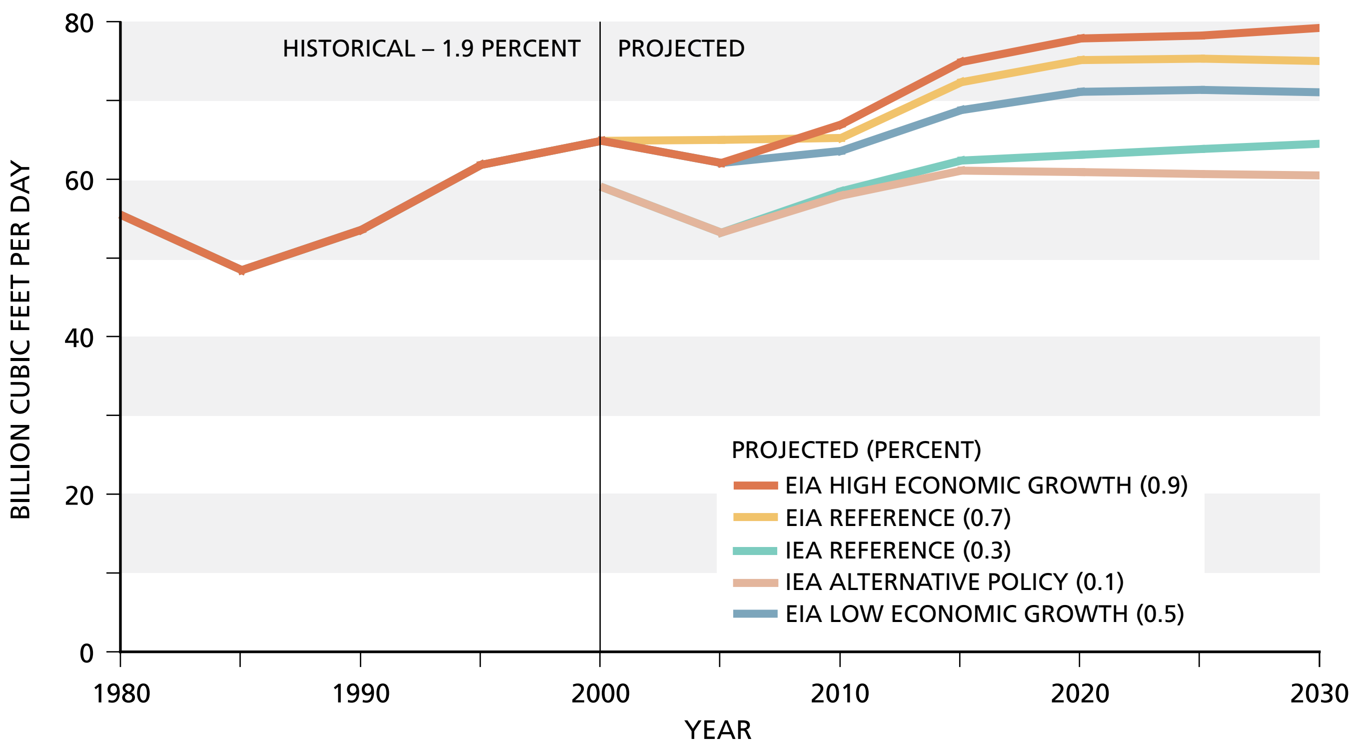


FIGURE 1-18. *U.S. Natural Gas Demand — Average Annual Growth Rates*

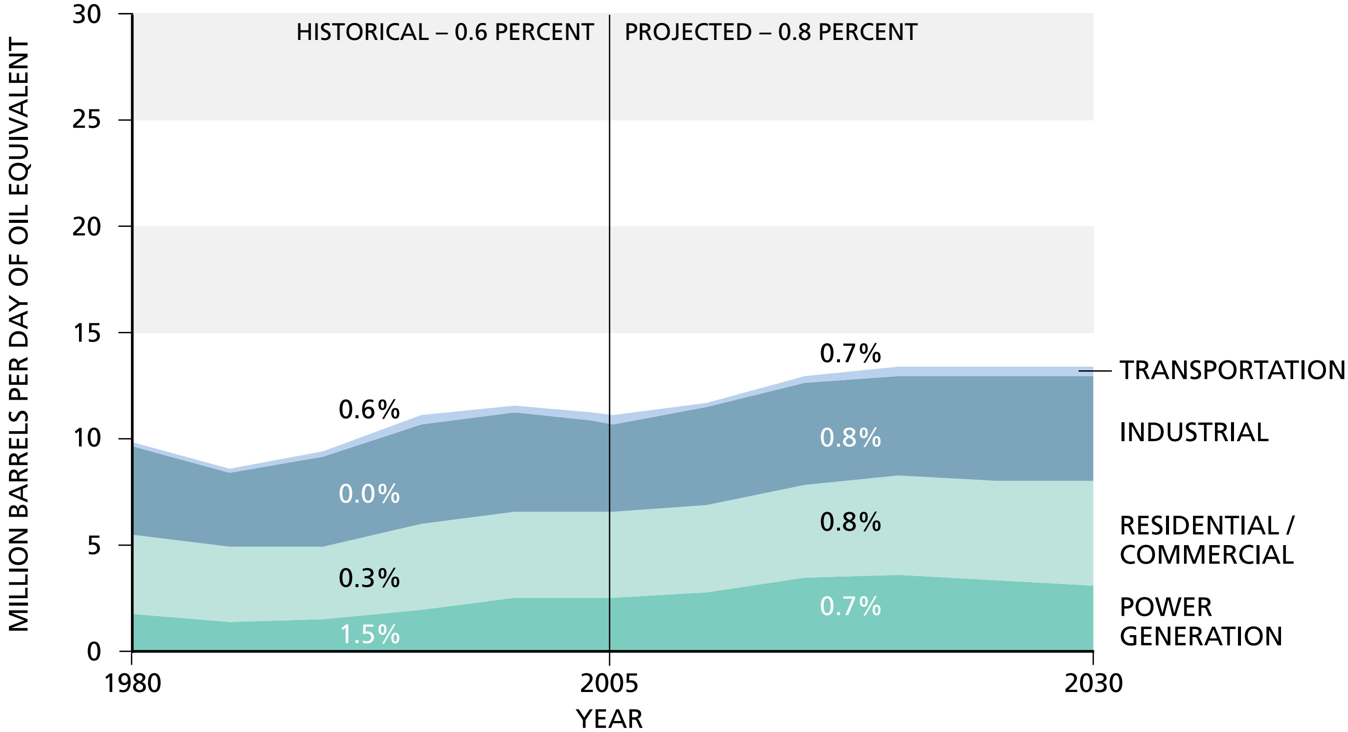


FIGURE 1-19. *U.S. Natural Gas Demand by Sector (EIA Reference Case) — Average Annual Growth Rates*

of the projected growth in coal demand from 2000 to 2030 is in China and India, where the economies are growing rapidly and coal is very competitive with other fuels. The indication is that share of total world energy consumption met by coal is projected to increase in all cases except where policies are enacted that place a limit on the use of coal.

Worldwide nuclear consumption growth in all outlooks is projected to be slower in the future than it has been in the past. The nuclear share of total worldwide energy demand declines in all projections except for the Alternative Policy Case, in which it increases very slightly. While the specific numbers are different in the U.S. projections, the trends are the same. The nuclear share of energy consumption is projected to decline slowly in the United States through 2030. The projections suggest that a major shift in nuclear policy will be required to increase the nuclear share of energy use.

The share of total worldwide energy consumption accounted for by other energy sources (hydro, biofuels, wind, solar, etc.) is projected to be higher in 2030 than in 2000.

As shown in Figure 1-20, worldwide carbon dioxide emissions grow in all of the projections. Carbon dioxide emissions are projected to range from 34 billion metric tons in 2030 in the IEA Alternative Policy Case to 51 billion metric tons in the EIA High Economic Growth Case, compared with 24 billion metric tons in 2000. In all cases, carbon dioxide emissions increase at about the same rate as energy demand. Carbon dioxide emissions in the United States are also expected to grow in all projections, although not as fast as for the world. In 2030, carbon dioxide emissions in the United States range from 6.3 billion metrics tons in the IEA Alternative Policy Case to 9 billion metric tons in EIA High Economic Growth Case (5.8 billion metrics tons in 2000).

The regional shares of energy use are projected to change over time. The share of total worldwide energy consumed in North America, OECD Europe, and Non-OECD Europe and Eurasia is projected to fall in all of the cases, while the share in Asia/Oceania grows. China is a major contributor to the substantial growth in Asia/Oceania share. In general, the change in the oil share of total worldwide oil consumed by region parallels the

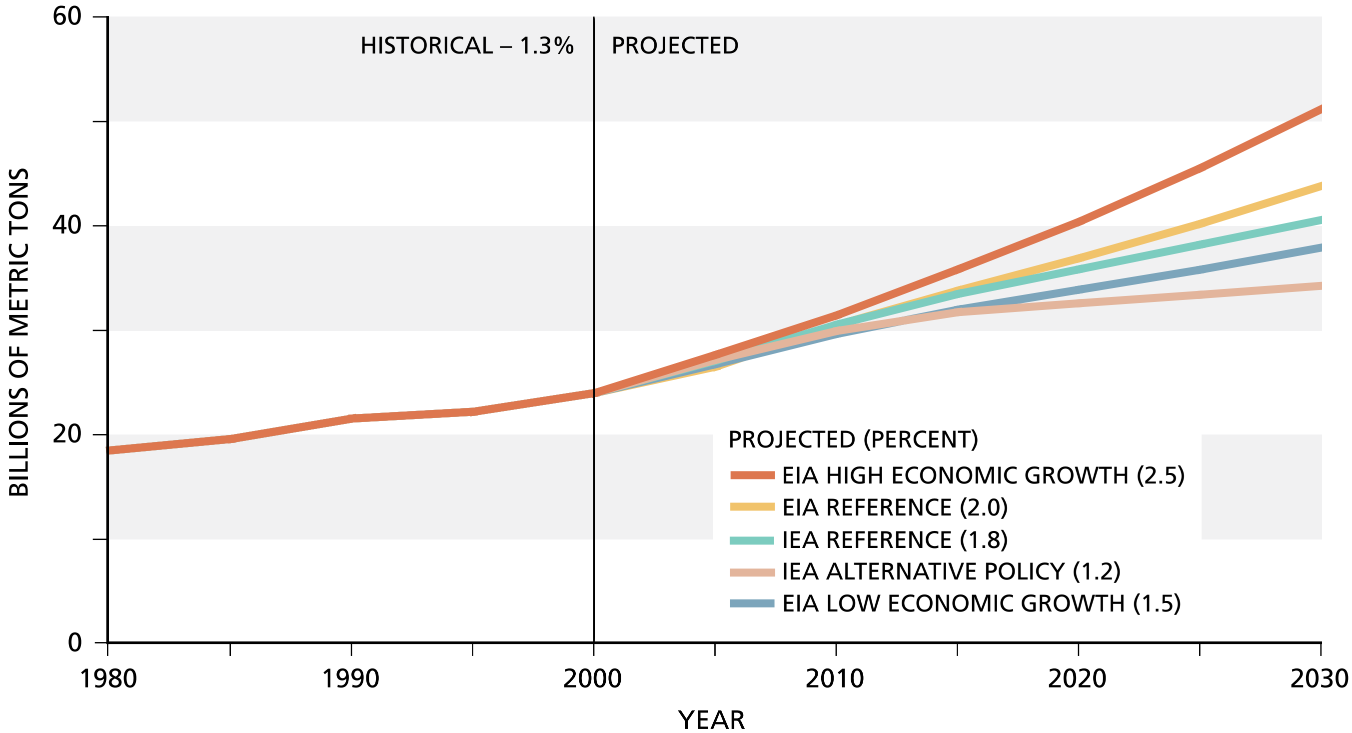


FIGURE 1-20. *World Carbon Dioxide Emissions — Average Annual Growth Rates*

change in the share of total energy consumption, with industrialized regions losing share and the Asia/Oceania oil share increasing significantly, as shown in Table 1-4.

Energy consumption per unit of GDP (energy intensity) is projected to decline in all regions. The Middle East, while not exhibiting the highest energy intensity in 2000, is projected to have the highest energy intensity in 2030 in all cases. North America, the region exhibiting the highest energy use per person in 2000, is still projected to have the highest energy use per person in 2030, but it declines in the IEA cases. Energy consumption per person in all other regions is projected to be higher than or equal to 2000 levels in 2030, as shown in Table 1-5.

Part of the study effort involved collecting energy demand projections from organizations other than EIA or IEA. Some of these projections were proprietary and, therefore, were collected by a third party with the data aggregated before being made available to study participants. Details of the aggregated data collection process are discussed in Chapter 7, "Methodology."

	2000 IEA	**2030 IEA Ref. Case**
North America	27%	21%
Central and South America	5%	5%
OECD Europe	18%	13%
Non-OECD Europe & Eurasia	10%	8%
Middle East	4%	6%
Asia/Oceania	31%	41%
Africa	5%	6%

TABLE 1-4. *Regional Energy Shares*

The results of the aggregated proprietary data collection effort confirmed that using the EIA and IEA projections was reasonable. As can be seen on

	2000 IEA	2030 IEA Ref. Case
North America	9.51	6.18
Central and South America	6.53	4.88
OECD Europe	6.49	4.35
Non-OECD Europe & Eurasia	21.27	9.40
Middle East	15.23	12.04
Asia/Oceania	8.04	4.64
Africa	12.00	7.07

TABLE 1-5*. Regional Energy Intensity (1,000 Btu/2000$ GDP)*

Figure 1-21, the aggregated proprietary projections for all three levels of the total submissions output (average of the two highest submissions, average of the two lowest submissions, and the average of all submissions) fall generally in the range of the EIA and IEA projections for total energy. The same is true for all the major energy types.

For the U.S. situation, there were an insufficient number of submissions to provide a high and low average. Figure 1-22 shows that the average for the proprietary data is in the range of the EIA and IEA projections for total energy. Similar observations hold for major energy types.

Other studies were provided to the study effort as public projections. Generally, the information in these studies was in less detail than provided in the EIA and IEA studies. There were other organizations that had sufficient data available to provide partially complete data input templates. The other studies support the finding that the EIA and IEA projections provide a reasonable range of results for assessing energy issues. With the exception of the IEA Alternative Policy Case, policy assumptions underpinning the projections are extensions of polices in place today. It is interesting to note that projections with lower energy demand growth rates are based on lower economic growth rates. As an example of the congruence of study results, the energy and carbon dioxide growth rates are shown in Table 1-6. There were other projections

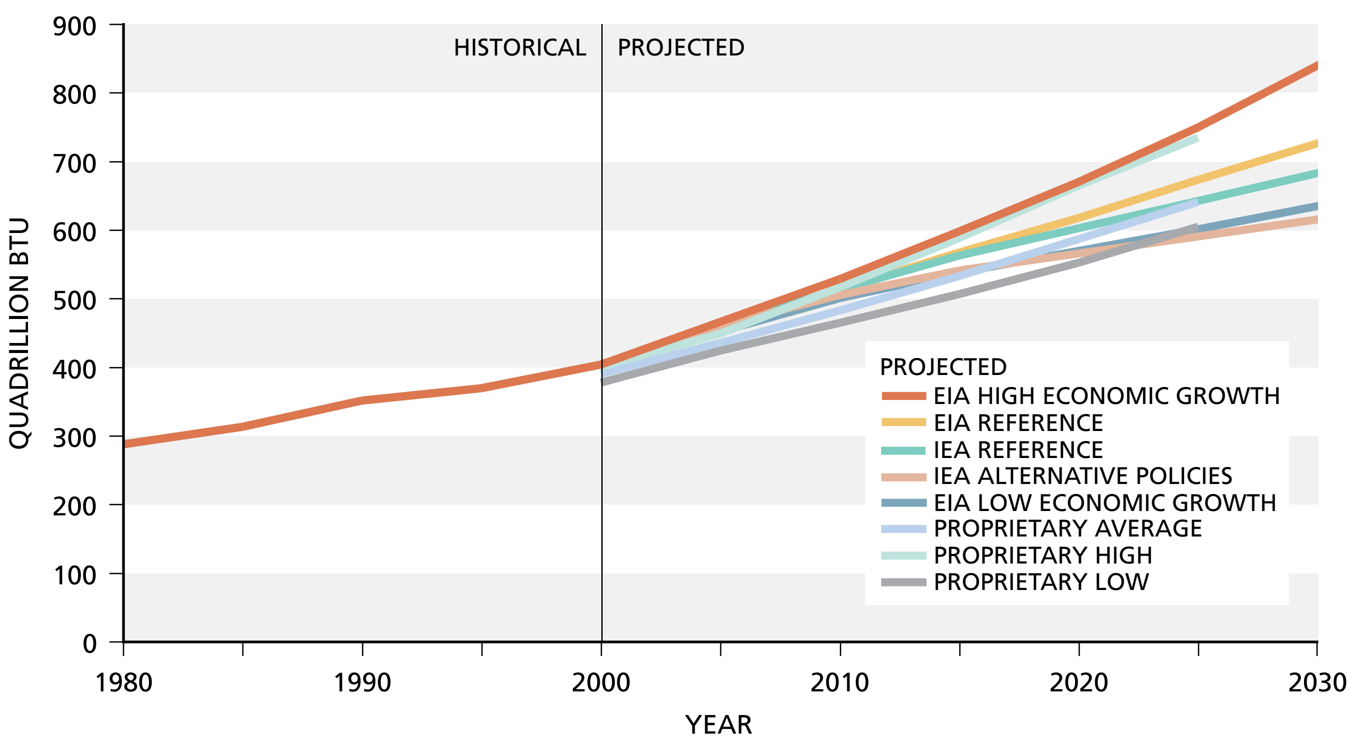


FIGURE 1-21. *World Energy Demand — Public and Proprietary Projections*

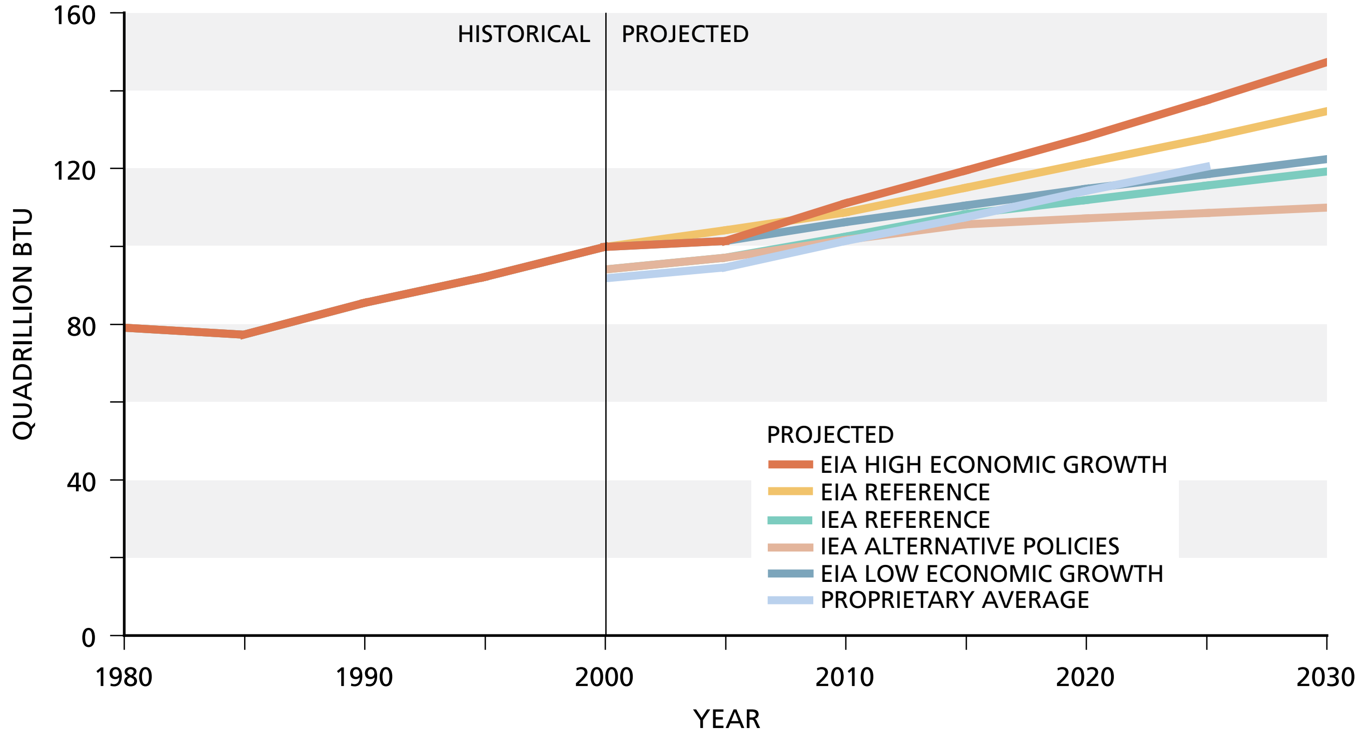


FIGURE 1-22. *U.S. Energy Demand — Public and Proprietary Projections*

	World Economy	World Population	World Energy	World CO_2
Energy Information Administration – reference	3.7%	1.0%	1.9%	2.0%
Energy Information Administration – low economic	2.9%	1.0%	1.4%	1.4%
Energy Information Administration – high economic	4.5%	1.0%	2.5%	2.6%
International Energy Agency – reference	3.7%	1.0%	1.6%	1.7%
International Energy Agency – alternative policy	3.4%	1.0%	1.2%	1.0%
European Commission	3.1%	0.9%	1.7%	1.6%
Institute of Energy Economics, Japan	3.1%	1.0%	1.7%	1.8%
Greenpeace & European Renewable Energy Council	3.1%	0.9%	1.4%	1.5%
U.S. Climate Change Science Program – MERGE	2.6%	0.8%	1.0%	1.2%
U.S. Climate Change Science Program – MINICAM	2.3%	0.9%	1.7%	1.5%
U.S. Climate Change Science Program – IGSM	3.1%	1.0%	1.9%	2.1%

TABLE 1-6. *Outside Study Comparison of Average Annual Growth Rates from 2004 to 2030*

that were submitted or captured in other efforts that did not have sufficient definition of underlying bases or data detail to be included in the comparison.

The Petroleum Federation of India (PFI) provided a series of outlooks for India. These projections offer perspective on the expected Indian energy situation. The data are limited, but there is sufficient information to look at the 2020 energy mix. The PFI total energy projection has a 2004 to 2020 energy demand growth rate of 3.3 percent per year for the Business as Usual Case. This growth rate is slightly higher than the 3.0 and 2.8 percent per growth rates developed in the EIA and IEA Reference Cases, respectively. One difference between the projections is in petroleum demand, where the PFI projection has an indicated 2004 to 2020 growth rate of 4.7 percent per year while the other two projections have indicated growth rates of 2.6 to 3.2 percent per year. Offsetting this difference, to some extent, is the lower growth in coal use expected by PFI relative to the other projections.

McKinsey Global Institute conducted a study in November 2006 that approached the issue of the potential for energy savings (*Productivity of Growing Global-Energy Demand: A Microeconomic Perspective*). The study provides an assessment of potential savings without regard for the time needed to achieve the estimated savings, or for the practicality of achieving them. The McKinsey study used 2020 as its horizon year. As indicated in Table 1-7, the McKinsey study suggests that between 2003 and 2020 essentially all U.S. energy growth, and about 75 percent of world energy growth, could be recovered by efficiency/conservation measures assuming they could be instituted within the time period. The McKinsey study adds support to the NPC study recommendations that efficiency/conservation measures are an important piece for providing a balanced U.S. energy program.

When preparing its International Energy Outlook, the EIA uses the Annual Energy Outlook as a major source of U.S. data. The EIA released an updated version of its Annual Energy Outlook during the first quarter of 2007. Table 1-8 contains a 2004 to 2030 growth rate comparison between the 2006 and 2007 Annual Energy Outlooks. There are only

	McKinsey		**EIA**	
	U.S.	**World**	**U.S.**	**World**
Energy consumption				
2003 – quadrillion Btu	92	422	101	433
2020 – quadrillion Btu	113	615	121	613
Growth – percent per year	1.2%	2.2%	1.0%	2.1%
2020-2003 – quadrillion Btu	21	193	19	181
Potential 2020 reduction				
Low estimate – quadrillion Btu	19	117	19	117
High estimate – quadrillion Btu	27	173	27	173
Percent of 2003 to 2020 growth				
Low – percent	90%	61%	99%	65%
High – percent	129%	90%	140%	96%

Sources: McKinsey Global Institute, *Productivity of Growing Global-Energy Demand: A Microeconomic Perspective*, November 2006; Energy Information Administration, *Annual Energy Outlook 2007*.

TABLE 1-7. *Comparison of Data from McKinsey Global Institute and Energy Information Administration*

	AEO 2006	AEO 2007
Primary Energy		
Petroleum Products	1.1%	1.0%
Natural Gas	0.7%	0.6%
Coal	1.7%	1.6%
Nuclear	0.4%	0.5%
Other	1.7%	1.6%
Total	1.1%	1.1%
Sectors		
Residential	0.8%	0.7%
Commercial	1.6%	1.6%
Industrial	0.9%	0.7%
Transportation	1.4%	1.3%
Electric Generation	1.3%	1.2%
Subtotal	1.2%	1.1%
Electricity	1.6%	1.4%
Total	1.1%	1.1%
Gross Domestic Product	3.0%	2.9%

TABLE 1-8. *Comparison of EIA Annual Energy Outlook 2006 and 2007 Reference Cases' Average Annual Growth Rates from 2004 to 2030*

minor differences between the two projections, which suggests that the overall analysis that uses the 2006 International Energy Outlook (IEO 2006) is basically unchanged as a result of the recently released EIA U.S. outlook. Data availability issues have lead to some of the analyses that support various components of the demand effort being based on the AEO 2007, which should not present any difficulties.

The EIA released the 2007 version of the International Energy Outlook (IEO 2007) on May 21, 2007. IEO 2007 suggests no changes in the overall demand related conclusions of the National Petroleum Council's Global Oil and Gas Study. However, there are some interesting differences between IEO 2006 and IEO 2007 that should be noted. A comparison between the two Reference Case outlooks is shown in Table 1-9.

World economic growth is higher in IEO 2007. From a regional perspective, the major differences are in Asia/Oceania where projected economic growth is faster, and in North America, where it is slower. All other regions show a greater growth in economy than in IEO 2006 with the Non-OECD Europe and Eurasia region projected difference slightly greater than in other regions.

While the economic growth projections used as a basis for IEO 2007 are generally greater than in IEO 2006, energy growth projections are equal or less than they were in IEO 2006. This suggests that the energy efficiency/conservation assumptions underpinning IEO 2007 are greater than in IEO 2006. Energy intensities (energy use per unit of economic activity) calculated from the two outlooks show that in all regions except North America energy intensity is lower in IEO 2007, supporting the idea that there is more energy efficiency/conservation incorporated in IEO 2007 than in IEO 2006.

The projected regional energy consumption pattern in IEO 2007 is little different than in IEO 2006. The biggest difference is in Asia/Oceania, where projected 2030 energy use share increased from 37.6 percent to 39.2 percent.

Considering the type of energy consumption, the most significant difference appears to be a lower projection of world natural gas use. Both nuclear and coal use are projected to be higher. There was an accounting convention change between the two outlooks for the way in which renewable liquids were handled. In IEO 2007, liquids from renewables are shown as petroleum products instead of as "other." This change accounts for most of the reduction in other energy use, but suggests that petroleum liquids from more traditional sources are somewhat lower in IEO 2007 than in IEO 2006.

An output from both projections is an estimate of carbon dioxide emissions. In 2030, the IEO 2006 estimate for Reference Case carbon dioxide emissions was 43.7 billion metric tons. The IEO 2007 carbon dioxide emissions estimate for 2030 is 42.9 billion metric tons.

	2003–2030		2030	2030	2007-2006	2030	2030
	Growth Rate (%/Year)		Share (%)		Difference (Quadrillion Btu)	Intensity (1,000 Btu/ 2000$ GDP)	
	IEO 2006	IEO 2007	IEO 2006	IEO 2007		IEO 2006	IEO 2007
Primary Energy							
Petroleum Products	1.4%	1.4%	33.1%	34.1%	-0.2		
Natural Gas	2.4%	2.0%	26.3%	24.3%	-19.5		
Coal	2.5%	2.6%	27.1%	28.4%	3.6		
Nuclear	1.0%	1.5%	4.8%	5.7%	5.0		
Other	2.4%	1.8%	8.6%	7.6%	-8.9		
Total	2.0%	1.9%	100.0%	100.0%	-20.0		
Regions (Energy)							
North America	1.3%	1.2%	23.0%	23.0%	-4.6	5.99	6.01
OECD Europe	0.7%	0.5%	13.1%	12.7%	-5.3	4.87	4.48
Central and South America	2.8%	2.4%	6.3%	5.9%	-4.3	5.49	4.67
Middle East	2.5%	2.5%	5.2%	5.4%	0.5	9.23	9.03
Non-OECD Europe and Eurasia	1.8%	1.4%	10.9%	10.2%	-7.5	8.60	7.24
Africa	2.6%	2.3%	3.7%	3.5%	-1.9	3.85	3.36
Asia/Oceania	3.1%	3.1%	37.6%	39.2%	3.2	4.20	3.56
Total	2.0%	1.9%	100.0%	100.0%	-19.9	5.14	4.55
Gross Domestic Product (billion 2000 dollars)					**Difference (B $2000)**		
North America	3.1%	2.9%	19.8%	17.4%	-849		
OECD Europe	2.2%	2.3%	13.8%	12.9%	519		
Central and South America	3.8%	4.0%	5.9%	5.7%	541		
Middle East	4.2%	4.3%	2.9%	2.7%	145		
Non-OECD Europe and Eurasia	4.4%	4.7%	6.5%	6.4%	691		
Africa	4.4%	4.6%	5.0%	4.8%	438		
Asia/Oceania	4.8%	5.5%	46.1%	50.0%	12,498		
Total	3.8%	4.2%	100.0%	100.0%	13,983		

TABLE 1-9. *Comparison of EIA International Energy Outlook — 2006 and 2007 Reference Cases*

ELECTRIC GENERATION EFFICIENCY

Power plant efficiencies presented in the EIA and IEA outlooks both show improvements over time. These expected improvements mainly come from the replacement of retired old plants with new plants that have better efficiencies. There are a few changes that can be made to make an existing unit more efficient. However, these changes typically will only result in a few percentage point improvements to efficiency.

Given the large aggregate capacity of existing coal-fired power plants and their long useful lives, efforts to improve the average efficiency of the existing stock by 1 or 2 percent could have a significant near term impact on fuel consumption rates and greenhouse gas emissions. Efficiency improvement potential for existing U.S. power plants is related to the age of the plant, the age of specific pieces of equipment in a plant, a plant's design, and the economics of the specific plant situation. When all is considered, most plants will fall in the 3-6 percent range of possible improvement. The practical or economic values will be lower. The newer plants might be in the 2-4 percent range and a certain population might be 2 percent or less because they were already upgraded. The overall range of potential efficiency improvement for existing U.S. coal fired power plants should be in the 2 to 4 percent range.[2]

Much of the discussion surrounding power plant efficiency will focus on the heat rate (Btu per kilowatt-hour). This is an ideal measure of efficiency since it defines the ratio of the input as fuel (Btu) to output as power (kilowatt-hour). The efficiency of a new power plant is largely a function of economic choice. The technology is well understood in order to produce a highly efficient plant. In order to produce higher efficiencies, higher pressures and temperatures are required. This increases the cost of the plant as special alloy materials will be needed. Technology improvements could assist by lowering the cost of these special materials through discovery and better manufacturing process.

Coal power plant efficiency merits much focus since coal represents over 50 percent of current generation in the United States. Many countries in the world from Germany to Japan have demonstrated coal plants with heat rates of less than 9,000 Btu per kilowatt-hour. The United States has also demonstrated such technology since the 1950s. However, the U.S. coal fleet current operating heat rate is nowhere near those levels, at 10,400 Btu per kilowatt-hour.

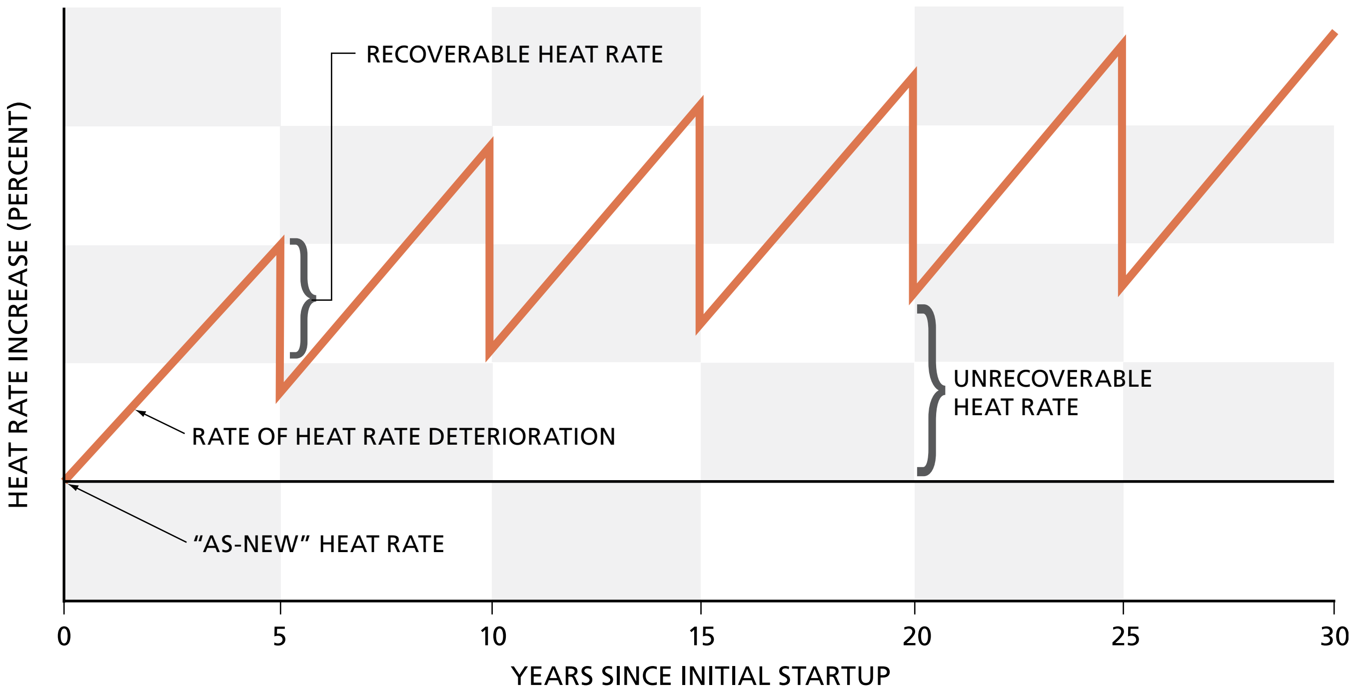
Existing coal-fired power plants worldwide do not achieve the highest efficiency possible based on their design. The efficiency loss can be categorized as controllable or non-controllable. Controllable losses are generally due to poor operation and maintenance practices. Non-controllable losses are due to environmental conditions (e.g., cooling-water temperature), dispatching requirements (e.g., customer demand), and normal deterioration.

Deterioration naturally occurs and, if left unchecked, can become substantial. Therefore, some amount of normal deterioration will always be present and non-controllable. Most of the normal deterioration can be recovered with regularly scheduled maintenance intervals, the frequency of which determines the average based on the resulting saw-tooth curve shown in Figure 1-23. There is a gradual increase in the unrecoverable portion as the unit ages, which would require a replacement rather than a refurbishment to eliminate. Poor maintenance practices regarding the timing of the intervals and the amount of refurbishment may result in excessive deterioration and is controllable.

Figure 1-24 shows historical and projected heat rates from U.S. natural gas and coal-fired power plants. Historical calculations are based upon EIA data that include both central station generation and end-use generation of electricity. The post-war boom of the late 1940s and 1950s saw a large increase in new power plants. However, these were, by today's standards, highly inefficient plants, with the overall fleet heat rate starting in 1949 at nearly 15,000 Btu per kilowatt-hour. By the end of the 1950s, more-efficient plant constructions drove the fleet heat rate to about 10,300 Btu per kilowatt-hour, where it remained relatively unchanged until the end of the century.

The overbuilding of natural gas combined-cycle units in the late 1990s decreased the natural gas fleet heat rate below 9,000 Btu per kilowatt-hour, where it currently resides. However, with the recent higher natural gas prices, coal generation still represents over 50 percent of current U.S. power generation. Therefore, overall U.S. fleet heat rate was not affected by the large gas combined-cycle build since coal-fired heat rates remain around 10,400 Btu per kilowatt-hour.

2 Equipment Refurbishing and Upgrading Options (taken from Asia Pacific Economic Cooperation document, June 2005).



Source: General Electric GER-3696D, *Upgradable Opportunities for Steam Turbines*, 1996.

FIGURE 1-23. *Change in Heat Rate over Time*

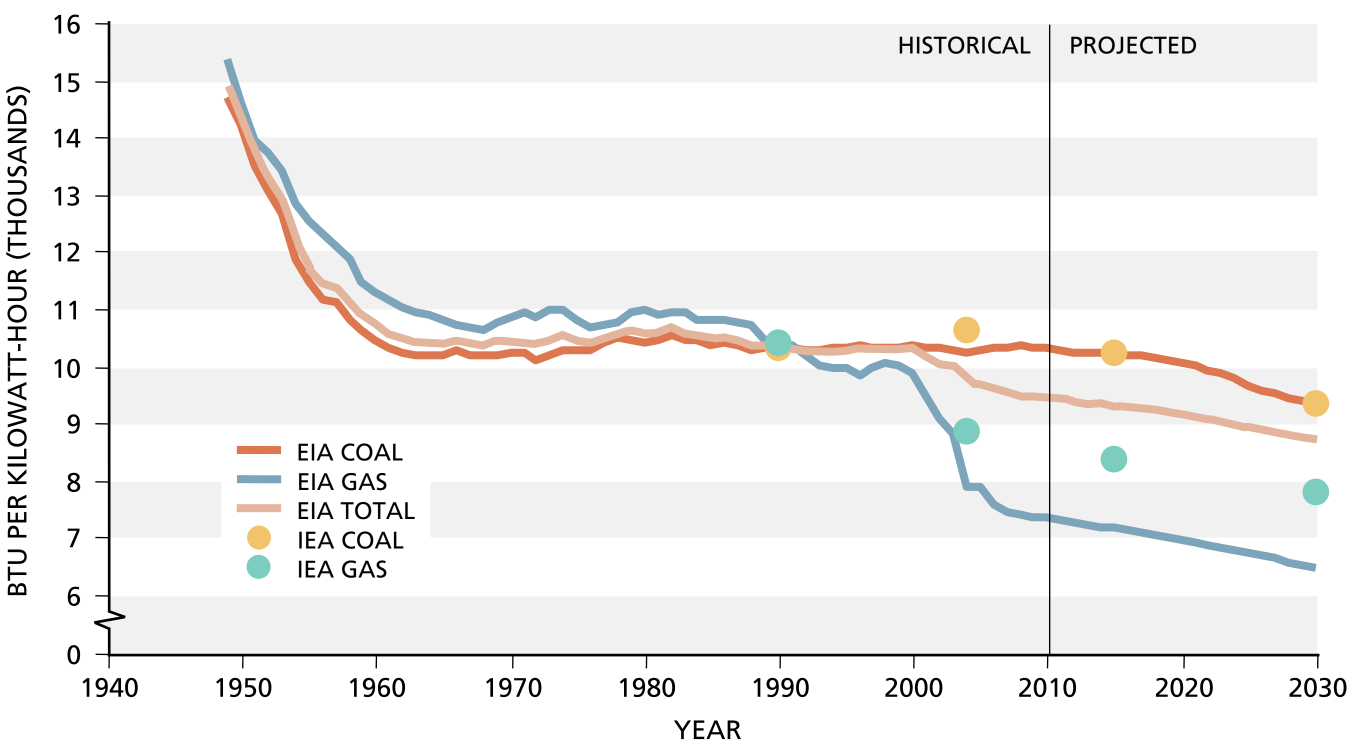


FIGURE 1-24. *U.S. Operating Heat Rates*

The EIA is projecting the natural gas fleet heat rate to continue to improve. Around the year 2023, electricity generation from natural gas units decreases faster than consumption, resulting in a slight increase to 8,300 Btu per kilowatt-hour. Currently, best technology combined-cycle units can achieve ~5,700 Btu per kilowatt-hour [General Electric H-System]. The gas heat rate includes combustion turbine plants that could have heat rates as high as 13,000 and as low as 8,550 Btu per kilowatt-hour in the future according to the EIA. These types of units will continue to be needed as they have the ability to turn on and off over a short time period leading to increased system stability.

The EIA projects moderate improvements in the coal fleet heat rate, achieving 9,700 Btu per kilowatt-hour by 2030. In terms of percentage improvement, it is about the same trend as gas units. This indicates many more new coal plants as compared to new gas plants in the projection. To see any appreciable improvement in fleet heat rate, a large number of new, efficient units would need to replace a large number of old, inefficient units and/or existing units would have to be retrofitted. With 40-year life spans and high capital costs (vs. natural gas plants) to construct, and risk of a CO_2-constrained environment, this is not achieved very quickly. The difference in fuel price (coal vs. natural gas) is another major driver for increased efficiencies in gas plants compared to coal plants. Major increases in combined-cycle efficiencies will make those units more competitive with coal in dispatch. With coal's current fuel price advantage, there is less incentive to make wholesale improvements in efficiency versus focusing on availability. Table 1-10 shows the EIA assumptions for new build heat rates for 2005, n^{th}-of-a-kind plant in the future and the best observed heat rates to date. Observed data for combustion turbines are not provided because efficiency is not their primary role in the supply stack. These units are used primarily as peakers, where efficiency is not of utmost concern.

Because historical data do not align properly between EIA and IEA due to differences in data definitions, heat-rate improvements were examined for the world and China, as opposed to absolute heat-rate values. Figures 1-25, 1-26, 1-27 show the percentage improvements in heat rate for EIA and IEA from each agency's base year. As expected, heat-rate improvements in

Technology	Heat Rate in 2005	Heat Rate n^{th}-of-a-kind (% improvement from 2005)	Best Current (2004)*
Scrubbed Coal	8,844	8,600 (2.8%)	8,842†
Integrated Gasification Combined Cycle (IGCC)	8,309	7,200 (13.3%)	N/A
IGCC w/carbon sequestration	9,713	7,920 (18.5%)	N/A
Conventional Combined Cycle	7,196	6,800 (5.5%)	6,335‡
Advanced Combined Cycle	6,752	6,333 (6.2%)	N/A
Advanced Combined Cycle w/carbon sequestration	8,613	7,493 (13.0%)	N/A
Conventional Combustion Turbine	10,842	10,450 (3.6%)	N/A
Advanced Combustion Turbine	9,227	8,550 (7.3%)	N/A

* "Operating Performance Rankings Showcase Big Plants Running Full Time," Electric Light & Power, Nancy Spring, managing editor, November 2005.
† Coal = TVA, Bull Run Plant.
‡ Conventional Combined Cycle = Sempra, Elk Hills Power.

TABLE 1-10. *EIA Heat-Rate Assumptions (Btu per Kilowatt-Hour)*

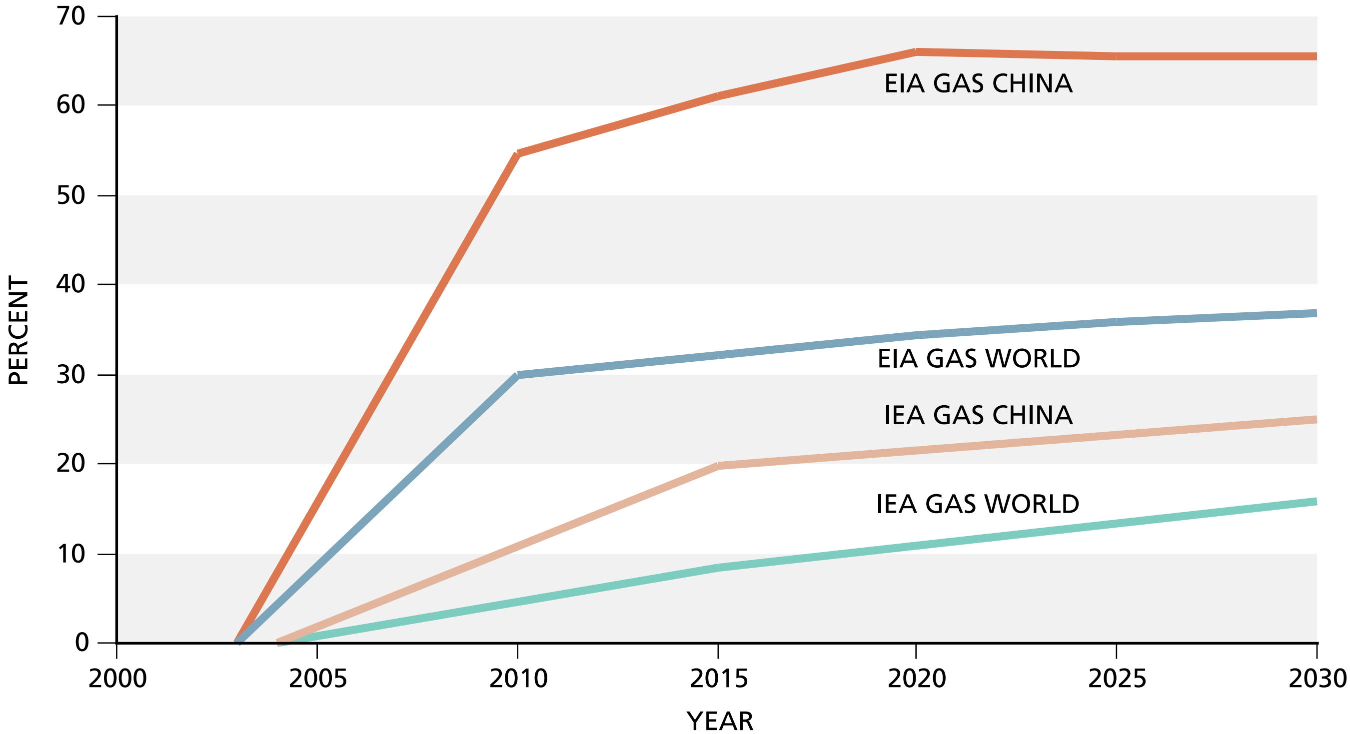


FIGURE 1-25. *Natural Gas Heat Rate Improvements*

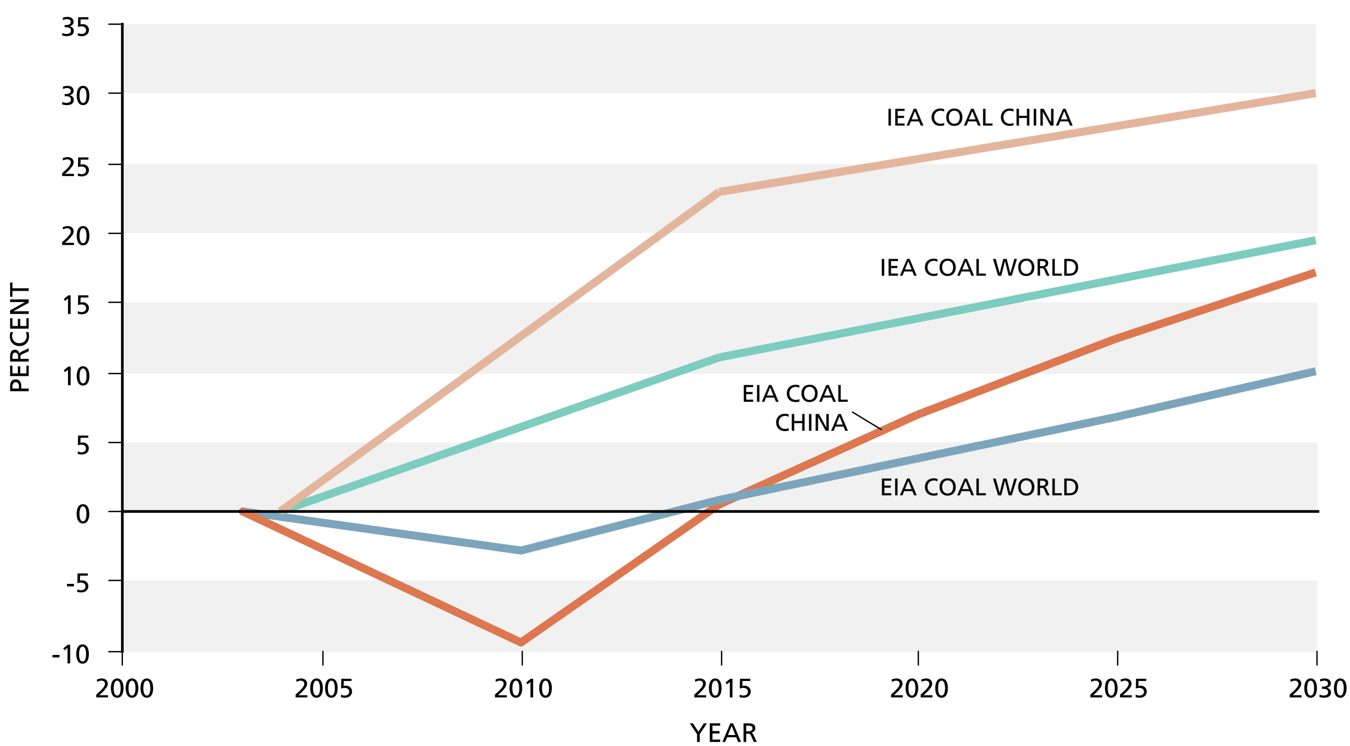


FIGURE 1-26. *Coal Heat Rate Improvements*

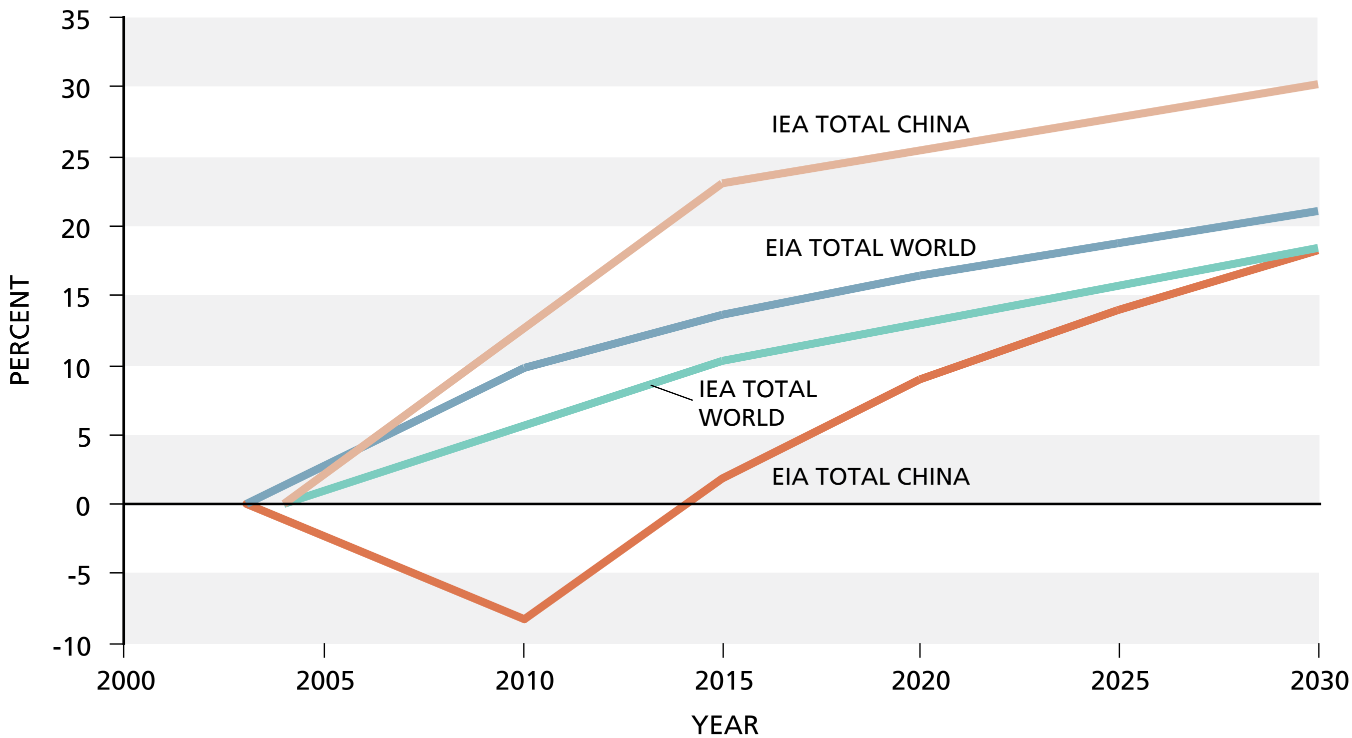
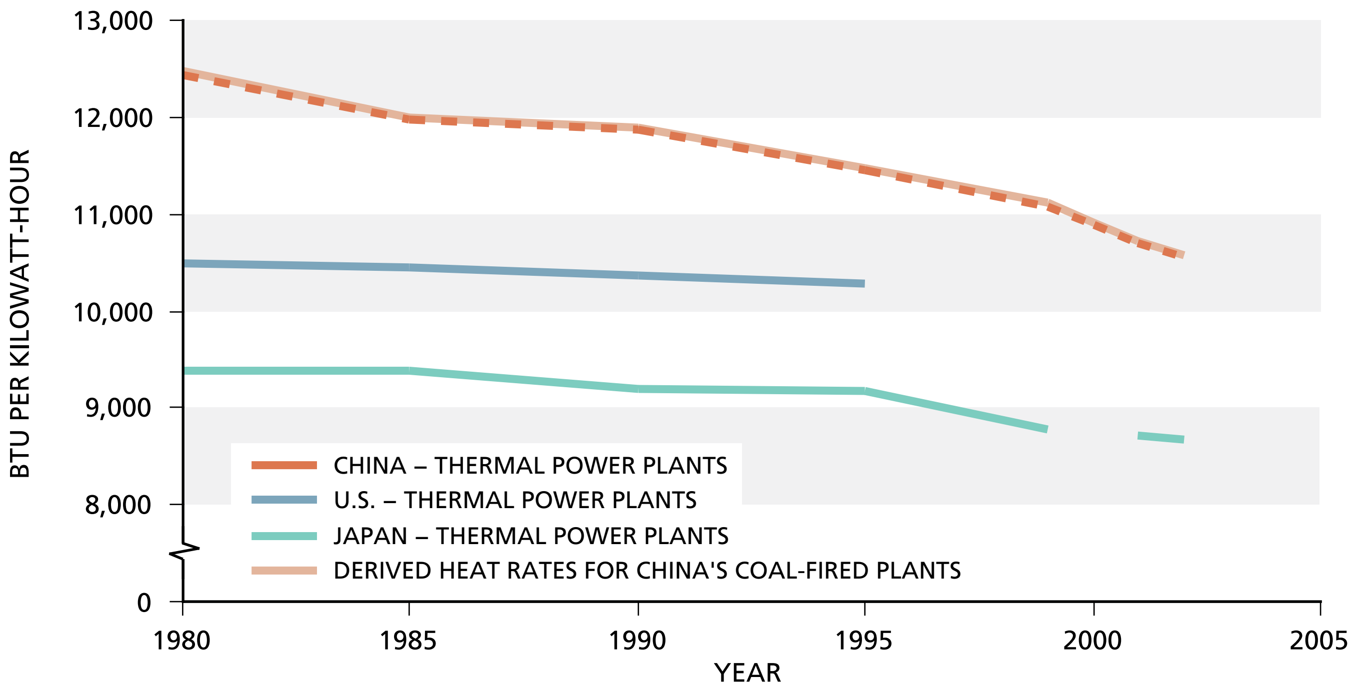


FIGURE 1-27. *Total Heat Rate Improvements*

China are projected to outpace worldwide improvements. Rapidly growing power demand is expected to drive a large increase in the number of new builds. With a larger percentage of fleet capacity coming from newer, efficient units, it is expected that overall improvements would increase rapidly in China. Worldwide heat-rate improvements are projected to increase moderately for both gas and coal plants according to both EIA and IEA. Again, this is the result of gradual replacement of older, inefficient units that have outlived their economic lives with new, efficient ones. The slower pace of this replacement leads to the slower increase in efficiency when compared with China alone.

An important distinction to note between the EIA and IEA projections is the heat-rate improvements for coal and natural gas. The EIA projects natural gas improvements for the world and China to greatly outpace improvements to coal-fired generation. Inversely, the IEA projects coal to improve more rapidly than for natural gas-fired plants. There are two schools of thought that can justify either scenario. One could argue that gas heat rates are expected to rapidly improve due to a large buildup of highly efficient combined-cycle units. This is the same phenomenon that was seen in the United States during the 1990s. With a rapid increase of combined-cycle units, the gas heat rate quickly improves. The large improvements in coal-fired heat rates could be justified by determining that gas-fired heat rates are asymptotically approaching their maximum achievable efficiency (though not achievable, 100 percent efficiency is 3,412 Btu per kilowatt-hour). Steam cycle coal units theoretically have more room for improvement since they are less efficient from the start.

Recently, a blue book of energy in China (The Energy Development Report of China, Edited by M. Cui, etc., Social Sciences Academic Press of China, 2006) reports that the average heat rates of thermal power plants in China improved 15.2 percent from 1980 to 2002. Figure 1-28 shows the average heat rates of thermal power plants in China, compared with those in the United States and Japan. Natural gas consists of only a small percentage of China's energy mix on a Btu basis. For example, natural gas comprised only 2.62 percent in 2002, in comparison to 65.28 percent for coal. In 2002, 54.7 percent of coal consumption in China went to power plants, and the report does not give the percentage of natural gas consumed by the power plants, but states that most of its natural gas went to residential use. The IEA World Energy



Source: The Energy Development Report of China, Edited by M. Cui, etc., Social Sciences Academic Press of China, 2006.

FIGURE 1-28. *Historical Heat Rates*

Outlook 2006 reports the electricity generation from thermal power plants. For China, coal consists of more than 90 percent of thermal power generation since 1990, and continues to increase its share.

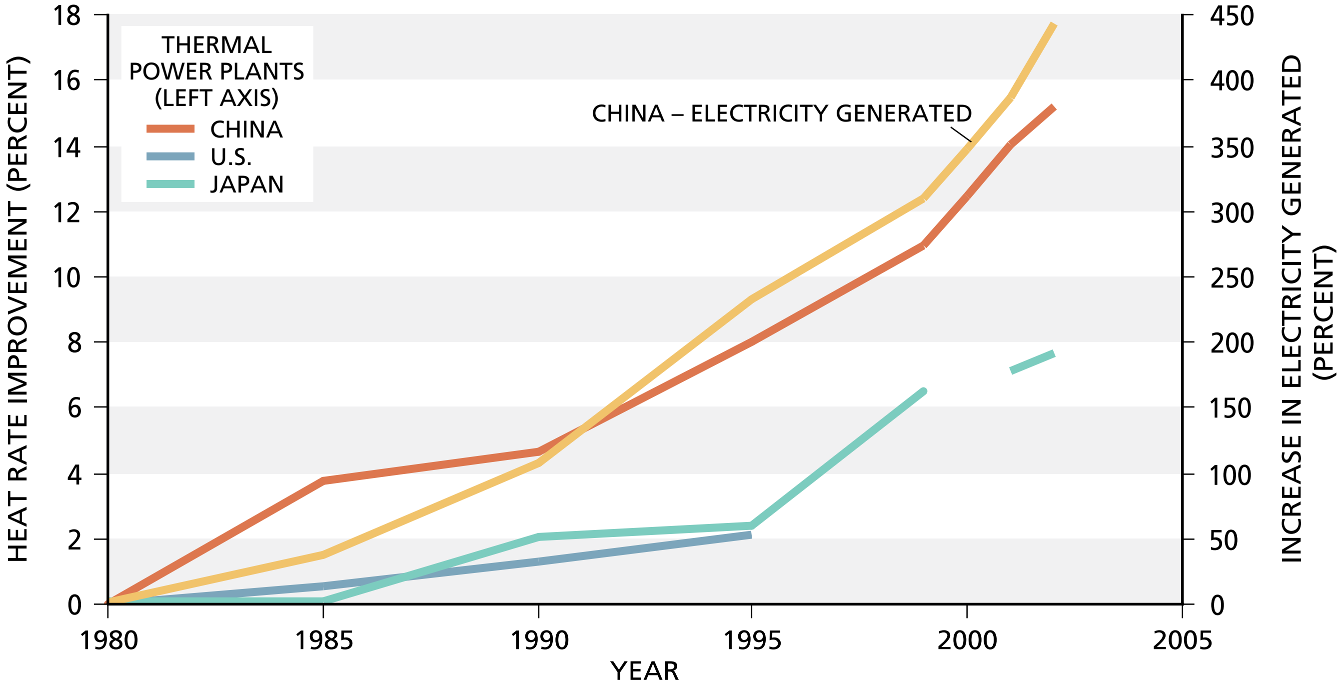
Japan has the lowest coal percentage in its thermal-generated electricity of the three countries. To conservatively estimate the average heat rate for Chinese coal-fired power plants, it is assumed that 1 percent of electricity generated from thermal power plants came from natural gas before 2004, and assume that the average heat rate of gas-fired plants is 30 percent better than that of coal-fired plants and that the average heat rate of oil-fired power plants is the same as that of coal-fired power plants. The derived heat rates for coal-fired plants in China are about 0.2 percent higher than the average heat rates of its thermal power plants. Of the three countries, China had improved its thermal power plants efficiency the most from 1980 to 2002. The great improvement in efficiency in the thermal power plants in China can be attributed to a large number of new builds. Figure 1-29 also shows increases in China's electricity output in the same period, of which the coal-fired plants contributed the most. For example, thermal power plants generated 82.64 percent of electricity in China in 2004. The large percentage of higher-efficiency coal-fired new builds drives China's average heat rates down quickly.

COAL IMPACT

The primary consumer of coal in the United States is the electric power industry, consuming 92 percent of the 1.1 billion tons used in 2005. About half the U.S. electricity generated in 2005 was from coal. EIA projects that coal consumed to generate power in the electricity sector will account for 85 percent of total U.S. coal consumption by 2030 (Figure 1-30). In the AEO 2006 Reference Case projection, the emergence of a coal-to-liquids (CTL) industry accounts for virtually all of the growth in coal use in the non-electricity sectors.

Coal is consumed in large quantities throughout the United States. As shown in Figure 1-31, coal production is focused in relatively few states, meaning that huge amounts of coal must be transported long distances. Therefore, U.S. coal consumers and producers have access to the world's most comprehensive and efficient coal transportation system.

All major surface-transportation modes carry large amounts of coal. According to the EIA, about two-



Source: The Energy Development Report of China, edited by M. Cui, etc., Social Sciences Academic Press of China, 2006.

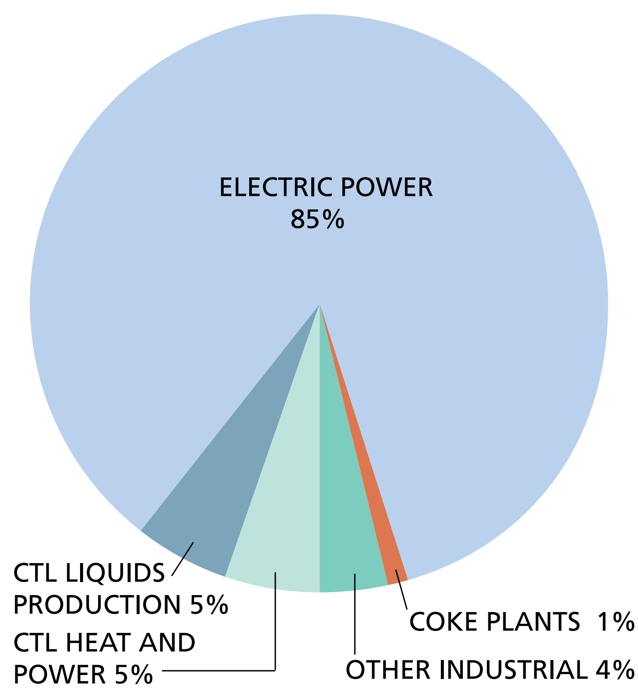
FIGURE 1-29. *Changes in Efficiency and Electricity Generated in China*

thirds of U.S. coal shipments were delivered to their final domestic destinations by rail in 2004, followed by truck (12 percent), the aggregate of conveyor belts, slurry pipelines, and tramways (12 percent), and water (9 percent, of which 8 percent were inland waterways and the remainder tidewater or the Great Lakes).[3]

Over the past 15 years, the rail share of coal transport has trended upward, largely reflecting the growth of western coal moved long distances by rail. The truck share has fluctuated, but has also trended upward since 1990, while the waterborne share has fallen.

The extent to which coal is able to help meet U.S. future energy challenges will depend heavily on the performance of coal transporters. If the past is a reliable guide, the various modes will be able to accommodate increased coal transportation demand, albeit perhaps with occasional "hiccups" and "bottlenecks" along the way.

Railroads, barges, and trucks are all critical coal transportation providers. Each mode faces challenges,



Source: EIA, *Annual Energy Outlook 2006.*

FIGURE 1-30. *U.S. Coal Consumption by Sector — 2030*

3 Energy Information Administration, "Coal Distribution Current and Back Issues," web site www.eia.doe.gov.

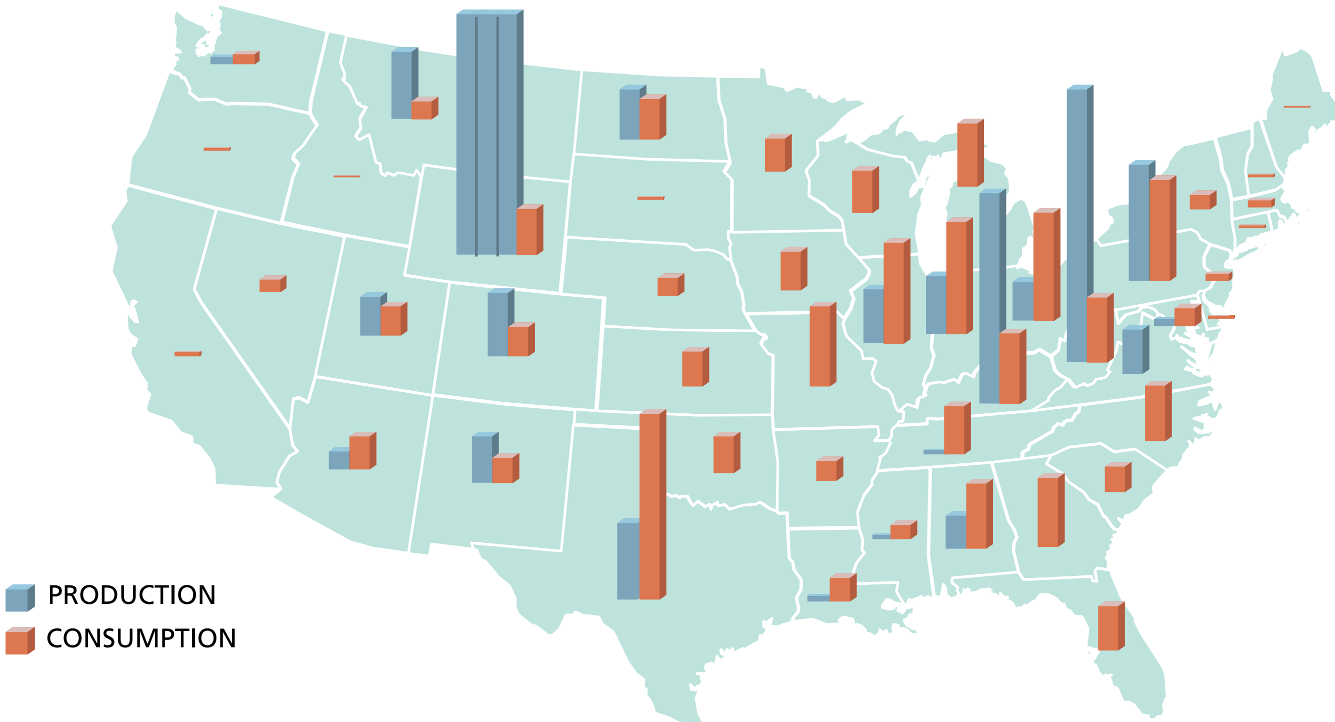


FIGURE 1-31. *U.S. Coal Consumption and Production by 2005*

some of which are unique to it and some of which are common to each of the modes. For each mode, having capacity that is adequate to meet growing demand is perhaps the most pressing need.

Available truck capacity will be determined by factors such as the amount of public spending on highways, how well the industry resolves the driver retention issue, and fuel costs.

Like trucks, waterways depend on publicly owned and maintained infrastructure. Waterway infrastructure is, in general, in need of significant maintenance and improvement. The availability of public funds to provide these improvements will feature prominently in how well waterways can handle future coal-transportation needs.

Railroads, on the other hand, rely overwhelmingly on privately owned, maintained, and operated infrastructure. As private-sector companies, railroads must be confident that traffic and revenue will remain high enough in the long term to justify the investments before they expand capacity. Railroads will continue to spend huge amounts of private capital to help ensure that adequate capacity exists, but they can do so only if regulations or laws do not hinder their earnings.

Worldwide, coal trade patterns have shown a steady evolution since the early days of the international coal industry. As long ago as the early 1980s, Australia was still a minor coal exporter. Indonesia, now the world's largest thermal coal exporter, did not emerge as a force in the international market until the 1990s. A similar pattern exists on the demand side. In the 1970s, there was regional trade in Europe with supply coming from Germany and Poland. The 1980s were dominated by Japan's demand for coal, while the 1990s saw Korea and Taiwan as significant markets. The early years of this decade have seen rapid increases in demand from smaller countries in Asia, as well as the emergence of China as both a significant coal exporter and a major import market.

Trade patterns are hard to project because some countries have dedicated export facilities as well as mines that are intended for purely domestic purposes. The current major exporters of coal are Indonesia, Australia, China, South Africa, Russia, and Colombia. All of these countries, except Indonesia and China, have current reserves-to-production ratios in excess of 100.

INDUSTRIAL EFFICIENCY

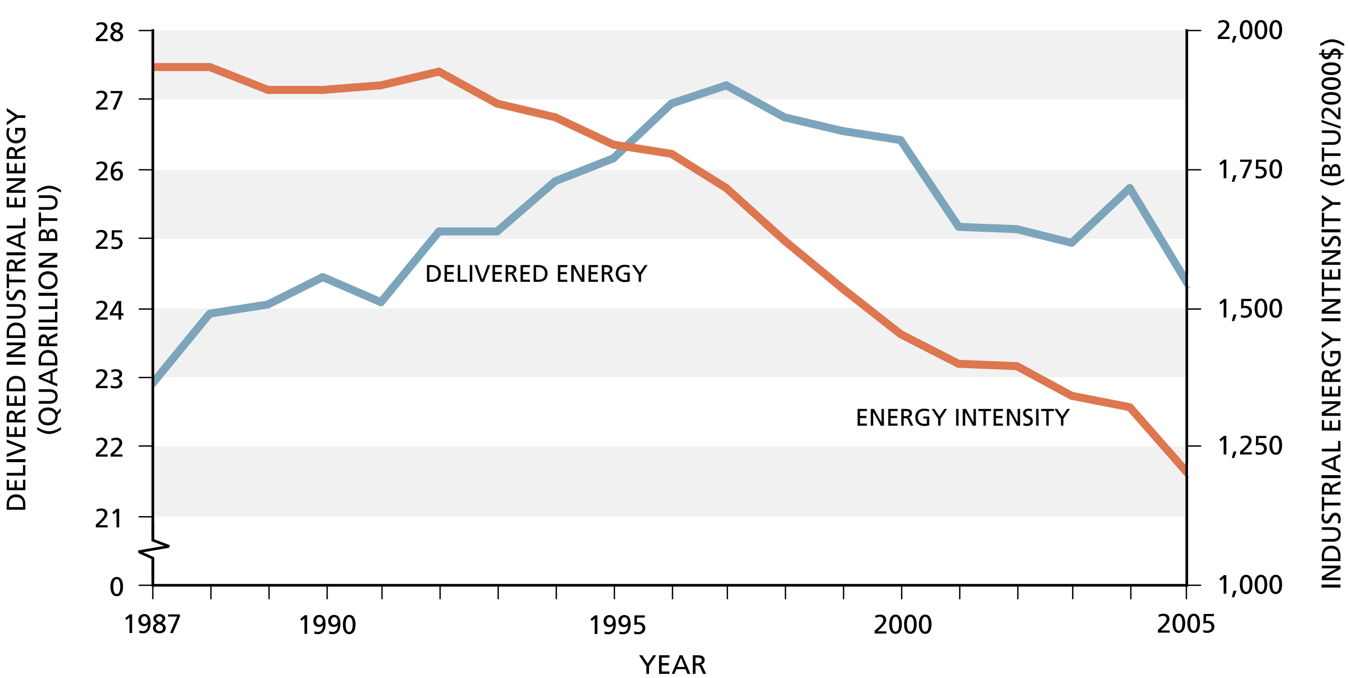
The industrial sector is a large and price-responsive consumer of energy, consuming roughly one-third of the energy used in the United States. U.S. energy-intensive industry and manufacturers in associated value chains rely on competitive energy supplies to remain globally competitive.

As natural gas prices have risen in the United States relative to those in the rest of the world, manufacturers with energy-intensive processes have responded in two ways: (1) by increasing the efficiency of their operations (shown as energy intensity on Figure 1-32), and/or (2) by shifting a greater proportion of energy-intensive industry outside the United States (shown by declining industrial energy use).

Despite this decrease in energy intensity, energy-intensive manufacturers in the United States struggle to remain competitive in the global marketplace. U.S. manufacturers are investing for strategic growth in regions of the world where energy costs are lower. For example, over the last 10 years, the United States has gone from one of the world's largest exporters of chemicals to an importer. Although less dramatic, trends are similar in the paper and metals industries. Figure 1-33 tracks the aggregate trade balance for the steel, paper, and chemicals industries compared to the price of natural gas. Significantly, the correlation between the two data series is -89 percent, indicating that high natural gas prices have hurt U.S. competitiveness in these industries.

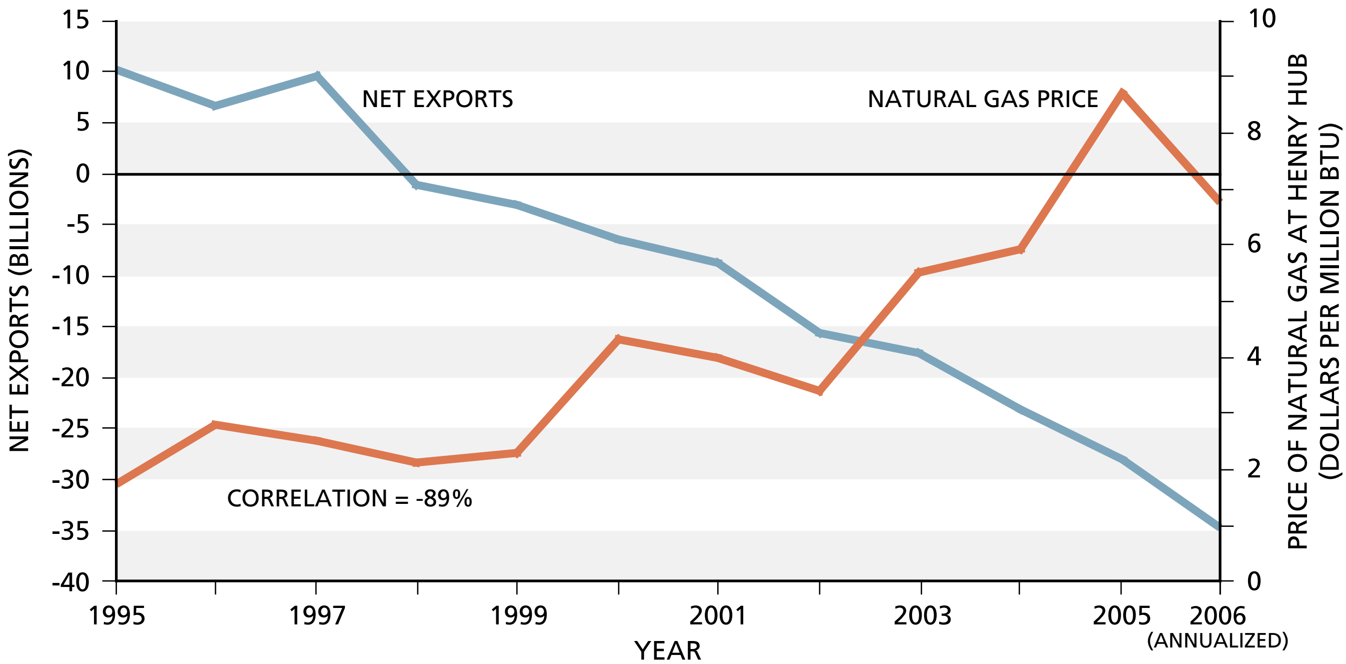
The extent to which U.S. industry can continue to compete for the domestic market is unclear. For instance, imports have provided 40 percent of the increase in U.S. gasoline use over the last 10 years. The impact of factors such as international supply and demand balances for oil and natural gas, geopolitical issues, the advent of disruptive technologies, and the evolution of the world's economies is unknown. The uncertainty in U.S. industrial energy consumption carries through to global balances. Since product consumption is unlikely to decline, product needs that are unmet by local production likely will be met by imports.

Projecting historical industrial energy patterns forward may illustrate this uncertainty. In the first scenario (called Stays), industrial use grows as it did between 1983 and 1996. In the second scenario (Flight), industrial consumption declines as it



Sources: Delivered Industrial Energy Consumption data from EIA, *Annual Energy Review 2005*.
GDP data from Bureau of Economic Analysis website.

FIGURE 1-32. *U.S. Industrial Energy Consumption and Energy Intensity*



Source: U.S. Dept. of Commerce data for SITC Code 5 (Chemicals and Related Products), 64 (Paper and Paperboard), and 67 (Iron and Steel) from tse.export.gov web site. Price data from Platt's.

FIGURE 1-33. *Trade Balance for Energy-Intensive Industry*

did between 1996 and 2005. These projections are intended to bound the EIA's AEO 2007 Base Case projection. Energy use growth rates for each are shown in Table 1-11 and depicted in Figure 1-34.

Bandwidth studies conducted for the U.S. DOE on the most energy-intensive manufacturing sectors (chemical, petroleum, and forest products industries) suggest energy-efficiency opportunities of up to 5 quadrillion Btu per year, or just under 15 percent of 2005 industrial energy use. Of these opportunities, about 2 quadrillion Btu per year can be achieved by using existing technology (Table 1-12). Processes requiring additional research and development include separation, distillation, catalysts, alternate feedstocks, fouling, heat integration, drying, forming, and pressing.

Adopting existing technology for combined heat and power systems (CHP) and implementing "best practices" for steam systems would each yield savings of about 1 quadrillion Btu per year without requiring significant research. Despite its thermal efficiency advantages, CHP implementation in the U.S. industrial sector totals 72 gigawatts, which is about 50 percent of the total potential for CHP in the industrial sector (CHP Installation Database and Onsite Energy, 2000).

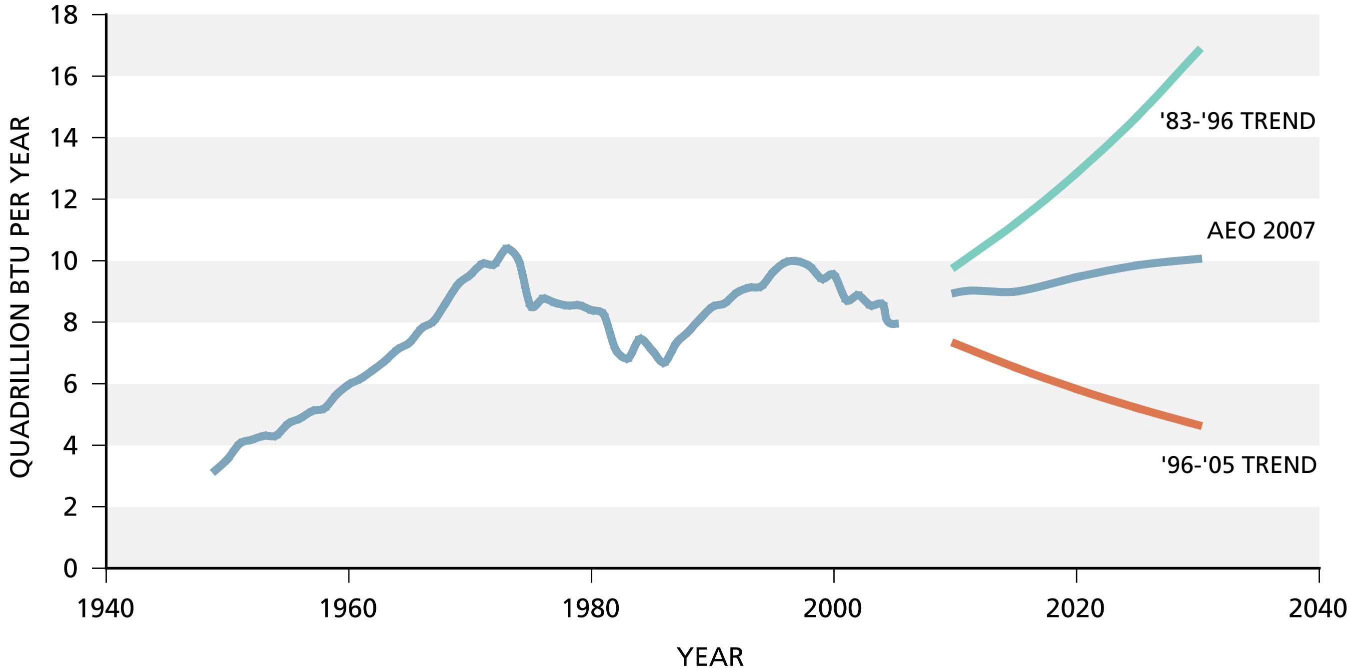
AEO 2007 projects a wide range of energy-intensity improvements in the manufacturing sector from 2005 to 2030, reflecting expected changes in that sector given

Growth Rates	Total Energy	Oil	Natural Gas
1949-1973	3.0%	3.9%	4.8%
1996-2005	-1.1%	0.5%	-2.2%
1983-1996	1.7%	1.4%	2.7%
Base 2005-2030	0.7%	0.4%	0.7%
Flight 2005-2030	-1.1%	0.5%	-2.2%
Stays 2005-2030	1.7%	1.4%	2.7%

Note: Growth rates average 2004/2005 values as a starting point to minimize the impact of Hurricanes Katrina and Rita on growth rate calculations.

Source: EIA, Table 2.1.d Industrial Sector Energy Consumption, 1949-2005, and *Annual Energy Outlook 2007*.

TABLE 1-11. *U.S. Industrial Energy Use Scenarios*



Source: EIA, Table 2.1.d Industrial Sector Energy Consumption, 1949-2005, and *Annual Energy Outlook 2007*.

FIGURE 1-34. *U.S. Industrial Energy Use Scenarios*

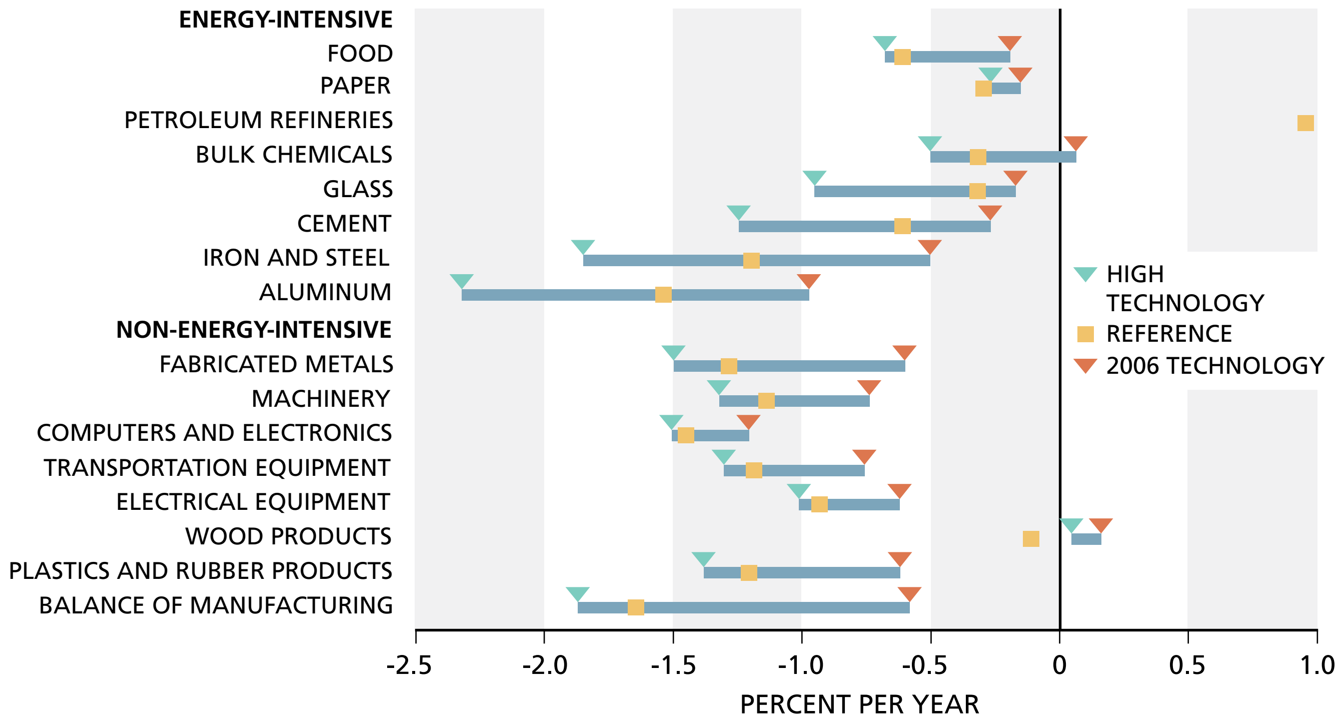
current conditions and trends. For example, the energy intensity of the aluminum sector is expected to decrease as secondary smelting, a less energy-intensive process, becomes the dominant technology in the United States. On the other hand, the energy intensity of the petroleum refining industry is expected to increase as liquids from coal come into use (Figure 1-35).

There are significant impediments to greater industrial efficiency. First, U.S.-government-funded energy R&D has fallen at least 70 percent in real terms from its peak in the late 1970s. Second, price volatility makes approval of efficiency projects difficult. Finally, lack of adequate, technically trained human resources impedes implementation of efficiency projects. Figure 1-36

Opportunity	Size (Quadrillion Btu per Year)	R&D Required?
Waste Heat Recovery	0.9	Yes
Industrial Boilers, Heat Recovery from Drying	0.8	Yes
Adoption of Best Practices in Heat and Power Systems and Steam Systems	0.9	No
Other – Requiring R&D	1.4	Yes
Other – Implementing Best Practices	1.1	No

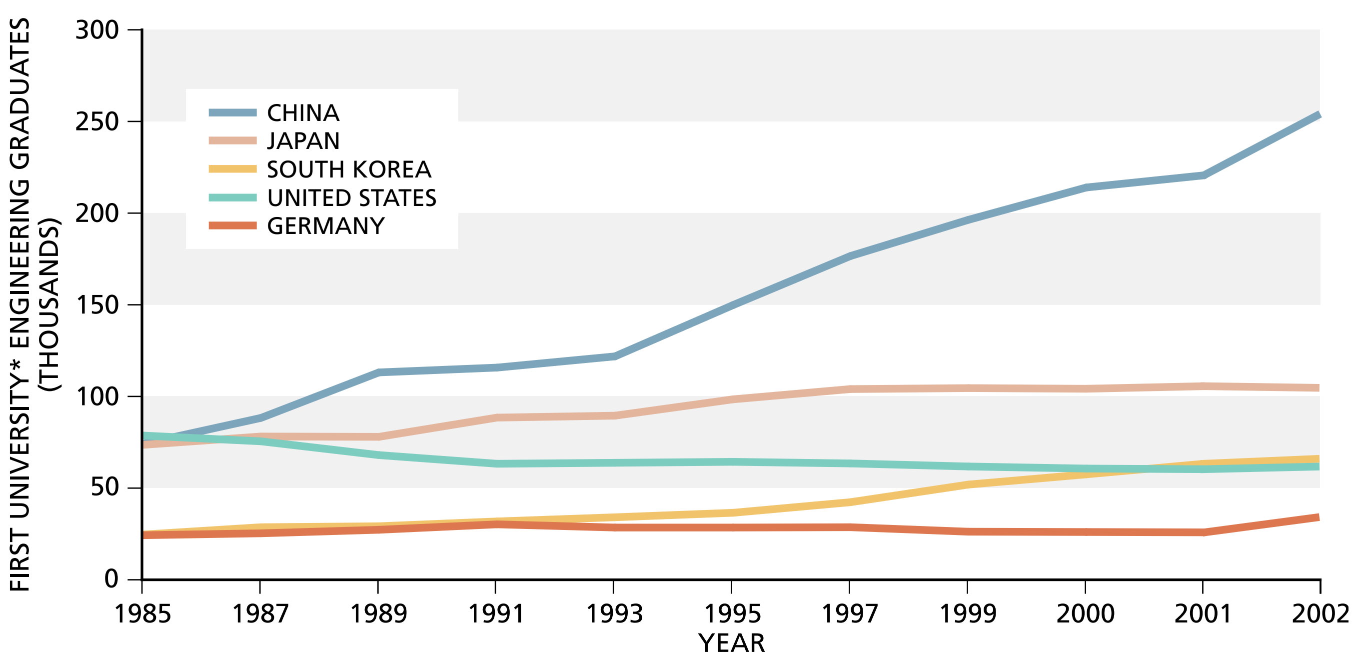
Source: *U.S. Department of Energy,* Energy Use, Loss and Opportunities Analysis: U.S. Manufacturing and Mining, *2004.*

TABLE 1-12*. Approximate Size of Efficiency Technology Opportunities*



Source: EIA, *Annual Energy Outlook 2007*.

FIGURE 1-35. *Average Change in Energy Intensity in the Manufacturing Subsectors, 2005-2030*

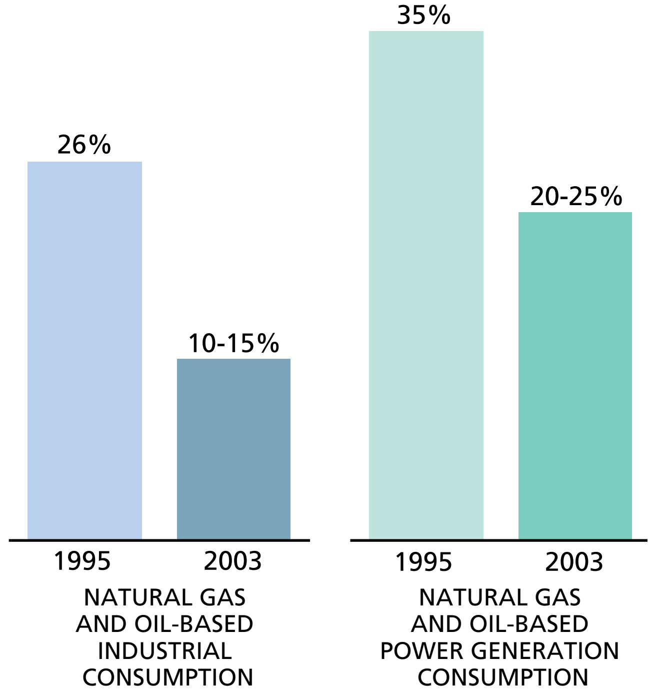


* International equivalent to a bachelor's degree.

Source: "U.S. Manufacturing Innovation at Risk," a study by Joel Popkin and Kathryn Kobe for The Manufacturing Institute and the Council of Manufacturing Associations, February 2006.

FIGURE 1-36. *Engineering School Graduates, by Year* shows the number of engineering-school graduates per year from several countries.

Industrial energy consumers play an important role in mitigating energy price volatility. Manufacturing provides a quick-acting buffer against supply or demand shocks in the energy industry. However, as demonstrated in Figure 1-37, this role has been reduced as the U.S. capability for fuel switching has fallen over the past decade, in both the power generation and industrial sectors.



Source: NPC Natural Gas Study, 2003.

FIGURE 1-37. *Fuel Substitution Capability*

CULTURAL/SOCIAL/ECONOMIC TRENDS

This area of investigation is extremely broad. However, after an analysis of the data, the following eight broad findings became apparent. The data analysis relied heavily on the Reference Case projections in WEO 2006 and IEO 2006.

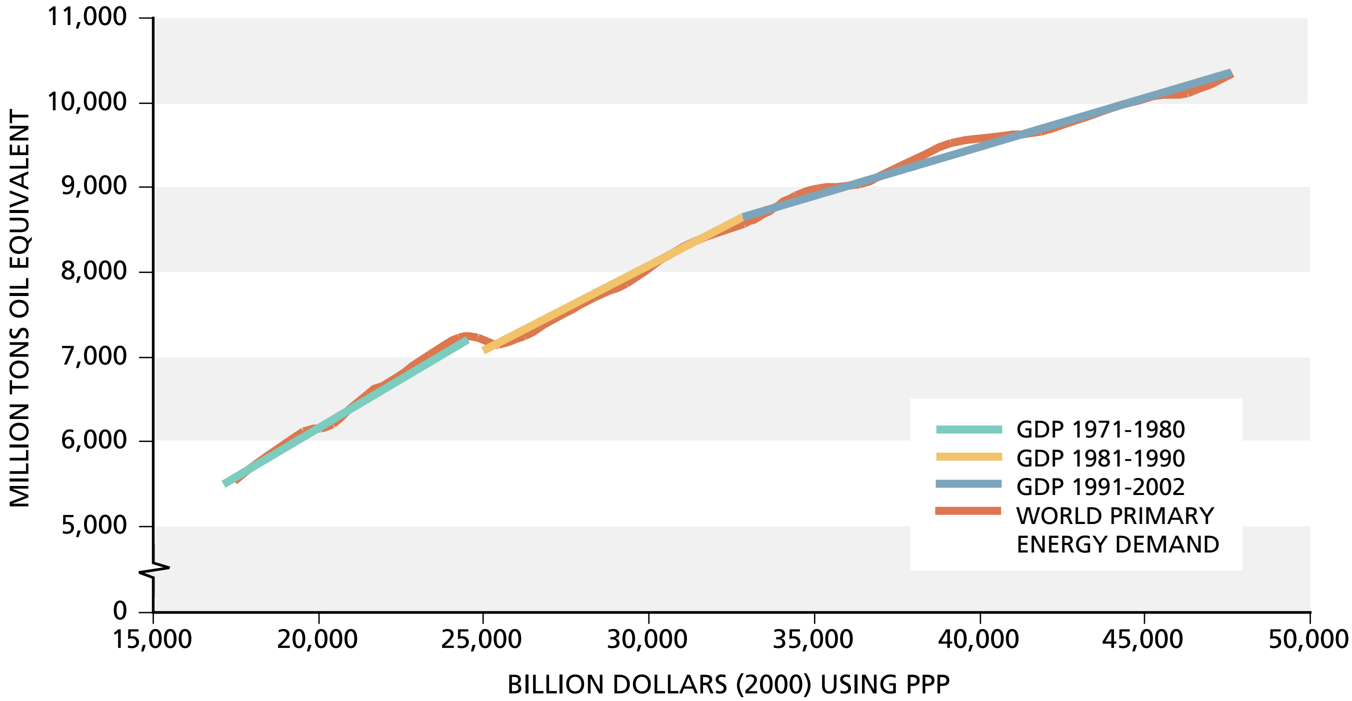
1. Income is the biggest determinant of demand for energy.

Due to the strong influence of income on energy demand, even small changes in assumptions about the Gross Domestic Product (GDP) have major implications for energy growth. Energy projections by the IEA and EIA are highly sensitive to GDP assumptions. In WEO 2006, a 1 percent growth in global GDP results in a 0.5 percent increase in primary energy consumption. This is consistent with the observation that the income elasticity of demand fell from the 0.7 in the 1970s to the 0.4 from 1991-2002 as shown in Figure 1-38. WEO 2006 cites warmer winter weather in the northern hemisphere (which reduced heating-fuel demand) and improved energy efficiency for the reduction in income elasticity for energy as a whole between the two periods.

Assuming that projected economic growth is desired, then to maintain current U.S. energy consumption would require a 45 percent reduction in energy intensity by 2030. To maintain current developing-country energy consumption levels would require a 70 percent reduction in global energy intensity by 2030. Put in perspective, over the last 55 years (1949-2005), U.S. energy intensity has fallen by a little more than half (Figure 1-39). To maintain energy consumption at current levels would require a global reduction in energy intensity of roughly twice that amount.

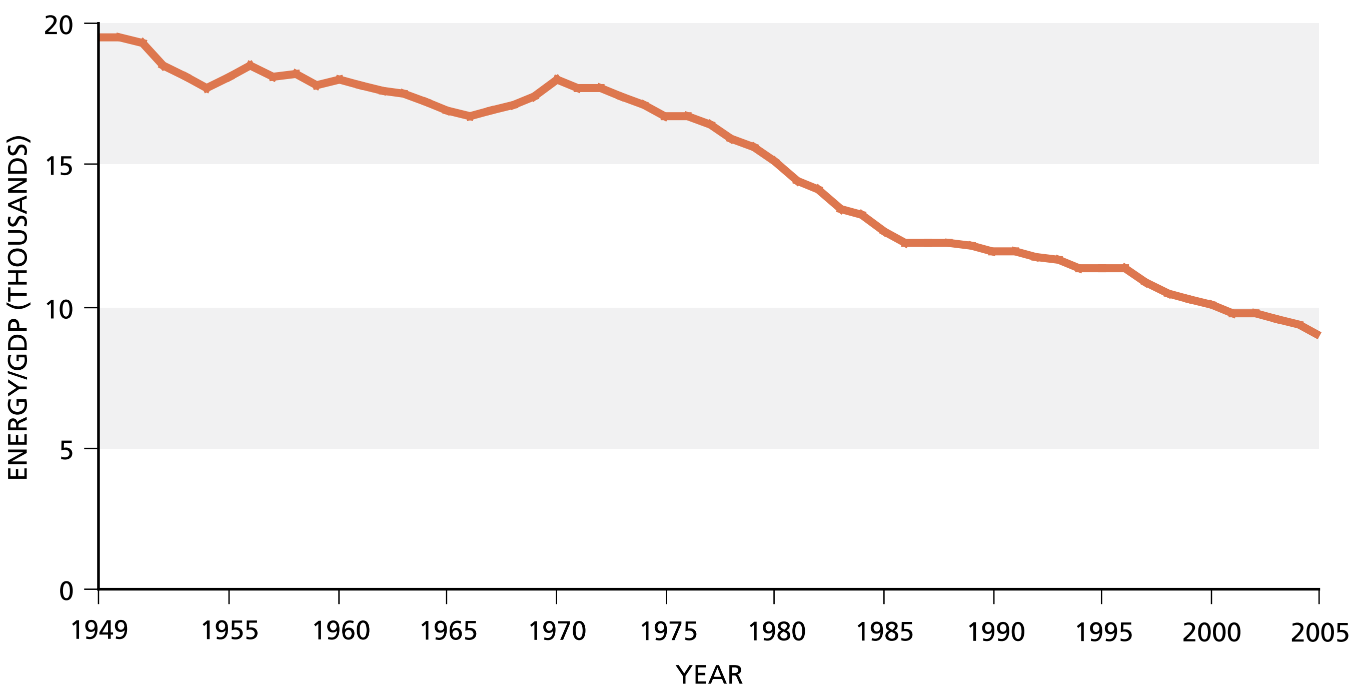
Aside from structural changes in the economy, the only way to reduce energy is through efficiency and conservation. For perspective, businesses and consumers have shown their unwillingness to make efficiency investments with returns of 10 percent. Two-year paybacks for businesses are often cited as the minimum for energy efficiency investments. Consumers often make decisions that imply returns of 50 percent or more. Lack of awareness and know-how are examples of barriers to investments in improved energy efficiency. It is likely that policy action would be required to encourage energy efficiency and conservation.

History suggests that energy-intensity reductions resulting from improved efficiency and structural change will be offset by increased demand for energy services unless policies are put in place to prevent such offsets. For example, technology that could have been used to increase vehicle miles per gallon in light duty vehicles has been used to increase vehicle horsepower and weight. Likewise, improvements in the efficiency (energy use per unit of service) of appliances and buildings have been offset by increased numbers of appliances and building sizes. While policies to promote improved energy efficiency may be more politically palatable than those that restrict demand



Source: IEA, *World Energy Outlook 2004.*

FIGURE 1-38. *World Primary Energy Demand and GDP, 1971-2002*



Source: EIA, *Annual Energy Review 2005.*

FIGURE 1-39. *U.S. Energy Intensity* for energy services, those improving efficiency may not be sufficient to yield significant reductions from baseline projected energy demand.

2. Oil and natural gas demand are projected to increase rapidly in coming decades.

Global oil consumption is expected to increase by 40 percent from 2005 levels by 2030. Global natural gas demand is expected to increase by two-thirds by 2030; U.S. natural gas demand is expected to increase more slowly. The increase in demand for fossil fuels in non-OECD countries will be far more rapid than in OECD countries, both in absolute and percentage terms.

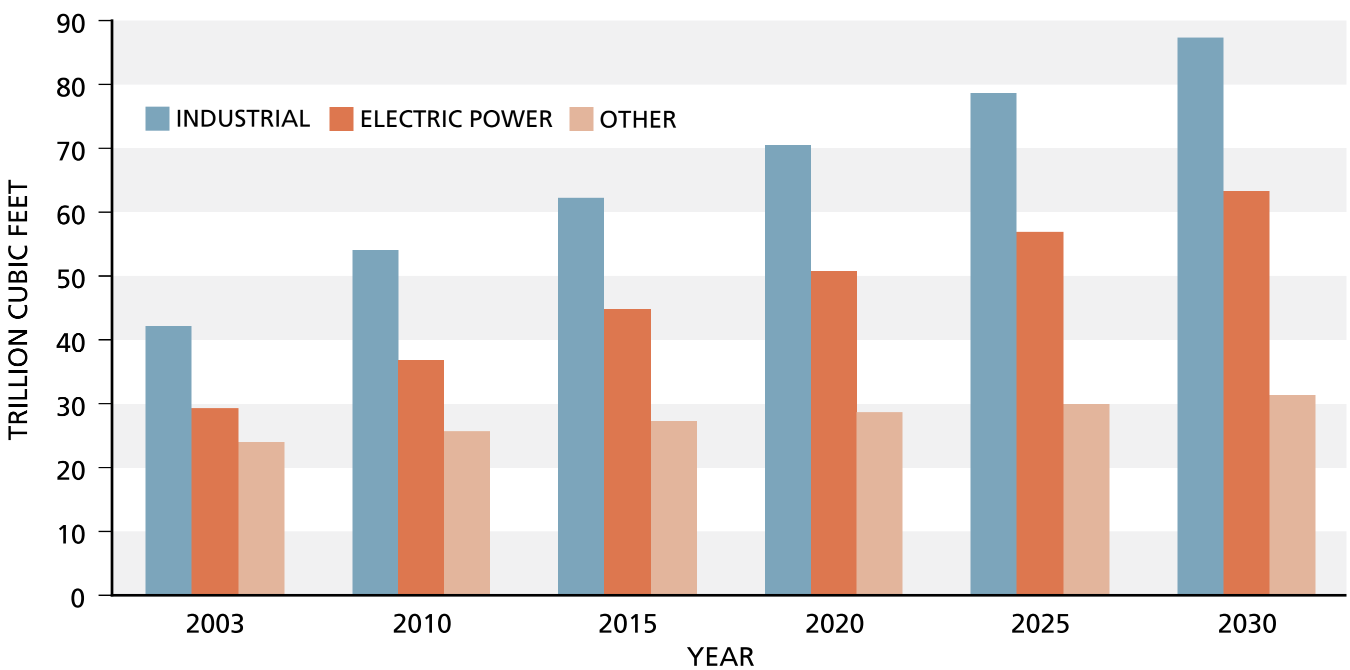
Transportation, industry, and "other" (mostly building heating) are the major sources of oil demand growth in the WEO 2006. Electric power sector demand is expected to decrease by about 1 million barrels per day. Oil demand growth in the transportation sector will exceed growth for all other uses combined. Projected industry and "other" category oil consumption are expected to increase by a large amount as well. These categories are expected to grow by 13 million barrels per day, which compares with a transportation oil consumption growth of around 22 million barrels per day.

Globally, electric generation and industry are the major sources of natural gas demand growth. Natural gas demand for electric generation and industry are expected to double. Natural gas use for building heating is also expected to increase (Figure 1-40).

Perhaps less obvious, electricity use in buildings will indirectly be a major source of natural gas demand growth. Appliances and other "buildings" related energy uses represent the largest component of electricity demand growth, and thus have major impact on the demand for natural gas. A large portion of electric generation growth is expected to be fueled by natural gas.

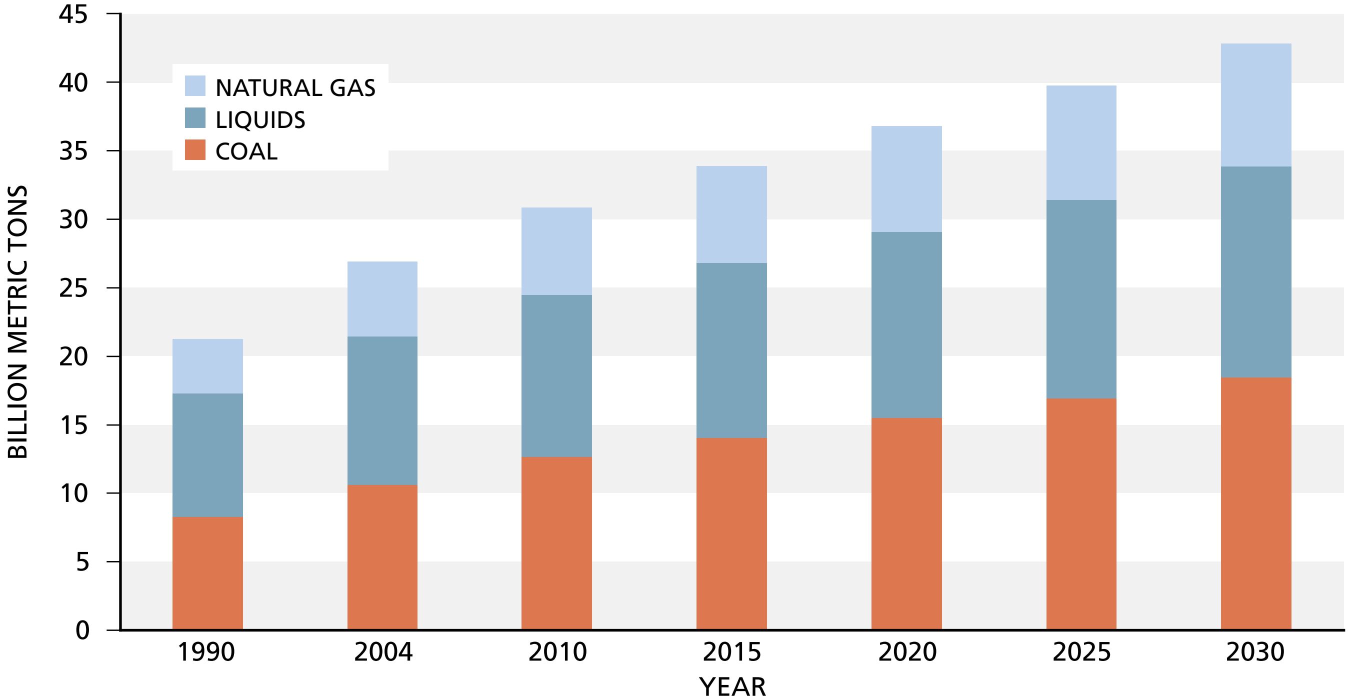
3. Carbon dioxide from fossil fuel combustion is growing.

Global CO_2 emissions are expected to increase by about half between 2004 and 2030, from around 27 billion tons to 40 billion tons (Figure 1-41). With slow growth in nuclear energy, and with renewable energy growing fast but starting from a low base, the carbon intensity of the global energy economy is projected to increase.



Sources: 2003: Derived from Energy Information Administration (EIA), *International Energy Annual 2003*; Projections: EIA, *International Energy Outlook 2006*.

FIGURE 1-40. *World Natural Gas Consumption by End-Use Sector, 2003-2030*



Source: EIA, *International Energy Outlook 2006*.

FIGURE 1-41. *World Energy-Related Carbon Dioxide Emissions by Fuel in the Reference Case*

The biggest contributor to global CO_2 emissions is coal, followed closely by oil and natural gas. Outside China, India, and the United States—all have large coal reserves—natural gas is expected to contribute significantly to the increase in CO_2 emissions.

The electric power sector is expected to be the dominant source of CO_2 emissions in the United States and globally—increasing from 40 percent in 2004 to 44 percent in 2030 worldwide (Table 1-13). The transportation sector, which is dominated by oil, will continue to be responsible for about one-fifth of CO_2 emissions. Yet much of the growth in electricity demand will come from residential and commercial buildings, which are already the largest single-sector source of CO_2 emissions when including the electricity generated that is used in buildings.

4. Keeping China in perspective.

Chinese energy use and GDP are projected to exceed those of the United States some time in the second half of the next decade. Chinese oil demand is projected to increase by twice as much as the U.S. oil demand through 2030 (Figure 1-42). Growth in China's oil demand is often cited as one of the major causes of higher global oil prices.

The fastest CO_2 emissions growth among major countries is occurring in China (Figure 1-43). Chinese emissions growth in 2000-2004 exceeded the rest of the world's combined growth due to increased use of coal and rapidly growing petroleum demand. Chinese CO_2 emissions are projected to pass U.S. emissions late in this decade.

While it is hard to overstate the ever-increasing importance of China in global energy markets and as a carbon emitter, it is important to put these numbers in perspective. The United States has had fast rates of energy and emissions growth for decades. As recently as the last decade (1990-2000), U.S. emissions growth was nearly as fast as China's is today. Even in 2030, China's projected oil demand will be less than the oil demand projected for the United States, both in per capita and absolute terms.

China has made major strides in reducing the carbon intensity of its economy (CO_2 per GDP). China's carbon intensity is roughly equal to that of the United States, and the intensities of both countries are projected to decrease at the same rate.

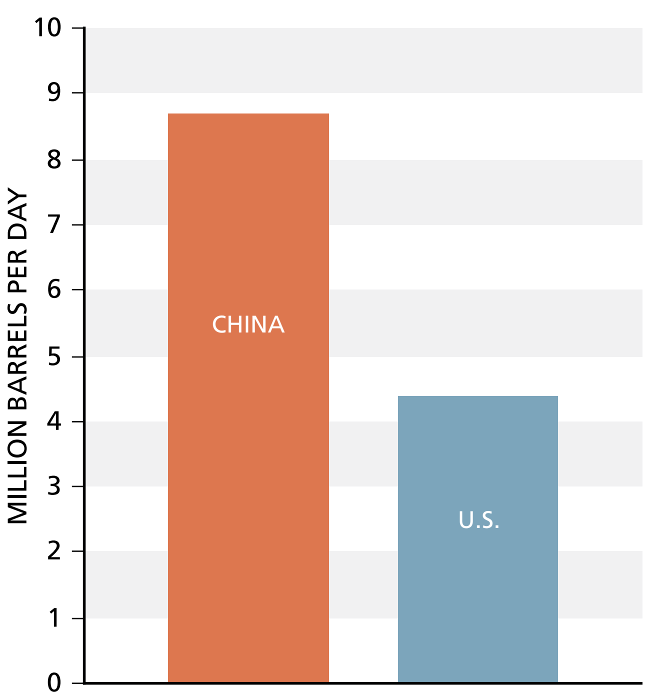
Nevertheless, while Chinese and U.S. carbon intensity will be similar during the next decade, per capita

	1990	2004	2010	2015	2030	2004-2030*
Power Generation	6,955	10,587	12,818	14,209	17,680	2.0%
Industry	4,474	4,742	5,679	6,213	7,255	1.6%
Transport	3,885	5,289	5,900	6,543	8,246	1.7%
Residential and Services†	3,353	3,297	3,573	3,815	4,298	1.0%
Other‡	1,796	2,165	2,396	2,552	2,942	1.2%
Total	**20,463**	**26,069**	**30,367**	**33,333**	**40,420**	**1.7%**

* Average Annual Growth Rate.
† Includes agriculture and public sector.
‡ Includes international marine bunkers, other transformation, and non-energy use.

TABLE 1-13. *World Energy-Related Carbon Dioxide Emissions by Sector in IEA's World Energy Outlook 2006 Reference Case (Million Metric Tons)*

carbon emissions will still be far lower in China. Likewise, on a per capita basis, U.S. oil demand is 10 times China's, and the United States will still consume 6 times as much per capita as China in 2030 (Figure 1-44).



Source: IEA, *World Energy Outlook 2006.*

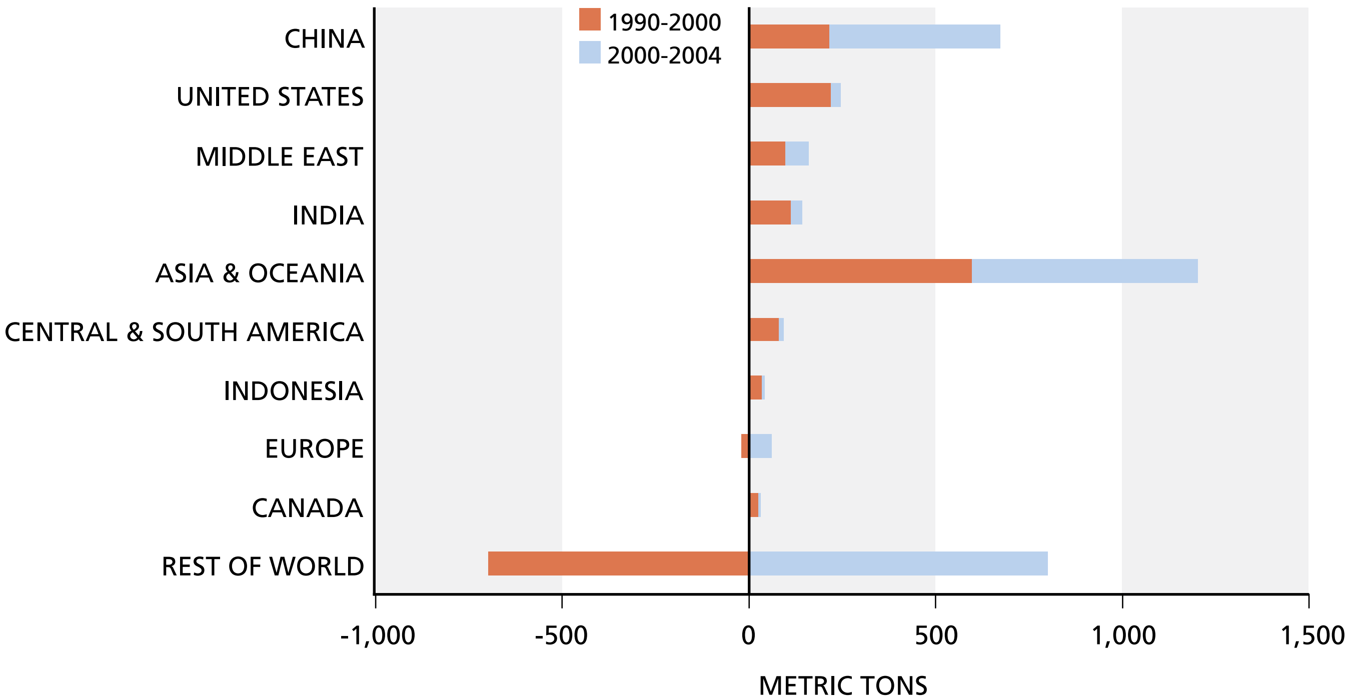
FIGURE 1-42. *Oil Demand Growth by 2030*

5. New technologies don't necessarily lead to reduced energy consumption.

There are any number of ways that information technologies could be used to reduce energy consumption, including telecommuting, dematerialization (i.e., the paperless office), and energy-efficient digital control systems in cars, buildings, and factories. The rapid penetration of information technologies in the economy has led some observers to predict accelerated reductions in U.S. and global energy intensity.

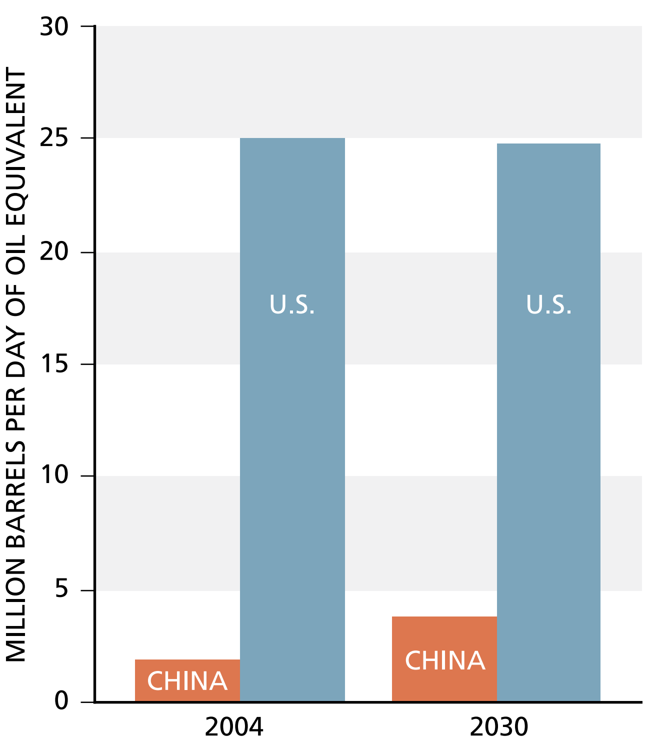
While the notion that technology development will lead to net reductions in energy use is appealing, is it proven, or even likely? Increased electric-plug loads associated with computers and other types of office equipment, and growing energy demand resulting from increased economic growth fueled by new information technologies, could induce a net increase in energy demand rather than a net decrease.

Based on various studies of information technology energy use, it can be estimated that information technology equipment currently uses about 210 terawatt-hours (210 trillion watt-hours), or about 5 percent of U.S. electricity consumption. This is almost as much electricity as could be saved by 2010 through efficiency measures with a cost of 10 cents or less per kilowatt-hour. In other words, the electricity consumed by information technologies in the United States, most introduced over the last decade, exceeds the



Source: EIA, *International Energy Annual 2004*.

FIGURE 1-43. *Regional Increase in Carbon Dioxide Emissions*



Source: IEA, *World Energy Outlook 2006*.

FIGURE 1-44. *Comparison of Oil Demand Per Capita — 2004 and 2030 Industry*

electricity-savings potential for refrigerators, washers, dryers, televisions, and the multitude of other electricity consuming appliances and equipment.

Technology advances make projecting energy-use trends particularly difficult. If excessive technological optimism causes an under estimation of future energy demand requirements, society could be forced to develop new energy sources hastily, at potentially great financial and environmental costs. Likewise, overly optimistic predictions that information technology (or any other technology) will reduce our reliance on fossil fuels might send the message that addressing energy challenges will not require any hard choices.

There are few historical precedents for new technologies actually reducing energy use (as opposed to just reducing energy intensity). New technologies often create new service demands at the same time that they improve the efficiency of existing service demands—the technology has the potential to reduce energy use, but gets called on for other purposes or allows (and in some cases even encourages) increased demand for new and additional energy services. For example, refrigerators are far more efficient (per cubic foot) than they were two decades ago, but more households have more than one refrigerator, and refrigerators have become bigger. Likewise, homes are better insulated and air conditioning and heating systems have become more efficient, but at the same time homes have grown in size. And cars, as discussed below, have become far more energy efficient, but that very efficiency has been offset by increased horsepower, size, and weight of vehicles.

In summary, care should be exercised when evaluating the future use of technology—information age or other—as a means of reducing future energy use.

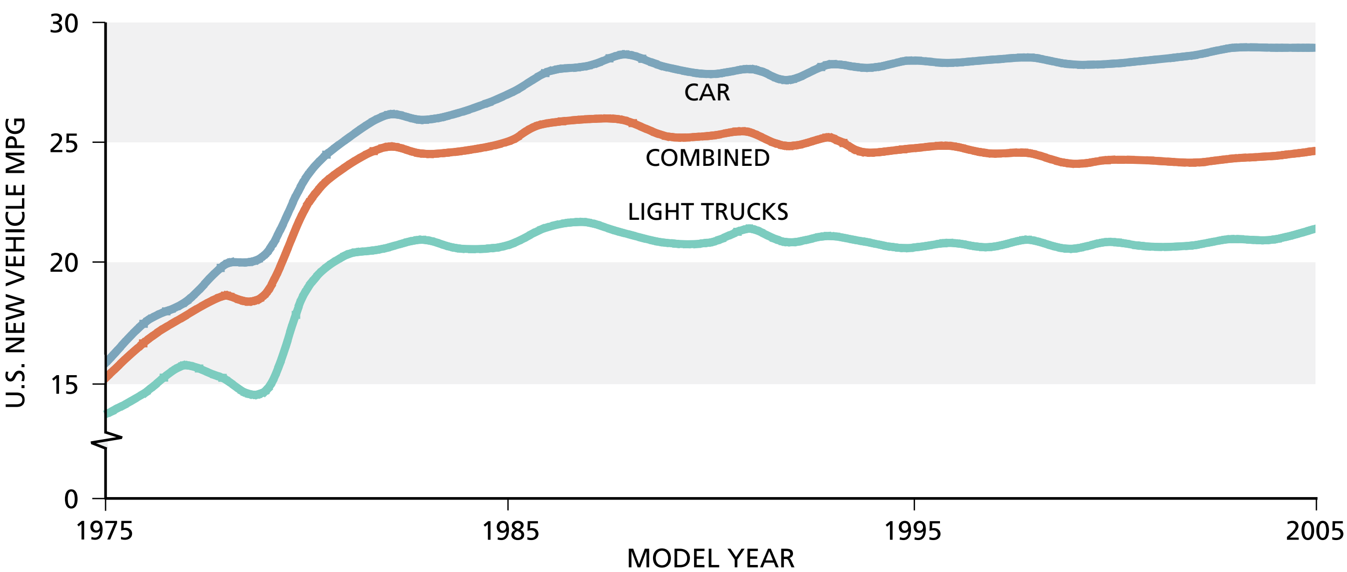
6. Large untapped potential for improved fuel economy in light duty vehicles.

Driven by rising incomes, global light duty vehicle (LDV) ownership rates are expected to increase from 100 vehicles per 1000 persons today to 170 in 2030. As a result, LDVs in use worldwide are expected to double, from 650 million in 2005 to 1.4 billion in 2030. Whereas U.S. and Japanese markets, for example, are expected to increase along with population, vehicle sales are expected to triple in non-OECD countries by 2030.

Vehicle fuel-use efficiency has increased. One recent study found that fuel-use efficiency (energy recovered per unit of fuel consumed) has increased by about 1 percent per year since 1987. This could have resulted in an increase of 0.2 miles per gallon per year. However, gains in efficiency have been offset by increases in vehicle weight, size, power, and accessories. If these factors had instead remained constant since 1987, average fuel economy would be 3-4 mpg higher for both cars and trucks than it is today (Figure 1-45).

Consequently, vehicle fuel economies (miles per gallon) in the United States have stagnated. Low fuel prices, combined with no increase in Corporate Average Fuel Economy (CAFE) standards, have led to U.S. light duty vehicle fleet-wide fuel economy that is essentially flat since the mid 1980s. At the same time, the structure of the CAFE standards allowed increased purchase of light trucks (SUVs, pick-ups, and minivans), which are subject to less-stringent fuel economy requirements. Cars still make up more than 60 percent of total vehicle miles traveled, but light trucks now account for more than half of the light duty vehicle sales in the United States, up from 20 percent in the 1976 to 53 percent in 2003. The period since the mid-1980s stands in stark contrast to the previous decade (1975-85), in which the fuel economy of America's light duty vehicles increased by two-thirds, driven by CAFE standards that increased annually.

There is a lot of uncertainty about business-as-usual trends in fuel economy. AEO 2006 projects that LDV fuel economy in the United States will increase 17 percent, from 24.9 mpg in 2003 to 29.2 mpg in 2030, in spite of an increase in horsepower of 29 percent. WEO 2006, however, projects an increase of just



Source: U.S. EPA, *Light-Duty Automotive Technology and Fuel Economy Trends: 1975-2003.*

FIGURE 1-45. *U.S. Car and Light-Truck Fuel Economy*

2.5 percent. Baseline expectations on improved fuel economy make a big difference in terms of how much energy savings we could expect from changes in CAFE standards or from other policies. Higher gasoline prices—if sustained—could result in the purchase of vehicles with better fuel economy, especially if fuel-economy improvements are available with little increase in price or reduced performance.

There are several technologies that could be used without short-changing vehicle performance, including continuously variable transmissions, engine supercharging and turbo charging, variable valve timing, cylinder deactivation, aerodynamic design, the integrated starter/generator, and low-resistance tires. In its 2002 report on fuel economy standards, the National Research Council found that a combination of various technologies could boost LDV fuel economy by one-third, and would be cost-effective for the consumer (would pay back over the life of the vehicles). With much higher gasoline prices, as seen in recent years, that savings potential is even greater. Note that all of these technological improvements could be used to improve other aspects of vehicle performance besides fuel economy.

Realizing such a fuel economy potential will likely require a range of policies to encourage improved fuel economy, including: increasing and/or reforming vehicle fuel economy standards, fuel taxes, and vehicle "feebates" (e.g., fee for low-fuel economy vehicles, rebate for high fuel economy vehicles).

7. Prices matter.

Rising prices, along with growing concerns about international energy security and global climate change have put energy in the news. Policymakers and business leaders want to know how much and when demand will respond to these high prices; and whether new policies and measures might stimulate the development of new energy resources and the more efficient use of existing energy resources.

Conventional wisdom, for example, suggests that there will be little quantity response to higher energy prices, at least in the short run. However, decades of econometric work suggests that over time consumers and businesses do adjust. Based on a meta-analysis by Carol Dahl (2006), which reviewed findings from 190 studies of elasticity conducted from 1990 through 2005, short-run price elasticity appears to range from around -0.1 to -0.3. In the long run, demand for various types of energy is roughly three times as responsive to price changes. However, demand is far more responsive to income than to price.

Past elasticities are not necessarily indicative of price responsiveness in the future. The magnitudes of all elasticities are influenced by changes in technology, consumer preferences, beliefs, and habits. It is entirely conceivable that a sustained period of high energy prices (for perhaps 5-10 years) could induce far greater percentage changes in the quantity of energy demand.

Elasticities could also be changed by policies. But given the relative importance of income compared to prices, if policies focus only on rising price signals without providing alternatives to current transportation and lifestyle patterns, consumers and businesses may view those policies as more punitive than productive.

8. Fuel-switching capabilities are declining in industry and increasing in transportation.

The ability to substitute fuels in a given sector affects how vulnerable that sector is to supply disruptions and associated price spikes. The ability to substitute fuels during a disruption lessens demand for the disrupted fuel, thereby reducing the size of the shortfall and the associated price spike. Lacking the ability to substitute fuels, prices need to rise to fairly high levels in times of shortage in order to reduce the activity that is generating the demand for fuel.

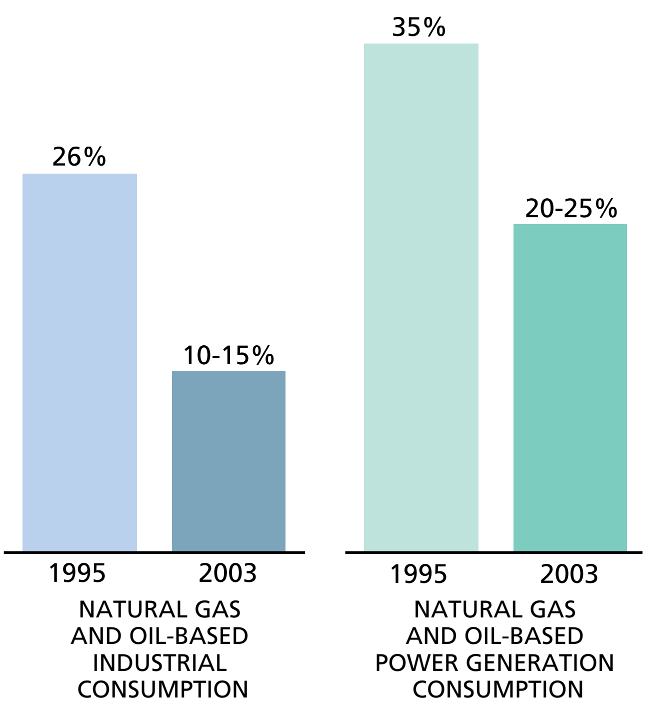
In the United States, the buildings sectors have very little ability (less than 5 percent) to switch fuel. Fuel-switching capabilities are higher, but falling, in the power and industrial sectors. Capability is low, but increasing, in the transportation sector.

The transportation sector is heavily reliant on petroleum and has little fuel substitution capability. About 5 million light duty vehicles in the United States have flexible fuel capability, representing about 2 percent of the total light duty fleet. By 2030, roughly one in ten light duty vehicle sales will have E-85 flex fuel (ethanol/gasoline) capability.

To make the widespread supply of E-85 economical will require more flex-fuel vehicles, substantial investments in the distribution system, and development of a second-generation feedstock that is not used for food (e.g., cellulosic ethanol). Even then, ethanol's ability to reduce price volatility for motor fuels will be limited unless there is spare ethanol production capacity. Meanwhile, increased reliance on ethanol could result in increased price volatility due to weather factors reducing crop size, transportation bottlenecks, high rail costs, and other local supply and demand factors.

Electric power generation appears to engage in significant short-term fuel switching, especially during times of high natural gas prices. This capability has declined over the last decade, from one-third of power generation gas boilers that were able to use residual fuel oil as a second fuel source in the mid-1990s to about one-quarter now (Figure 1-46). The reasons for the decline in fuel-switching capability include environmental restrictions, costs for additional storage of secondary fuels, and siting and related permitting complications that arise with multi-fuel generation facilities.

In the industrial sector, roughly one-fifth of the natural gas consumed can be switched to another fuel. Protection from highly volatile energy prices for residential and commercial consumers can be had indirectly via the other consuming sectors. To the extent that fuel flexibility and switching in the transportation, power, and industrial sectors mitigates price spikes and volatility, a spillover benefit accrues to the residential and commercial sectors.



Source: NPC Natural Gas Study, 2003.

FIGURE 1-46. *Fuel Substitution Capability*

RESIDENTIAL/COMMERCIAL EFFICIENCY

Buildings are major consumers of oil and natural gas both nationally and globally, both directly and indirectly through the consumption of electricity generated from oil and natural gas. While most energy consumed in buildings is for traditional uses such as heating, cooling, and lighting, a growing portion is going to new electric devices, many of which were rare or even nonexistent just a few years ago. And, while significant efficiency improvements have been made in building shells, systems, and appliances, the potential energy savings have been partially offset by additional energy service demand requirements that have occurred as a result of increased home sizes as well as new and larger electric devices.

If all achievable, cost-effective energy-efficiency measures were deployed in residential and commercial buildings, anticipated energy use could be reduced by roughly 15-20 percent. The potential for cost-effective energy efficiency improvements depends heavily on the price of energy, consumer awareness and perceptions, and the relative efficiency of available products in the marketplace. These factors are determined in part by government policies.

The major barriers to energy-efficiency investments are low energy prices relative to incomes, due in part to externalities not being included in prices and government subsidies, split incentives (consumers of energy different from those selecting energy consuming facilities or paying for energy), and consumers' lack of information. To the extent that societal benefits from improved efficiency are recognized, government policies to promote energy efficiency are used. To reduce energy consumption significantly below levels associated with the current policy environment will require additional policy related improvements in energy efficiency. These policies should take into account the potential to increase energy-service consumption as a result of less energy consumption.

When energy losses in the generation and distribution of electricity are included, about 40 percent of U.S. energy is consumed in the residential and commercial buildings sectors. Current projections indicate that building energy use will increase by more than one third by 2030. Commercial building energy use is expected to increase by nearly half, due to continued growth in the service economy. Residential energy use is expected to grow at half that rate. The combined energy use growth in residential and commercial buildings is expected to represent about 45 percent of total primary energy growth.[4]

According to AEO 2007, buildings currently represent only about 6 percent of economy-wide petroleum consumption, a share projected to decline to about 4 percent by 2030. The natural gas story is quite different. Buildings consume 55 percent of natural gas and are expected to be responsible for about three quarters of the growth in natural gas consumption through 2030 (including gas used for electricity supplied to buildings). Commercial and residential buildings represent 52 percent and 25 percent, respectively, of overall projected natural gas consumption growth from 2005-2030.[5]

United States Residential/ Commercial Energy Use

The AEO Reference Case is an attempt by analysts at the EIA to predict efficiency improvements given projected energy prices and other factors influencing the penetration of various energy-saving technologies. Energy efficiency savings potential including additional policies, standards, behavioral changes, and technological breakthroughs far exceed the efficiency included in the AEO Reference Cases. Specific estimates of the exact magnitude of this potential vary widely.

Estimates of achievable, cost-effective reductions in building electricity use for commercial and residential buildings in the United States range from 7 to 40 percent below the Reference Case projections. The midrange appears to be around 20 percent for commercial buildings, and slightly less in residential buildings.

EIA (AEO 2007) estimates residential sector energy consumption (not just electricity consumption) would be 24 percent lower than in its Reference Case if "consumers purchase the most efficient products available at normal replacement intervals regardless of cost, and that new buildings are built to the most energy-efficient specifications available, starting in 2007." Energy-efficient building components would include, for example, solid-state lighting, condensing gas furnaces, and building envelope improvements such as high-efficiency windows and increased insulation.

Similarly, EIA (AEO 2007) estimates that commercial building energy consumption in 2030 would be 13 percent less than projected in its Reference Case if "only the most efficient technologies are chosen, regardless of cost, and that building shells in 2030 are 50 percent more efficient than projected in the Reference Case [including] the adoption of improved heat exchangers for space heating and cooling equipment, solid-state lighting, and more efficient compressors for commercial refrigeration." Table 1-14 lists efficiency improvements that could be achieved in several categories by 2030.

EIA efficiency-potential estimates are on the high end of the residential studies we examined, and on the low to mid range of the commercial estimates (see Figures 1-47 and 1-48). Note, however, that the EIA projections assume that cost is no concern, so inasmuch as the other efficiency potential studies include cost-effectiveness tests, we would expect the EIA estimates to be at the high end of the studies. Furthermore, the other studies are for the most part examining the potential for electricity savings, not energy savings overall.

According to the 2006 McKinsey Global Institute study of energy-efficiency potential, if all energy-efficiency measures with internal rates of return of 10 percent or better are implemented, U.S. residential energy demand could be reduced by 36 percent below its 2020 baseline and commercial energy use could be reduced by 19 percent. Using the same investment criteria, McKinsey estimates global residential building energy demand could be reduced by 15 percent below baseline and global commercial building energy demand could be reduced by 20 percent.[6]

As previously mentioned, most of the studies we examined estimated an efficiency potential of 10 to 20 percent in commercial buildings and 10 to 15 percent in residential buildings beyond business as usual, with the American Council for an Energy-Efficient Economy (ACEEE) studies estimating potentials as high as 35 percent for residential buildings in Florida and 40 percent for commercial buildings in Texas.

At the other extreme, the Electric Power Research Institute (EPRI) developed a supply curve for electric demand-side measures in 2010—including residential

4 Energy Information Administration, *Annual Energy Outlook 2007 with Projections to 2030*, Table 2, February 2007, http://www.eia.doe.gov/oiaf/aeo/excel/aeotab_2.xls.

5 Calculations based on data from *Annual Energy Outlook 2007*, Table 2.

6 McKinsey Global Institute, *Productivity of Growing Global-Energy Demand: A Microeconomic Perspective*, November 2006.

Category	Appliance	Efficiency Improvement
Appliance	Refrigerators	22%
	Freezers	8%
Space heating	Electric heat pumps	10%
	Natural gas heat pumps	14%
	Geothermal heat pumps	5%
	Natural gas furnaces	6%
	Distillate furnaces	2%
Space cooling	Electric heat pumps	20%
	Natural gas heat pumps	10%
	Geothermal heat pumps	6%
	Central air conditioners	22%
	Room air conditioners	7%
Water heaters	Electric	3%
	Natural gas	6%
	Distillate fuel oil	0%
	Liquefied petroleum gases	6%
Building shell efficiency	Space heating – Pre 1998 homes	7%
Note: Index includes size of structure in the calculation	Space cooling – Pre 1998 homes	2%
	Space heating – New construction	2%
	Space cooling – New construction	2%

Source: Energy Information Administration, *Annual Energy Outlook 2007,* table 21, http://www.eia.doe.gov/oiaf/aeo/supplement/sup_rci.xls.

TABLE 1-14. *Residential Stock Efficiency Improvements, 2007-2030*

and commercial buildings, and industry.[7] According to the EPRI analysis, by 2010 the United States could reduce electricity use by about 150 terawatt-hours (3.9 percent of total U.S. electricity consumption) with measures costing less than 10 cents per kilowatt-hour and 210 terawatt-hours (5.5 percent) at 20 cents per kilowatt-hour or less. For reference, electricity consumption in 2005 totaled about 3,800 terawatt-hours[8] and the retail price of electricity in 2005 was 9.5 cents per kilowatt-hour for residential, 8.7 cents per kilowatt-hour for commercial, and 5.7 cents per kilowatt-hour for industrial.[9] At these prices, about 50 terawatt-hours (1.3 percent) of electric efficiency improvements could be achieved.

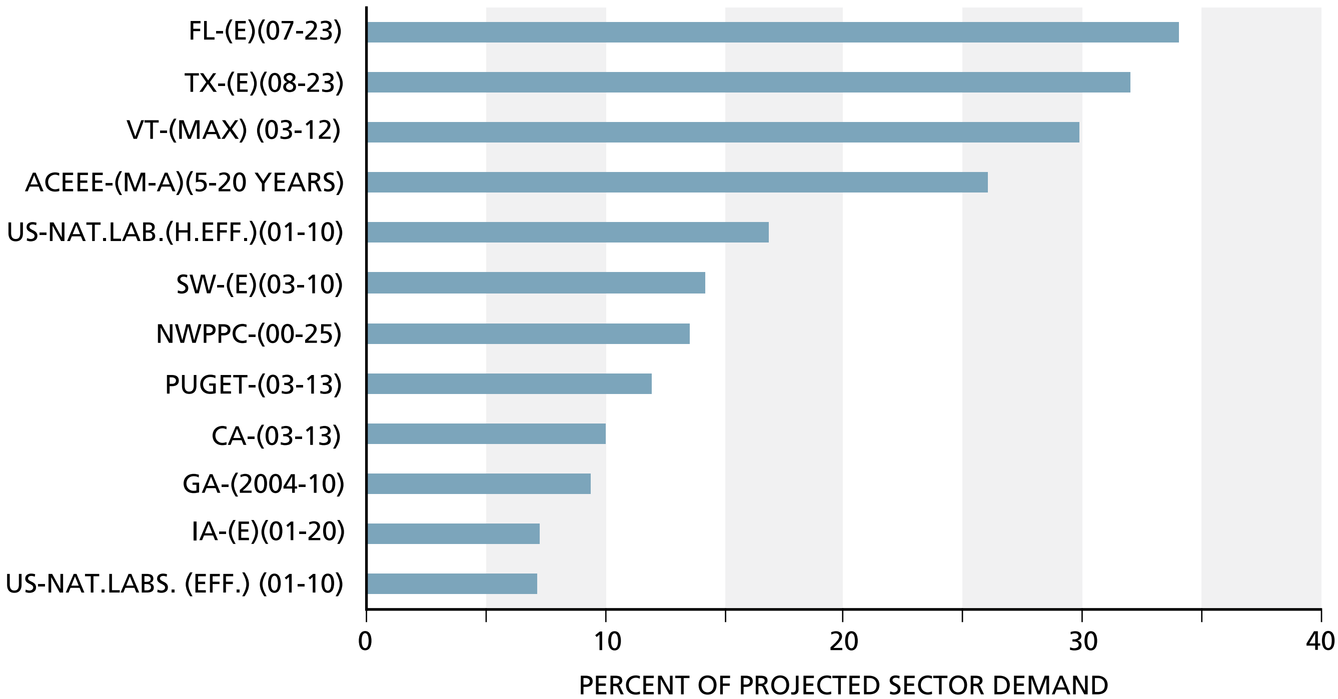
Buildings typically last decades if not centuries. Many of the features of buildings that affect their energy consumption—e.g., solar orientation, windows, tightness, and wall thickness—largely will go unchanged throughout the life of the building. Technologies and practices affecting these long-lived systems will be slow to penetrate the buildings stock and affect overall efficiency.

Building-energy codes typically target only new buildings and major rehabilitations, which is important

7 Clark Gellings, Greg Wikler and Debyani Ghosh, "Assessment of U.S. Electric End-Use Energy Efficiency Potential," *The Electricity Journal*, November 2006, Vol. 19, Issue 9, Elsevier Inc, 2006, p.67.

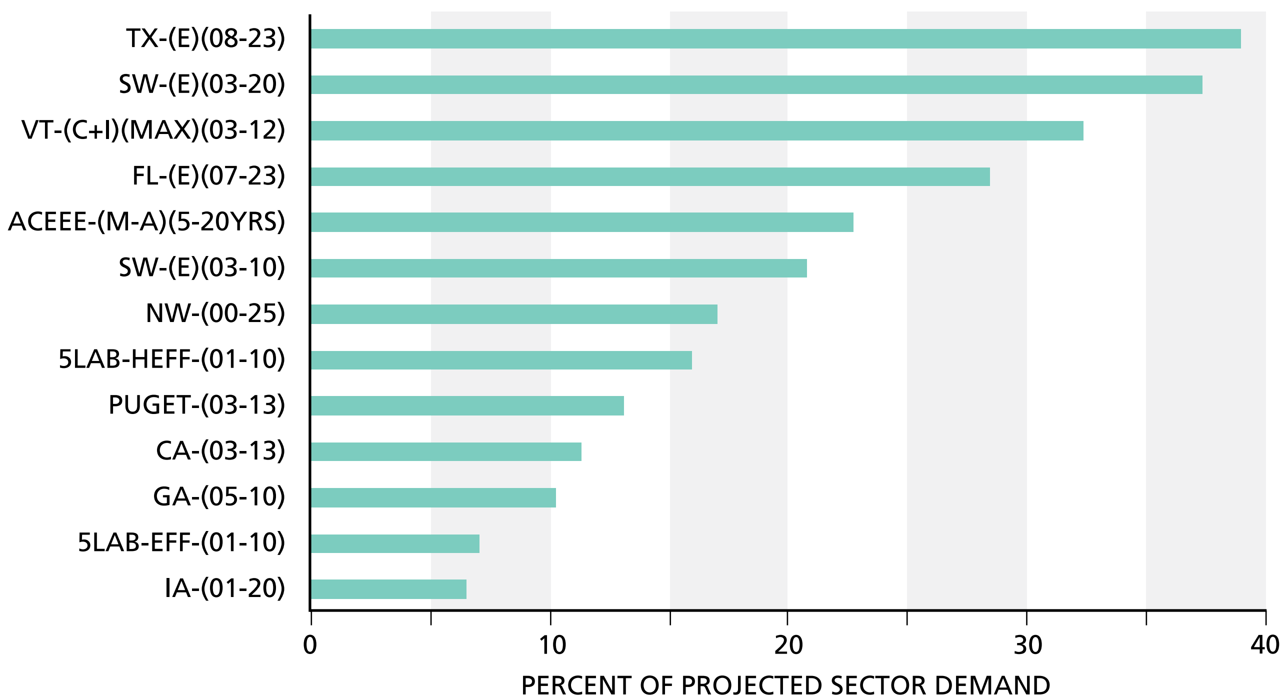
8 Energy Information Administration, Electric Power Annual with data for 2005, November 2006, http://www.eia.doe.gov/cneaf/electricity/epa/epates2.html.

9 Energy Information Administration, Electric Power Annual with data for 2005, November 2006, http://www.eia.doe.gov/cneaf/electricity/epa/epat7p4.html.



Source: Alliance to Save Energy, 2007.

FIGURE 1-47. *Achievable Potential for Electricity Savings in the Residential Sector (Various Studies)*



Source: Alliance to Save Energy, 2007.

FIGURE 1-48. *Achievable Potential for Electricity Savings in the Commercial Sector (Various Studies)* because today's new buildings are tomorrow's existing buildings. New building codes and appliance standards can be bolstered to improve overall building energy use, but to significantly impact building energy use policies that induce significant savings in existing buildings are necessary. Appliance standards, labels and other measures target appliances and other equipment used in existing buildings.

Appliances, heating equipment, and air conditioning facilities are replaced as they wear out. Energy use can be addressed by standards for these applications as the equipment is replaced.

New buildings can be constructed to meet current "best practices" at the time of construction. Since buildings are usually constructed and used by different groups it is likely that standards would be needed to ensure construction that is economically thermally efficient for the areas in which construction takes place.

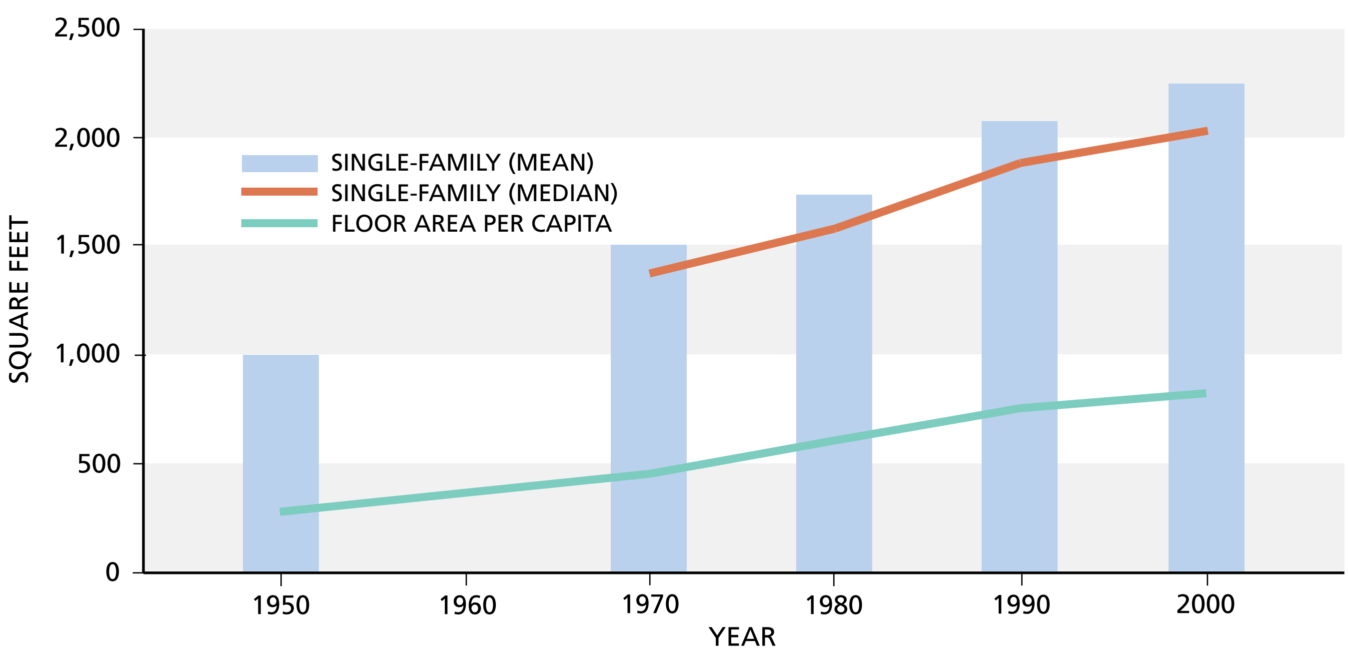
Translating Efficiency Into Reduced Energy Demand—"Consumption-Based Efficiency"

It is not always clear to what extent efficiency improvements are translated into actual reductions in energy demand. While the energy efficiency of homes has increased, so have home sizes. The average American home's floor area more than doubled between 1950 and 2000, as did floor area per capita; both square footage per home and per capita have increased by more than half just since the 1980s (see Figure 1-49).[10] Similarly, according to EIA's Residential Energy Consumption Survey (RECS), refrigerator energy use per household was roughly the same in 1993 and 2001, even though energy use per unit virtually halved during that time period.[11] While it is possible that second refrigerators would be commonplace regardless of unit efficiencies, it can at least be said that the demand for new energy services has increased as fast as efficiencies.

The demand for new energy services, such as second (and third) refrigerators and bigger homes, is driven by growing incomes, low energy prices, and to

10 National Association of Home Builders (NAHB), "Housing Facts: Figures and Trends 2003," 2003, Washington, DC.

11 EIA, *Residential Energy Consumption Survey 1993*, 1993, Table 5.27, http://eia.doe.gov/pub/consumption/residential/rx93cet6.pdf, & *Residential Energy Consumption Survey 2001*, 2001, Table CE5-1c, http://www.eia.doe.gov/emeu/recs/recs2001/ce_pdf/appliances/ce5-1c_climate2001.pdf; estimated average household site electricity consumption for refrigerators was 5 million Btu in 2001 and 4.7 million Btu in 1993.



Source: Harris et al., *Don't Supersize Me! Toward a Policy of Consumption-Based Energy Efficiency,* Environmental Energy Technology Division, Lawrence Berkeley National Laboratory, 2006. Original data from National Association of Home Builders.

FIGURE 1-49. *U.S. House Size (Floor Area)* some extent reduced operating costs due to improved efficiency. Some reductions in demand from energy-efficiency improvements are "taken back" in the form of increased demand for less-costly energy services. For example, efficiency improvements result in lower energy costs for refrigeration, which leads to increased demand for refrigerators. This "snapback" or rebound effect is estimated to be about 10 to 20 percent of the initial energy savings for most efficiency measures, although it varies depending on several factors, including end-use and elasticity of demand.[12]

Some energy-efficiency programs may even be contributing to—or at least not dampening—the increased demand for bigger appliances. The categorization of energy-using products for purposes of standards and labeling development may provide some perverse incentives to purchase products that are bigger, more powerful, or have more amenities. For example, ENERGY STAR label eligibility requirements for refrigerators vary by size—in some cases, the most efficient refrigerator in a larger class (which is therefore eligible for the ES label) may consume more energy than the least efficient in the smaller class (which is not eligible for the label). As a result, the ENERGY STAR label may inadvertently steer consumers toward "more efficient" refrigerators that are larger or have more amenities when the smaller refrigerator with fewer amenities and lower energy consumption might otherwise have been the choice.[13]

DEMAND STUDY POTENTIAL POLICY OPTIONS

From the work that was done by the Demand Task Group, the following list of potential policy actions was developed. The fundamentals supporting the list revolve around factors such as impact related to demand level, understanding of use, and effect on energy security. From this list, the overall study group developed three policies as study recommendations (see Policy Recommendations section below).

1. **Enhance international energy security framework.**

   China and India will account for a significant share of future growth in oil and gas demand. The United States should lead the enhancement of an international energy security framework, such as an expanded International Energy Agency, that includes China and India.

2. **U.S. leadership on environmental concerns.**

   If policy makers conclude that additional action to reduce carbon dioxide emissions is warranted, then the United States should take a leadership role to develop an effective global framework that involves all major emitters of carbon dioxide. Initiatives may be disjointed without U.S. leadership because some high growth developing countries are not likely to engage in such efforts unless developed countries, and especially the United States, take a clear leadership role.

3. **Areas should be identified where market solutions to support energy efficiency may not be fully effective.**

   Policy makers should consider policies that encourage energy-efficiency improvements, including metrics to measure progress.

4. **Raise vehicle fuel efficiency at the maximum rate consistent with available and economic technology.**

   Vehicle fuel efficiency standards should be raised. The interests of all concerned parties should be considered when establishing new efficiency standards. Significant gains in efficiency have occurred in the past. The average fuel efficiency of new cars doubled from 1974 to 1985. The Transportation Efficiency Subgroup analysis said "technologies exist, or are expected to be developed, that have the potential to reduce fuel consumption by 50 percent relative to 2005."

5. **The federal government should a) encourage states to implement more aggressive energy efficient building codes and b) update appliance standards.**

   Building codes and appliance standards should be updated to reflect currently available technology. New, up-to-date standards should be enforced. Options should be developed for enhancing current incentives to retrofit existing structures for improved energy efficiency.

12 Resources for the Future, "Retrospective Examinations of Demand-Side Energy Efficiency Policies," Discussion Paper, 2006.

13 Jeffrey Harris, Rick Diamond, Maithili Iyer, Chris Payne and Carl Blumstein, *Don't Supersize Me! Toward a Policy of Consumption-Based Energy Efficiency*, Environmental Energy Technologies Division, LBNL, 2006 ACEEE Summer Study on Energy Efficiency, p. 7-108.

6. **Encourage greater efficiency in the industrial sector.**

   Foster research, development, demonstration, and deployment of energy efficiency technologies and practices in the industrial sector. The U.S. industrial sector consumes one-third of the energy used in the United States. Technologies exist that could save 15 percent of this energy, but only one-third of this is currently economic. Further research and development is required to implement the remaining potential gain in efficiency. Areas of opportunity include waste heat recovery and boiler/steam efficiency. Make permanent the research and development tax credit is an option to increase industrial energy efficiency.

7. **Visible and transparent carbon dioxide cost.**

   If policy makers conclude that additional action to limit carbon dioxide emissions is warranted, then a mechanism should be developed that establishes a cost for emitting carbon dioxide. The mechanism should be economy-wide, visible, transparent, applicable to all fuels, and durable for the long-term. By establishing a cost (or price), companies will be better positioned to determine how to restrain carbon dioxide emissions. A carbon dioxide cap-and-trade system or a carbon dioxide tax are two possibilities that could reduce emissions and establish a carbon dioxide cost.

8. **The U.S. manufacturing industry and national security will be enhanced through a diverse range of fuels to generate power.**

   Fuel choice for power generation should be fostered to avoid increasing dependence on a single fuel. Reference projections indicate that the United States will be increasingly reliant on LNG imports to satisfy domestic natural gas demand. There are several potential drivers that could result in even higher domestic natural gas demand—e.g., escalating construction costs and greenhouse gas considerations, both of which favor natural gas over coal for new electrical power generation. Relying too heavily on natural gas for power generation could displace energy intensive manufacturing from the United States.

9. **Improve energy data collection.**

   Energy data collection efforts around the world should be expanded to provide data in a consistent and timely fashion. India and China should be encouraged to participate in world energy data collection.

10. **Improve energy modeling.**

    Development and use of economic activity feedback projection techniques should be encouraged to aid in evaluation of critical policies such as carbon constraint.

POLICY RECOMMENDATIONS

Improve Vehicle Fuel Economy

Nearly half of the 21 million barrels of oil products that the United States consumes each day is gasoline used for cars and light trucks. The Reference Case in AEO 2007 projects that gasoline consumption will increase by an average of 1.3 percent per year, totaling an increase of 3 million barrels per day between 2005 and 2030.

The CAFE standards have been the primary policy used to promote improved car and light-truck fuel economy in the United States over the last three decades. The original standards created one economy requirement for cars, and another less stringent one for light trucks to avoid penalizing users of work trucks. At the time, light-truck sales were about one-quarter of car sales. Since then, sport utility vehicles and minivans classified as light trucks have increased their share of the market. Now, these light-truck sales exceed car sales, and the increase at the lower truck fuel economy standard has limited overall fuel economy improvement.

Cars and trucks sold today are more technically efficient than those sold two decades ago. However, the fuel economy improvements that could have been gained from this technology over the last two decades have been used to increase vehicle weight, horsepower, and to add amenities. Consequently, car and truck fuel economy levels have been about flat for two decades, as previously shown in Figure 1-45.

Based on a detailed review of technological potential, a doubling of fuel economy of new cars and light trucks by 2030 is possible through the use of existing and anticipated technologies, assuming vehicle performance and other attributes remain the same as today.[14] This economy improvement will entail

14 See in this report, "Transportation Efficiency" section of Chapter 3, Technology. The extent to which technologies translate into reductions in fuel consumption depends on several factors, including costs, consumer preferences, availability, deployment, and timing.

higher vehicle cost. The 4 percent annual gain in CAFE standards starting in 2010 that President George W. Bush suggested in his 2007 State of the Union speech is not inconsistent with a potential doubling of fuel economy for new light duty vehicles by 2030. Depending upon how quickly new vehicle improvements are incorporated in the on-road light duty vehicle fleet, U.S. oil demand would be reduced by about 3-5 million barrels per day in 2030.[15] Additional fuel economy improvements would be possible by reducing vehicle weight, horsepower, and amenities, or by developing more expensive, step-out technologies.

Recommendation

The NPC makes the following recommendations to increase vehicle fuel economy:

- Improve car and light-truck fuel economy standards at the maximum rate possible by applying economic, available technology.
  - Update the standards on a regular basis.
  - Avoid further erosion of fuel economy standards resulting from increased sales of light trucks, or, alternatively, adjust light-truck standards to reflect changes in relative light-truck and car market shares.

Potential Effect: 3-5 million barrels of oil per day in the United States from the increased base in 2030.

Reduce Energy Consumption in the Residential and Commercial Sectors

Forty percent of U.S. energy is consumed in the residential and commercial sectors, including the energy lost while generating and distributing the electricity used. The EIA projects that U.S. residential and commercial energy use will increase almost one-third by 2030.

Significant efficiency improvements have been made in buildings over the last several decades. Improvement areas include the building structure itself; heating, cooling, and lighting systems; and appliances. However, these improvements have been partly offset by increased building sizes and by use of larger and multiple appliances. Cost-effective energy efficiency building technologies have outpaced current U.S. federal, state, and local policies. If applied, currently available efficiency technology would reduce energy use an additional 15-20 percent.[16]

Buildings typically last for decades. Many of the features of buildings that affect their energy consumption, such as wall thickness, insulation, structural tightness, and windows, will go largely unchanged throughout the life of the building. Technologies and practices affecting these long-lived systems will be slow to penetrate the building stock and affect their overall efficiency, making it important to implement policies early to achieve significant long-term savings.

Major barriers to energy efficiency investments include initial costs, insufficient energy price signals, split incentives (where the consumer is different from the facility provider), and individual consumer's limited information. To reduce energy consumption significantly below the projected baseline will require policy-driven improvements in energy efficiency.

Building Energy Codes

Building energy codes have proved to be a significant policy tool to encourage increased energy efficiency in new buildings, and in buildings undergoing major renovations. Building codes are administered by the 50 states and by thousands of local authorities. To help state and local governments, national model energy codes are developed and updated every few years. Under federal law, states are not obligated to impose energy codes for buildings, although at least 41 states have adopted some form of building energy code.

Adopting a building code does not guarantee energy savings. Code enforcement and compliance are also essential. Some jurisdictions have reported that one-third or more of new buildings do not comply with

15 The potential fuel savings of 3 to 5 million barrels per day in 2030 is relative to a scenario where current fuel economy standards remain unchanged through 2030.

16 Baseline projections taken from Energy Information Administration, *Annual Energy Outlook 2007 with Projections to 2030*, Table 2, February 2007, http://www.eia.doe.gov/oiaf/aeo/excel/aeotab_2.xls; savings estimates taken from several studies including *Building on Success, Policies to Reduce Energy Waste in Buildings*, Joe Loper, Lowell Ungar, David Weitz and Harry Misuriello – Alliance to Save Energy, July 2005. "Achievable" used here means that the measures are currently available and the savings can be realized with a reasonable level of effort and with acceptable reductions, if any, in perceived amenity value.

For additional discussion, see the *National Action Plan for Energy Efficiency*, which is available at: http://www.epa.gov/cleanrgy/actionplan/eeactionplan.htm critical energy code requirements for windows and air conditioning equipment, which are among the easiest energy saving features to verify.[17]

Building energy codes typically target only new buildings and major renovations. Additional policies are needed to encourage incremental, significant savings in existing buildings.

Appliance and Equipment Standards

Standards for appliances and other equipment are major policy measures that reduce energy use in existing buildings. These products may not consume much energy individually, but collectively they represent a significant portion of the nation's energy use.[18]

Energy efficiency standards currently do not apply to many increasingly common products, including those based on expanded digital technologies. Product coverage must be continuously evaluated and expanded when appropriate to assure inclusion of all significant energy consuming devices. In addition, industry and other stakeholders have negotiated standards for other products, such as residential furnaces and boilers. Implementing and enforcing expanded and strengthened standards would reduce energy consumption below the levels that will result from current Department of Energy requirements.[19]

Residential and commercial efficiency gains are partially consumed by increased use of the services and products that become more efficient. For example, U.S. house sizes have increased steadily over the years, offsetting much of the energy efficiency improvements that would have resulted had house sizes not swelled. Similarly, household refrigerators have increased in number and size, consuming much of the reduced energy use per refrigerator gained by efficiency standards. Energy efficiency programs should consider steps to avoid increasing the demand for energy services.

Recommendation

The NPC makes the following recommendations to improve efficiency in the residential and commercial sectors:

- Encourage states to implement and enforce more aggressive energy efficiency building codes, updated on a regular basis.
- Establish appliance standards for new products.
- Update federal appliance standards on a regular basis.

Potential Effect: 7-9 quadrillion Btu per year by 2030 in the United States, including 2-3 quadrillion Btu per year of natural gas (5-8 billion cubic feet per day), 4-5 quadrillion Btu per year of coal, and ~1 quadrillion Btu per year (0.5 million barrels per day) of oil.

Increase Industrial Sector Efficiency

The industrial sector consumes about one-third of U.S. energy, and contributes to a large share of the projected growth in both oil and natural gas use globally and in the United States. Worldwide, industrial demand for natural gas is expected to double by 2030. Worldwide, industrial sector demand for oil is expected to increase by 5 million barrels per day, or 15 percent of total oil demand growth through 2030.

The industrial sector is a price-responsive energy consumer. U.S. energy-intensive industries and manufacturers rely on internationally competitive energy supplies to remain globally competitive. In recent years, U.S. natural gas prices have risen faster than those in the rest of the world. As a result, U.S. energy-intensive manufacturers using natural gas as

17 From *Building on Success, Policies to Reduce Energy Waste in Buildings*, Joe Loper, Lowell Ungar, David Weitz and Harry Misuriello – Alliance to Save Energy, July 2005, pp. 18-19. For a compilation of compliance studies, see U.S. Department of Energy, *Baseline Studies*, on web site (http://www.energycodes.gov/implement/baseline_studies.stm). Arkansas reports 36 of 100 homes in the study sample did not meet the HVAC requirements of the state energy code.

18 From *Building on Success, Policies to Reduce Energy Waste in Buildings*, Joe Loper, Lowell Ungar, David Weitz and Harry Misuriello – Alliance to Save Energy, July 2005, p. 24

19 For additional savings potential see Steven Nadel, Andrew deLaski, Maggie Eldridge, & Jim Kleisch, *Leading the Way: Continued Opportunities for New State Appliance and Equipment Efficiency Standards*, March 2006, http://www.standardsasap.org/a062.pdf.

a fuel or feedstock have responded by increasing the efficiency of their operations and/or by shifting more of their operations to lower energy cost regions outside the United States.

Across the industrial sector, there are opportunities to increase energy efficiency by about 15 percent.[20] Areas for energy savings include waste-heat recovery, separation processes, and combined heat and power.[21] While 40 percent of that opportunity could be implemented now, further research, development, demonstration, and deployment are required before the remaining savings can be achieved. Providing programs that encourage deployment of energy efficiency technologies and practices will hasten their implementation. Making the federal research and development tax credit permanent is one way to encourage private investment in these areas. However, a lack of technically trained workers can impede the implementation of efficiency projects while the uncertainty from price volatility can make justifying those projects difficult.

20 From the *Chemical Bandwidth Study*, DOE, 2004; *Energy Bandwidth for Petroleum Refining Processes*, DOE, 2006; *Pulp and Paper Industry Energy Bandwidth Study*, AIChE, 2006.

See also *Curbing Global Energy Demand Growth: The Energy Productivity Opportunity*, McKinsey Global Institute, May 2007.

21 "Combined heat and power" refers to using the excess heat from generating electricity to meet processing or building heat needs. This combination is frequently called "cogeneration" and results in a substantial increase in efficiency versus generating electricity and heat separately.

Recommendation

The NPC makes the following recommendations to improve efficiency in the industrial sector:

- The Department of Energy should conduct and promote research, development, demonstration, and deployment of industrial energy efficiency technologies and best practices.
- The research and development tax credit should be permanently extended to spur private research and development investments.

Potential Effect: 4-7 quadrillion Btu per year by 2030 in the United States, about equal parts coal, gas, and oil.

Generation of electricity uses a significant amount of energy. In the United States, about 30 percent of primary energy is used by the electric power generating sector. Only modest generation efficiency improvements appear economically feasible in existing plants (2 to 6 percent), as efficiency improvements are incorporated during routine maintenance. The major potential for efficiency improvement comes when existing generation plants are replaced with facilities using updated technology and designs. Retirement of existing facilities and selection of replacement technology and design is driven by economics affected by fuel cost, plant reliability, and electricity dispatching considerations.