STATEMENT OF

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HEARING ON THE NATION'S ENERGY FUTURE: ROLE OF RENEWABLE ENERGY AND ENERGY EFFICIENCY

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Mr. Chairman and Members of the Committee:

I appreciate the opportunity to appear before you today to discuss renewable energy and energy efficiency in the United States.

The Energy Information Administration (EIA) is an autonomous statistical and analytical agency within the Department of Energy. We are charged with providing objective, timely, and relevant data, analysis, and projections for the use of the Department of Energy, other government agencies, the U.S. Congress and the public. We do not take positions on policy issues, but we do produce data and analysis reports that are meant to help policy makers determine energy policy. Because we have an element of statutory independence with respect to the analyses that we publish, our views are strictly those of EIA. We do not speak for the Department, nor for any particular point of view with respect to energy policy, and our views should not be construed as representing those of the Department or the Administration. However, EIA's baseline projections on energy trends are widely used by government agencies, the private sector, and academia for their own energy analyses.

The projections in this testimony are from the *Annual Energy Outlook 2001* (*AEO2001*), published by EIA in December 2000, which provides projections and analysis of domestic energy consumption, supply, prices, and energy-related carbon dioxide emissions through 2020. These projections are not meant to be exact predictions of the future, but represent a likely energy future, given technological and demographic trends, current laws and regulations, and consumer behavior as derived from known data. EIA recognizes that projections of energy markets are highly uncertain, subject to many random events that cannot be foreseen, such as weather, political disruptions, strikes, and technological breakthroughs. In addition to these short-term phenomena, long-term trends in technology development, demographics, economic growth, and energy resources may evolve along a different path than assumed in the *AEO2001* reference case. Many of these uncertainties are explored through alternative cases in the *AEO2001*.

Energy Consumption to 2020

Total energy consumption is projected to increase from an estimated 96.1 quadrillion British thermal units (Btu) in 1999 to 127.0 quadrillion Btu between 1999 and 2020, an average annual increase of 1.3 percent. Energy consumption in the United States increased from 67.9 Btu in 1970 to 81.0 Btu in 1979, with a downturn in 1974 and 1975 during the first oil price increase. During the early 1980s, energy consumption again declined to 73.3 Btu in 1983, due in part to the second oil price increase. Since 1983, energy consumption has been generally increasing, with an average annual increase of 1.7 percent through 1999.

Total renewable energy consumption, including ethanol used in gasoline, is projected to increase from 6.6 quadrillion Btu in 1999 to 8.3 quadrillion Btu in 2020, an average annual growth of 1.1 percent. Renewable energy consumption in the United States has increased from 4.1 quadrillion Btu in 1970 and has included primarily hydroelectric power, wood, and waste, with small amounts of geothermal and other renewable sources. The share of total energy consumption that is derived from renewable sources is projected to be 7 percent in 2020, approximately the same share as in 1999. In 2020, about 55 percent of renewables are used for electricity generation and the rest for dispersed heating and cooling, industrial uses (primarily cogeneration), and fuel blending (Figure 1).

The projections incorporate promulgated efficiency standards for new energy-using equipment in buildings, as authorized by the National Appliance Energy Conservation Act of 1987 and periodically updated by the Department of Energy, and for motors, as required by the Energy Policy Act of 1992. Since *AEO2001* included only those laws, regulations, and standards in effect as of July 1, 2000, the new standards for residential clothes washers, water heaters, and central air conditioners and heat pumps and commercial heating, cooling, and water heating equipment issued in January 2001 are not included. In addition to the impact of efficiency standards, improvements in efficiency are projected as a result of expected technological improvement and market forces.

Transportation. Transportation energy demand is expected to increase at an average annual rate of 1.8 percent to 38.5 quadrillion Btu in 2020 and is the fastest growing end-use sector. The growth in transportation use is driven by 3.6-percent growth in air travel, the most rapidly increasing transportation mode, and 1.9-percent annual growth in light-duty vehicle travel, the largest component of transportation energy demand, coupled with slow growth in vehicle efficiency.

Historically, the average efficiency of new automobiles has increased from 15.8 miles per gallon in 1975 to 27.9 miles per gallon in 1986, staying in the 27 to 28 mile range over the next decade (Figure 2). The efficiency of new light trucks also improved from 13.7 miles per gallon in 1975 to 21.4 miles per gallon in 1986, remaining at about 21 miles per gallon for the next decade. While the average efficiency of all new light-duty vehicles is expected to increase from 24.2 miles per gallon in 1999 to 28.0 miles per gallon in 2020, improvements in the average efficiency of the fleet is slowed by stock turnover (Figure 3). Between 1999 to 2020, the average stock efficiency of all light-duty vehicles increases from 20.5 to 21.5 miles per gallon. With fuel efficiency standards for light-duty vehicles assumed to stay at current levels, fuel efficiency is projected to improve at a slower rate through 2020 than it did in the 1980s, due to projected low fuel prices and higher personal income which are expected to increase the demand for larger, more powerful vehicles. Average horsepower for new cars in 2020 is projected to be about 55 percent above the 1999 average, but advanced technologies and materials are expected to keep new vehicle fuel economy from declining.

Advanced technology vehicles, representing automotive technologies that use alternative fuels or require advanced engine technology, are projected to reach nearly 2.7 million vehicle sales (16.7 percent of total projected light-duty vehicle sales) by 2020 (Figure 4). The leading technologies are gasoline hybrid electric vehicles, followed by turbo direct injection diesels, and alcohol flexible-fueled vehicles. The use of renewables in the transportation sector, specifically ethanol, is projected to increase at an average rate of 3.6 percent per year between 1999 to 2020. This represents a doubling of the use of ethanol to 0.24 quadrillion Btu by 2020. Ethanol in the form of E85 is consumed primarily by light-duty flexible-fueled vehicles and dedicated E85 vehicles, but the majority of ethanol is used for gasoline blending, about 87.5 percent in 2020. All alternative fuels are projected to displace about 203,000 barrels of oil equivalent per day by 2020, or 2.1 percent of light-duty vehicle fuel consumption.

Residential. Residential energy consumption is projected to increase at an average annual rate of 1.2 percent, reaching 24.4 quadrillion Btu in 2020. The growth is led by energy demand for a variety of electricity-using equipment and appliances (Figure 5). Residential electricity use is projected to increase at an annual rate of 1.9 percent. The energy intensity of households, measured as delivered energy consumption per household, was 148 million Btu per household in 1970, generally declining through the 1980s to a low of 95 million Btu per household in 1990 (Figure 6). Delivered energy use per household is expected to increase slightly from 102 to 107 million Btu per household between 1999 and 2020, an average annual increase of 0.2 percent. Primary energy use per household, including all losses associated with the generation and transmission of the electricity used in the sector, increases at a slower rate, 0.1 percent per year, due to the increasing efficiency of electricity generation. Total energy use per household is expected to increase from 184 to 188 million Btu per household between 1999 and 2020, an average annual increase of 0.1 percent. Total energy use per square foot of floorspace is actually projected to slowly decrease at an average annual rate of 0.1 percent between 1999 and 2020, in part due to equipment standards, which help to increase the efficiency of residential appliances (Figure 7). However, it is also expected that new homes will continue to increase in size, consistent with recent trends, leading to the increase in energy consumption per household.

Energy use for space heating, the most energy-intensive end use in the residential sector, grew by 1.8 percent per year from 1990 to 1997. Future growth is expected to be slowed by higher equipment efficiency and tighter building codes. Building shell efficiency gains are projected to cut space heating demand by nearly 10 percent per household in 2020 relative to the demand in 1997.

A variety of appliances are now subject to minimum efficiency standards, including heat pumps, air conditioners, furnaces, refrigerators, and water heaters. Current standards for a typical residential refrigerator limit electricity use to 690 kilowatthours per year, and revised standards are expected to reduce consumption by another 30 percent by 2002. Energy use for refrigeration has declined by 1.8 percent per year from 1990 to 1997 and is expected to decline by about 2.0 percent per year through 2020, as older, less efficient refrigerators are replaced with newer models.

The ""all other"" category, which includes smaller appliances such as personal computers, dishwashers, clothes washers, and dryers, has grown by 5 percent per year from 1990 to 1997 and now accounts for 30 percent of residential primary energy use. It is projected to account for 40 percent in 2020, as small electric appliances continue to penetrate the market. The promotion of voluntary standards, both within and outside the appliance industry, is expected to forestall even larger increases. Even so, the ""all other"" category is projected to exceed other components of residential demand by 2020.

The *AEO2001* reference case projects an increase in the stock efficiency of residential appliances, as stock turnover and technology advances in most end-use services combine to reduce residential energy intensity over time. For most appliances covered by the National Appliance Energy Conservation Act of 1987, the most recent Federal efficiency standards are higher than the 1998 stock, ensuring an increase in stock efficiency (Figure 8) without any additional new standards. Future updates to the Federal standards could have a significant effect on residential energy consumption, but they are not included in the reference case. New efficiency standards for clothes washers, water heaters, central air conditioners, and heat pumps were finalized in January 2001.

For almost all end-use services, technologies now exist that can significantly curtail future energy demand if they are purchased by consumers. The most efficient technologies can provide significant long-run savings in energy bills, but their higher purchase costs tend to restrict their market penetration. For example, condensing technology for natural gas furnaces, which reclaims heat from exhaust gases, can raise efficiency by more than 20 percent over the current standard; and variable-speed scroll compressors for air conditioners and refrigerators can increase their efficiency by 50 percent or more. In contrast, there is little room for efficiency improvements in electric resistance water heaters, because the technology is approaching its thermal limit.

Commercial. Commercial sector energy consumption is projected to increase at an average rate of 1.4 percent annually, to 20.8 quadrillion Btu in 2020. Similar to the residential sector, electricity consumption for telecommunications, computers, office equipment, and other appliances is the fastest growing area, with total commercial electricity demand increasing at an average annual rate of 2.0 percent. Delivered energy consumption per square foot of commercial floorspace was 146 thousand Btu in 1970, declining generally through the next two decades, reaching a low of 118 thousand Btu per square foot in 1992 (Figure 9). In the projections, delivered energy consumption increases from 121 thousand Btu per square foot in 1999 to 129 thousand Btu per square foot in 2020, an average annual increase of 0.3 percent, due in part to growth in office equipment and other electronic devices, although growth is moderated somewhat by equipment standards. Similar to the residential sector, primary energy consumption in the commercial sector is expected to increase at a slower rate of 0.1 percent through 2020, from 249 to 253 thousand Btu per square foot.

Currently, the combined residential and commercial buildings sectors use about 0.5 quadrillion Btu of renewable energy, primarily wood consumed for residential space heating and secondary heating. This is not expected to change through 2020. Renewable energy is also used in applications such as ground-source heat pumps that use geothermal energy for heating and cooling and photovoltaic (PV) solar systems that generate electricity. The use of geothermal and solar energy in the buildings sectors is projected to grow 2.0 percent per year from 1999 through 2020. The market share for residential ground-source heat pumps is projected to double by 2020 although that share is projected to remain below 1 percent over the forecast horizon. Grid-connected PV solar systems on buildings are projected to comprise over 750 megawatts of distributed generating capacity by 2020, aided in large measure by programs such as Million Solar Roofs that promote growth in the PV market.

Industrial. Industrial energy demand is projected to increase at an average rate of 1.0 percent per year, reaching 43.4 quadrillion Btu in 2020. Total industrial output is expected to grow at an average rate of 2.6 percent per year; however, the fastest growing industrial sector is non-energy-intensive manufacturing with an average annual growth of 3.3 percent. Energy-intensive manufacturing and nonmanufacturing have growth rates of 1.2 and 1.6 percent, respectively. This structural shift in the industrial sector, combined with ongoing efficiency improvements, helps to moderate the increase in industrial energy demand. Industrial energy intensity, measured as consumption per dollar of output, declined sharply following the oil price shocks of 1978-1979, from a high of 10.1 thousand Btu per 1992 dollar of output in 1979 to 8.2 thousand Btu per dollar output in 1987 (Figure 10). Subsequently, the rate of the decline moderated. Over the period 1978 to 1999, industrial primary energy intensity declined at an average rate of 1.4 percent per year. From 1999 to 2020, intensity is projected to decline at a rate of 1.5 percent per year from 7.4 to 5.4 thousand Btu per 1992 dollar of output.

The share of total industrial output attributed to the energy-intensive industries is projected to fall from 23 percent in 1999 to 17 percent in 2020. Consequently, even if no specific industry experienced a decline in intensity, aggregate industrial intensity would decline. Figure 10 shows projected changes in energy intensity due to structural effects and efficiency effects separately. Over the forecast period, industrial delivered energy intensity is projected to drop by 26 percent, and the changing composition of industrial output alone is projected to result in approximately a 19-percent drop. Thus, two-thirds of the expected change in delivered energy intensity for the sector is attributable to structural shifts and the remainder to changes in energy intensity associated with projected increases in equipment and production efficiencies.

Consumption of biomass byproducts in the pulp and paper, lumber, and food industries accounts for most of the renewable energy consumed in the industrial sector. Biomass consumption is projected to increase from 2.2 quadrillion Btu in 1999 to 3.1 quadrillion Btu in 2020, a 1.7-percent average annual growth rate. Biomass often is used in cogeneration, the simultaneous production of useful thermal energy and electricity. The higher projected availability of biomass leads to additional biomass-based cogeneration capacity, which is projected to increase from an estimated 4.5 gigawatts in 1999 to 7.4 gigawatts in 2020, a 2.4-percent average annual growth rate.

Total Energy Intensity. Total energy intensity, measured as energy use per dollar of gross domestic product (GDP), has declined since 1970, most notably when energy prices have increased rapidly (Figure 11). Between 1970 and 1986, energy intensity declined at an average rate of 2.3 percent per year as the economy shifted to less energy-intensive industries and more efficient technologies. Without significant price increases and with the growth of more energy-intensive industries, intensity declines moderated to an average of 1.3 percent per year between 1986 and 1999. Through 2020, energy intensity is projected to decline at an average rate of 1.6 percent per year as efficiency gains and structural shifts in the economy offset growth in demand for energy services. Energy use per person generally declined from 1970 through the mid-1980s, and then tended to increase as energy prices declined. Per capita energy use is expected to increase slightly through 2020, as efficiency gains only partly offset higher demand for energy services.

Electricity Generation. During the 1960s, electricity demand grew by more than 7 percent per year, nearly twice the rate of economic growth (Figure 12). In the 1970s and 1980s, however, the ratio of electricity demand growth to economic growth declined to 1.5 and 1.0, respectively. Several factors have contributed to this trend, including increased market saturation of electric appliances, improvements in equipment efficiency and utility investments in demand-side management programs, and more stringent equipment efficiency standards. Throughout the forecast, growth in demand for office equipment and personal computers, among other equipment, is dampened by slowing growth or reductions in demand for space heating and cooling, refrigeration, water heating, and lighting. The continuing saturation of electricity appliances, the availability and adoption of more efficient equipment, and efficiency standards are expected to hold the growth in electricity sales to an average of 1.8 percent per year between 1999 and 2020, compared with 3.0-percent annual growth in GDP.

Generation from both natural gas and coal is projected to increase through 2020 to meet growing demand for electricity and offset the decline in nuclear power expected from retirements of some existing facilities. Coal remains the primary fuel for generation; however, the share of coal generation is expected to decline from 51 to 44 percent between 1999 and 2020. Assumptions about electricity industry restructuring, such as higher cost of capital and shorter financial life of plants, tend to favor the less capital-intensive and more efficient natural gas generation technologies. The natural gas share of total generation is expected to increase from 16 to 36 percent between 1999 and 2020. Historically, consumption for electricity generation by fossil-fired generators has increased at an approximately equivalent pace with generation; however, largely due to the expected penetration of natural gas-fired, combined-cycle technologies, fuel consumption is projected to grow at a slower rate than fossil-fired generation as efficiency improves (Figure 13).

Total grid-connected electricity generation from renewable sources is projected to increase from 389 billion kilowatthours in 1999 to 448 billion kilowatthours in 2020. Renewables decline from a 10.5-percent share of electricity generation in 1999 to 8.5 percent in 2020. Generation from renewables other than hydroelectricity is projected to increase from 77 billion to 146 billion kilowatthours by 2020, increasing slightly from a 2-percent share of total generation in 1999 to a 3-percent share in 2020. Conventional hydroelectricity is expected to decline slightly through 2020, as output from existing facilities declines. Most of the projected increase in renewables is expected from biomass, landfill gas, geothermal energy, and wind power (Figure 14). State mandates and other incentives, including the Federal production tax credit for generation from wind, encourage much of the growth in renewables in the earlier part of the forecast period.

Further penetration of renewables is slowed by the total cost of renewable generation relative to fossil-fired technology. Despite cost reductions that are projected over time, the total cost of wind generation is expected to remain higher than that of either coal or natural gas-fired combined cycle generation through 2020 (Figure 15). However, all nonhydroelectric renewable electricity generation is projected to grow at a faster rate than all conventional energy sources of generation, with the exception of natural gas. If, in reality, future natural gas supplies and prices are different than projected in *AEO2001*, the expected outlook for renewable sources of energy could be different.

Alternative Cases

In order to show the impact of alternative assumptions concerning the key factors driving energy markets, we include a number of alternative cases in *AEO2001*, including cases with more optimistic assumptions for renewable generating technologies and cases varying the assumptions about the rate of improvement for energy-consuming technologies.

High Renewables. A high renewables case assumes more favorable characteristics for nonhydroelectric renewable generating technologies than in the reference case, including lower capital, operations and maintenance costs, increased biomass fuel supplies, and higher capacity factors for solar and wind generation. The assumptions in this case approximate the renewable energy technology goals of the U.S. Department of Energy. Under these assumptions, total generation from nonhydroelectric renewables is projected to reach 242 billion kilowatthours in 2020, compared with 146 billion kilowatthours in the reference case, increasing from 2.8 percent of total generation to 4.6 percent (Figure 16).

Alternative Technology. Another alternative case assumes more rapid improvement in new technologies for end-use demand, through lower costs, higher efficiencies, and earlier availability for new technologies, relative to the reference case, as well as more rapid improvement in the costs and efficiencies of advanced fossil-fired and new renewable generating technologies. In the high technology case, aggregate energy intensity is expected to decline at an average rate of 1.9 percent per year from 1999 to 2020, compared with 1.6 percent per year in the reference case (Figure 17). As a result, projected energy demand in 2020 is 8 quadrillion Btu lower than in the reference case, reducing carbon dioxide emissions to 1,875 million metric tons carbon equivalent in 2020, compared to 2,041 million metric tons carbon equivalent in the reference case (Figure 18). Such technology improvements could result from increased research and development, but should not be considered the most optimistic improvements that could occur with a very aggressive program of research and development.

The *AEO2001* reference case assumes continued improvements in technology for both energy consumption and production; however, it is possible that technology could develop at a slower rate. In the 2001 technology case, it is assumed that all future equipment choices will be made from the equipment and vehicles available in 2001, with new building shell and industrial plant efficiencies frozen at 2001 levels. New generating technologies are assumed not to improve over time. As a result, the average decline in energy intensity is reduced to 1.4 percent per year from 1.6 percent per year in the reference case. Efficiencies improve over the forecast period as new equipment is chosen to replace older stock and the capital stock expands; however, projected energy demand in 2020 is 6 quadrillion Btu higher than in the reference case, increasing carbon dioxide emissions to 2,157 million metric tons carbon equivalent.

Figure 19 displays the impact of different assumptions about technology development in the residential sector alone. In the 2001 technology case, 3.1 percent, or 0.8 quadrillion Btu, of additional energy is required in 2020. In the high technology case, 6.0 percent, or 1.5 quadrillion Btu, of energy is saved in 2020 due to the earlier penetration of more efficient technologies. In a best available technology case, it is assumed that the most energy-efficient technology is always chosen in the forecast regardless of cost. Under this assumption, energy consumption in the residential sector is 22.5 percent, or 5.5 quadrillion Btu, lower in 2020 relative to the reference case. In the commercial sector, using similar assumptions, the 2001 technology case requires 2.4 percent, or 0.5 quadrillion Btu, more energy in 2020 than in the reference case (Figure 20). In the high technology case, commercial energy consumption in 2020 is reduced by 3.5 percent, or 0.7 quadrillion Btu, from the reference case, and, in the best available technology case, consumption in 2020 is reduced by 14.1 percent, or 2.9 quadrillion Btu, relative to the reference case.

Energy Policies and Programs. Due to the policy neutrality of EIA, we do not propose or advocate any particular policies and programs. We do note that, in general, there are a wide range of policies that could alter the energy future described in the *AEO2001* by encouraging the development and adoption of more energy-efficient and renewable technologies and stimulating production of domestic energy resources. Such policies include, but are not limited to, programs to foster research, development, and deployment of technologies, government-industry partnerships, voluntary programs, tax credits and other financial incentives, and minimum appliance efficiency and renewable standards.

Conclusion. Over the forecast period, we expect total energy intensity to continue to improve, however, at a slower rate than experienced at other periods in the last twenty years. Increasing demand for energy services is offset to some degree by energy efficiency improvements, some of which occur due to equipment standards. The use of renewable sources of energy is expected to increase; however, at a relatively slow pace, due in part to the relative costs of these technologies compared with fossil-fueled technologies. Technology costs or fossil fuel prices that differ from those in the projections could alter the outlook for renewables. These forecasts also incorporate an expectation of efficiency improvements in both demand and supply although different paths for technological development and other incentives could lead to slower or more rapid efficiency gains.

Thank you, Mr. Chairman and members of the Subcommittee. I will be happy to answer any questions you may have.

Figure 1. Renewable Energy Consumption by Sector, 1999-2020
(quadrillion Btu)

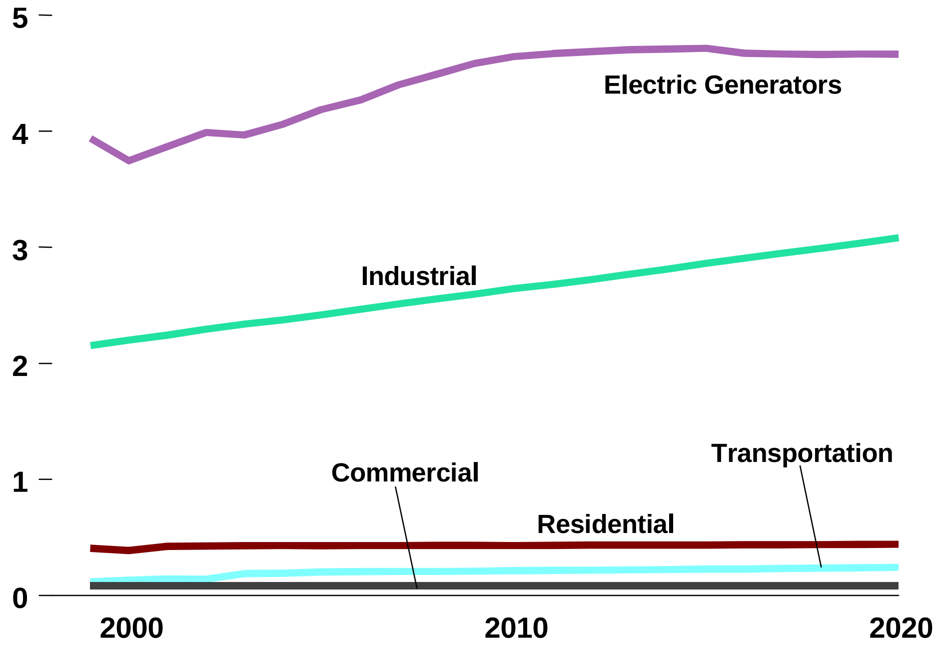

Figure 2. New Light-Duty Vehicle Fuel Efficiency, 1975-2020
(miles per gallon)

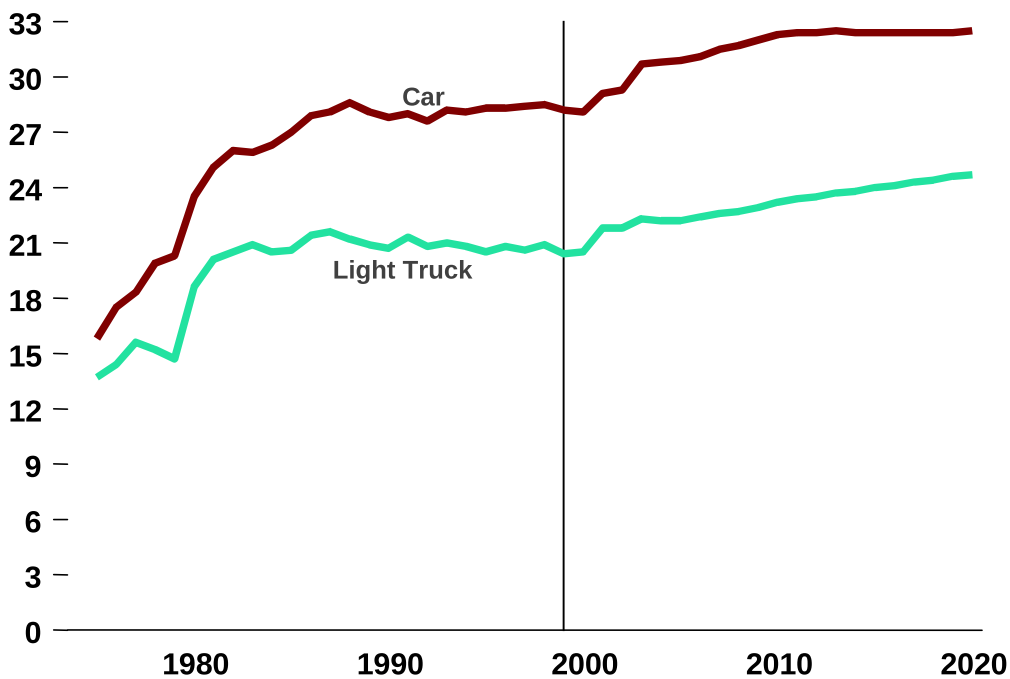

Figure 3. Light-Duty Vehicle Efficiency, 1998-2020
(miles per gallon)

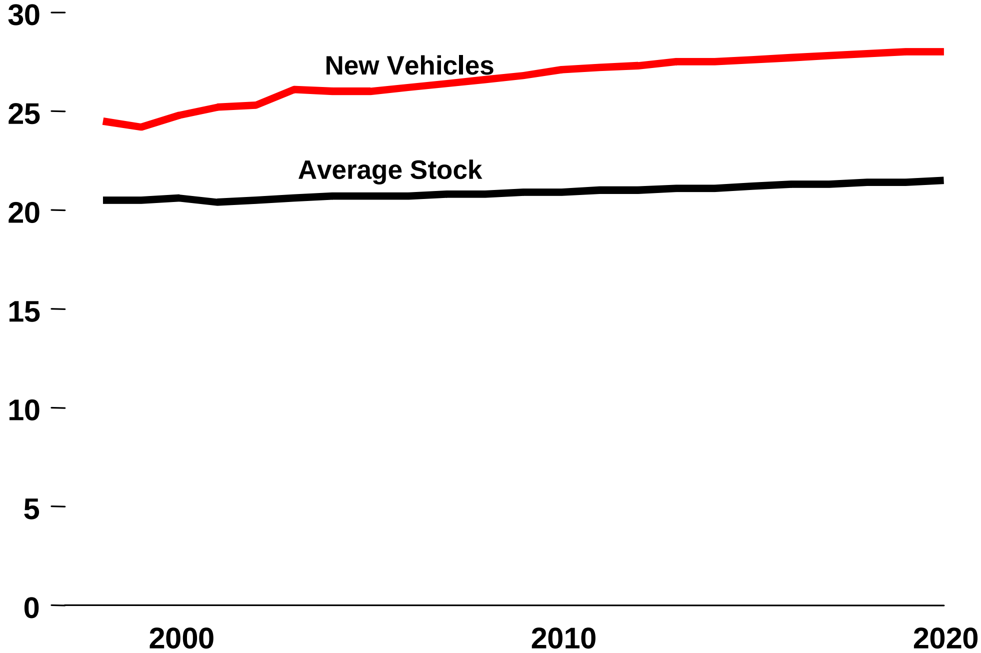

Figure 4. Projected Sales of Advanced Technology Light-Duty Vehicles by Fuel Type, 2010 and 2020
(thousand vehicles sold)

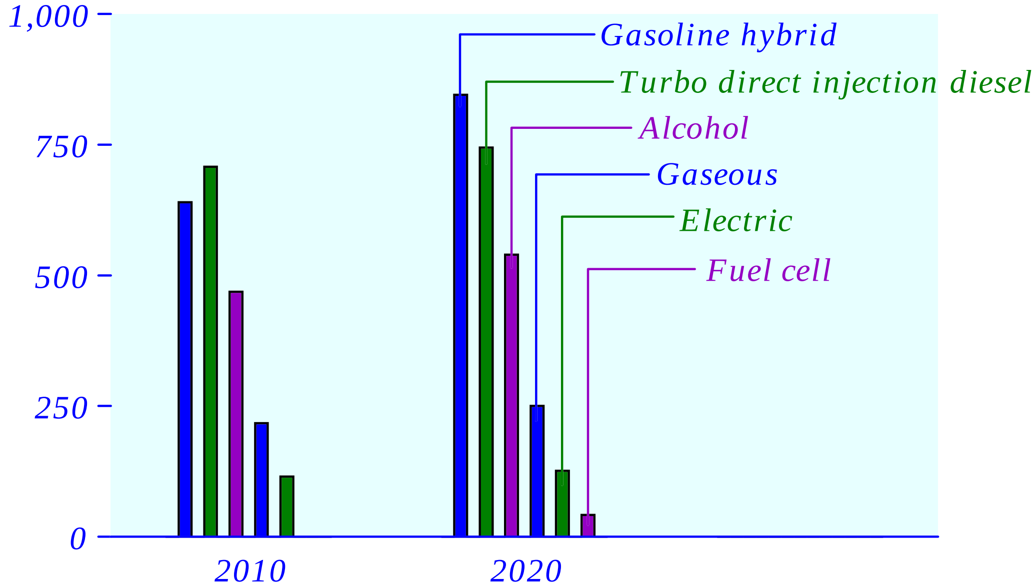

Figure 5. Residential Primary Energy Consumption by End Use, 1990, 1997, 2010, and 2020
(quadrillion Btu)

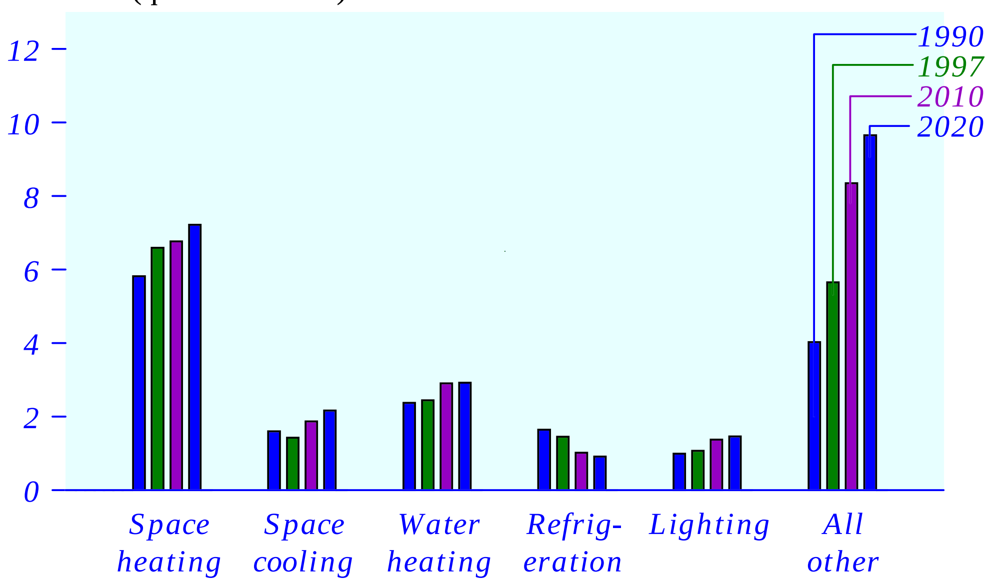

Figure 6. Residential Sector Energy Intensity, 1970-2020
(index, 1999=1.0)

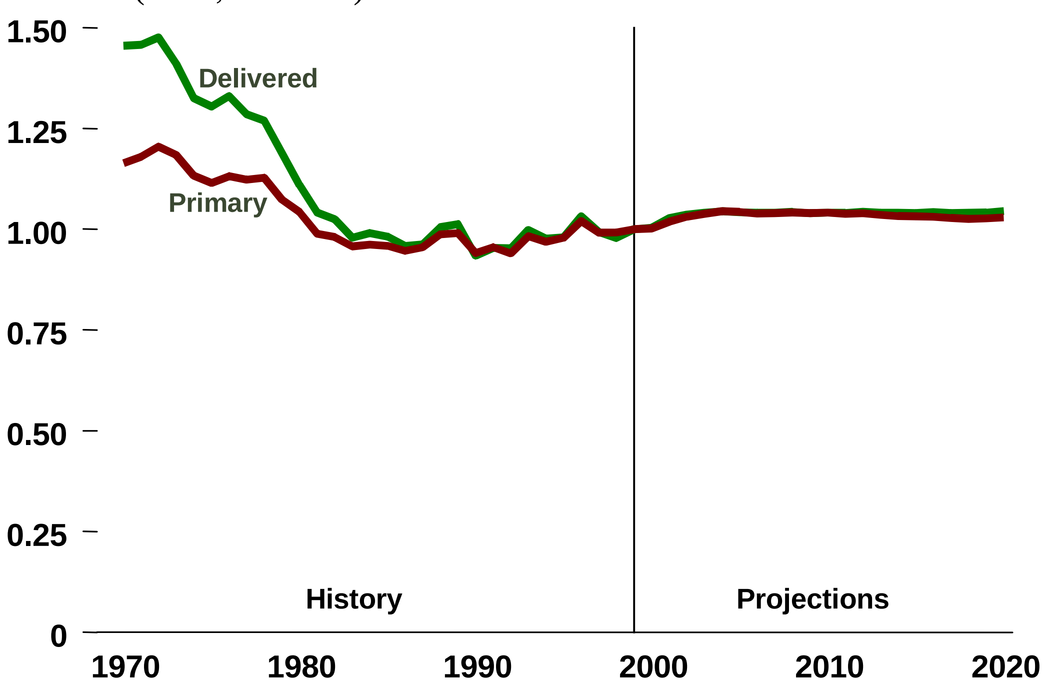

Figure 7. Residential Appliance Stock Efficiency, 1972-2020
(index, 1972=1.0)

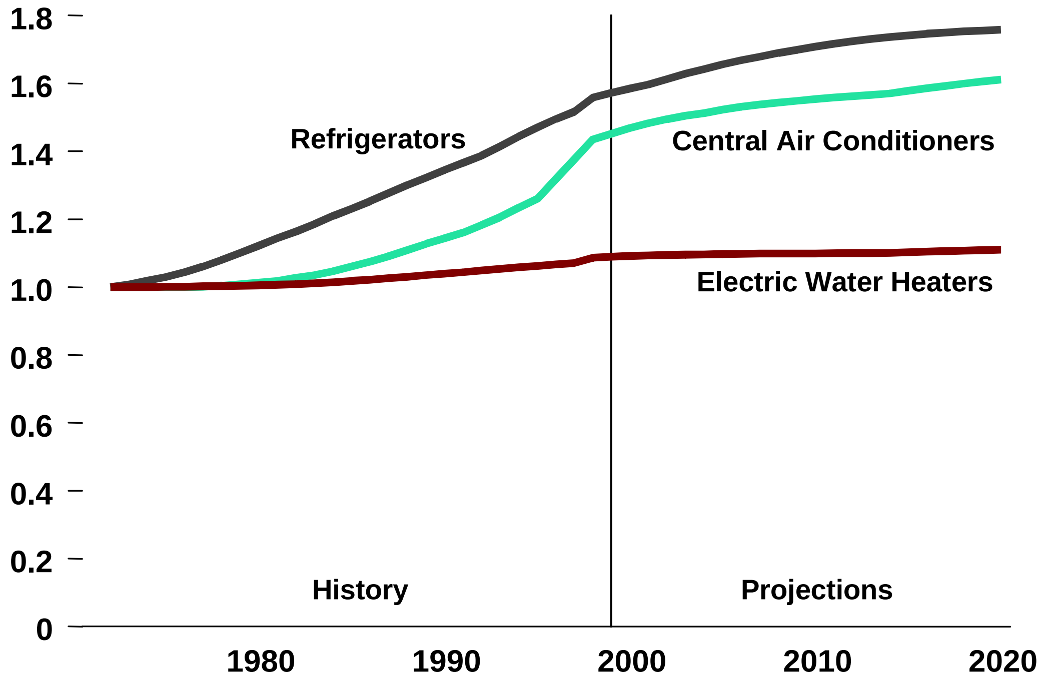

Figure 8. Efficiency Indicators for Selected Residential Appliances,
1999 and 2020
(index, 1999 stock efficiency=1)

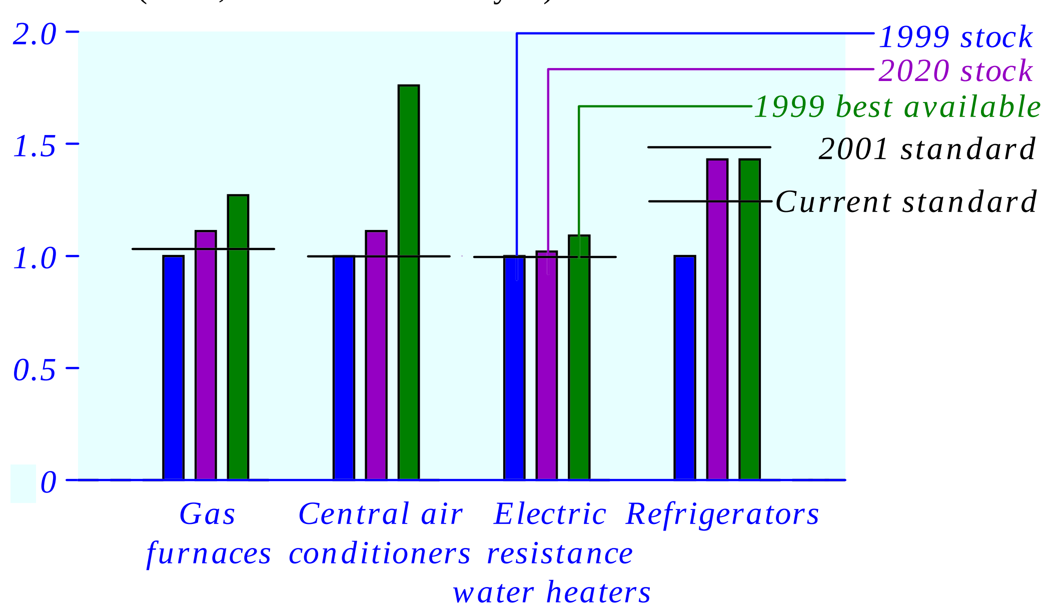

Figure 9. Commercial Sector Energy Intensity, 1970-2020
(index, 1999=1.0)

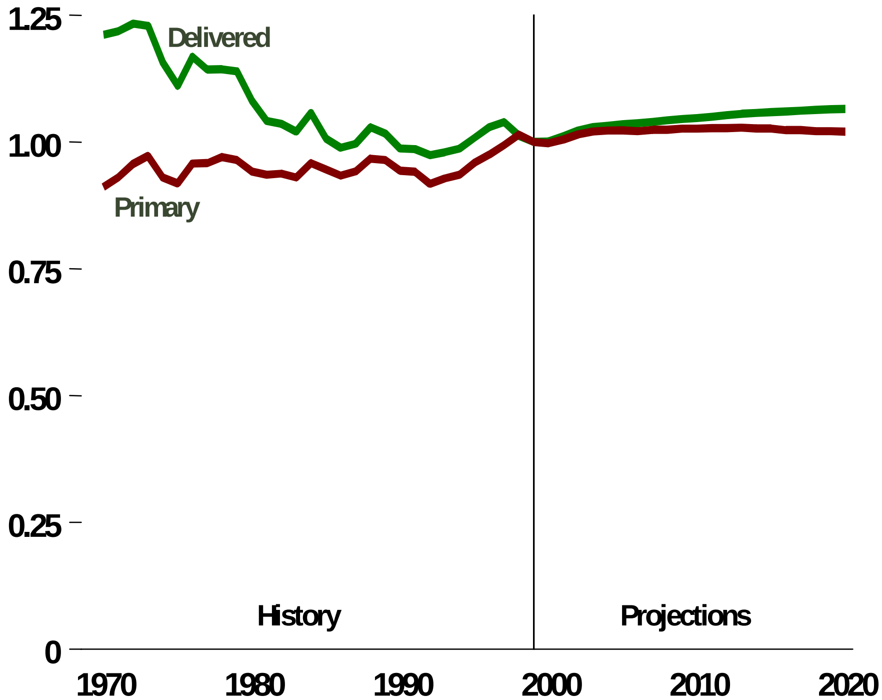

Figure 10. Industrial Sector Energy Intensity, 1978-2020
(index, 1999=1.0)

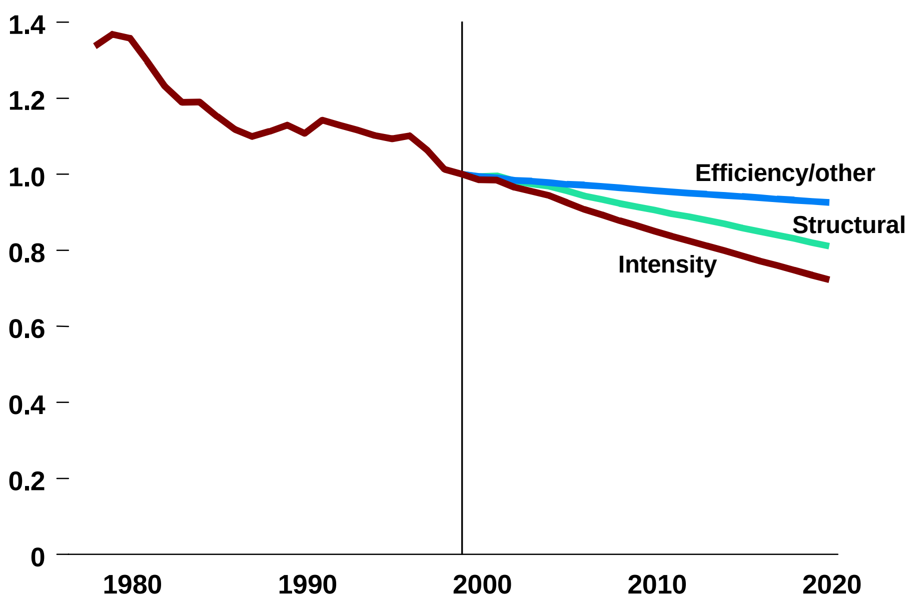

Figure 11. Energy Use Per Capita and Per Dollar of Gross Domestic Product, 1970-2020
(index, 1970=1)

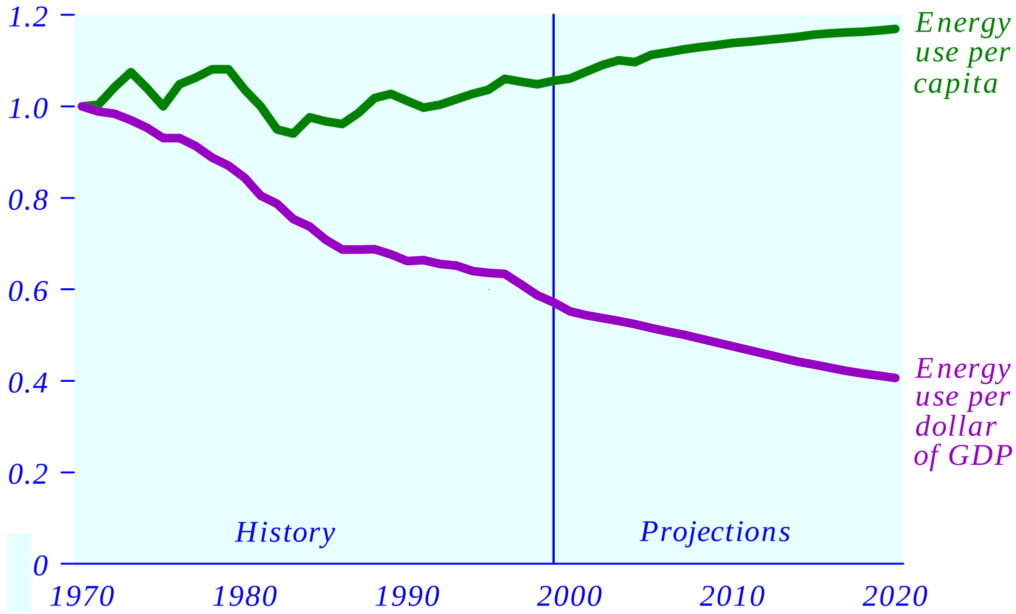

Figure 12. Population, Gross Domestic Product, and Electricity Sales, 1965-2020
(5-year moving average annual percent growth)

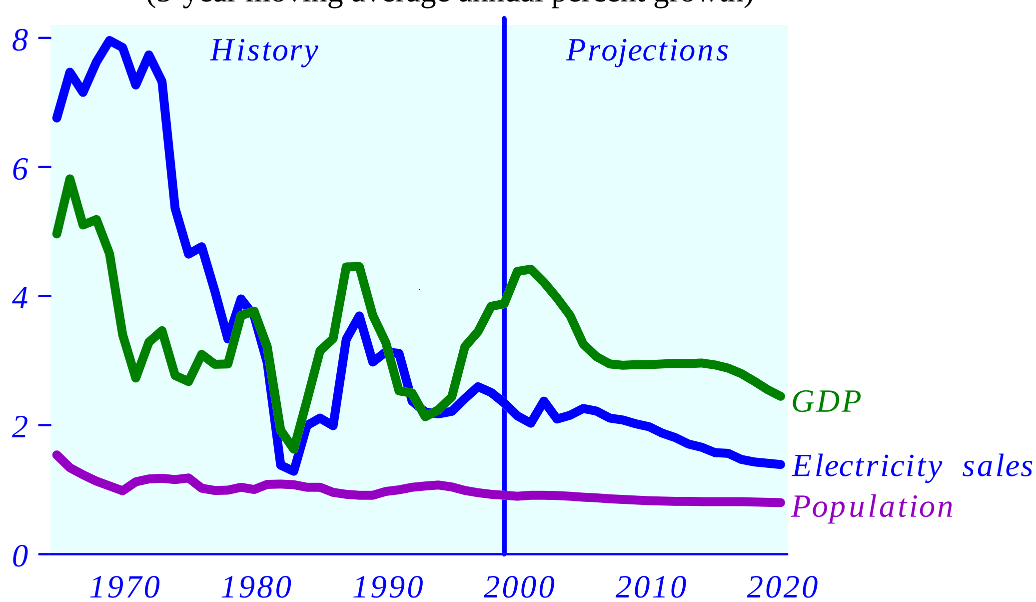

Figure 13. Generation and Fuel Consumption by Fossil-Fired Generators, 1970-2020
(index, 1999=1.0)

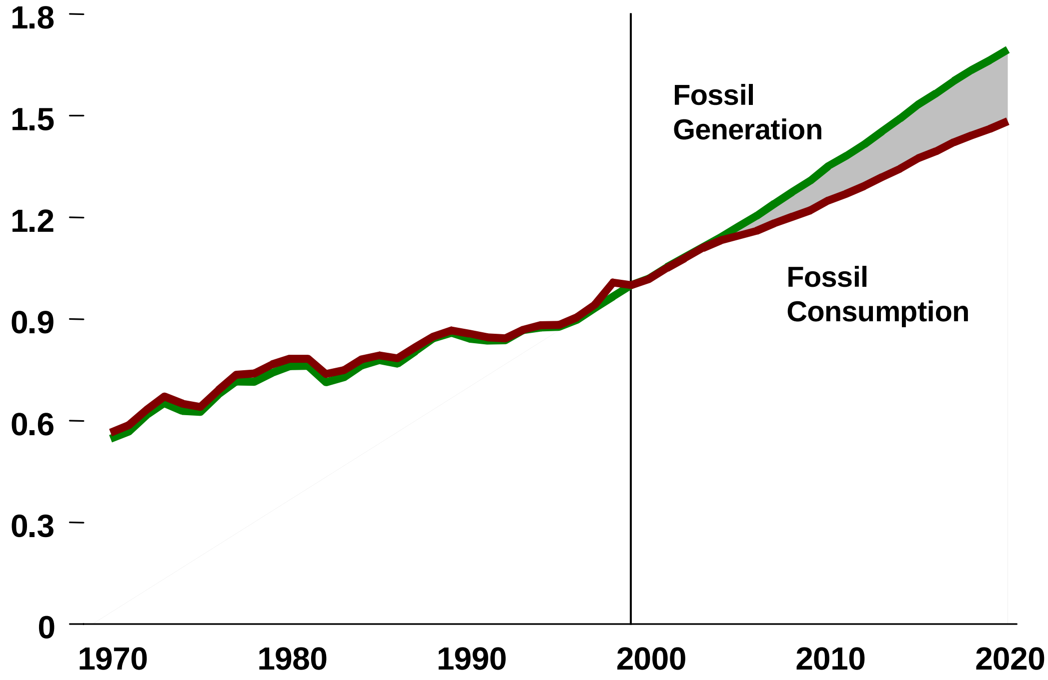

Figure 14. Projected Nonhydroelectric Renewable Electricity Generation by Energy Source, 2010 and 2020
(billion kilowatthours)

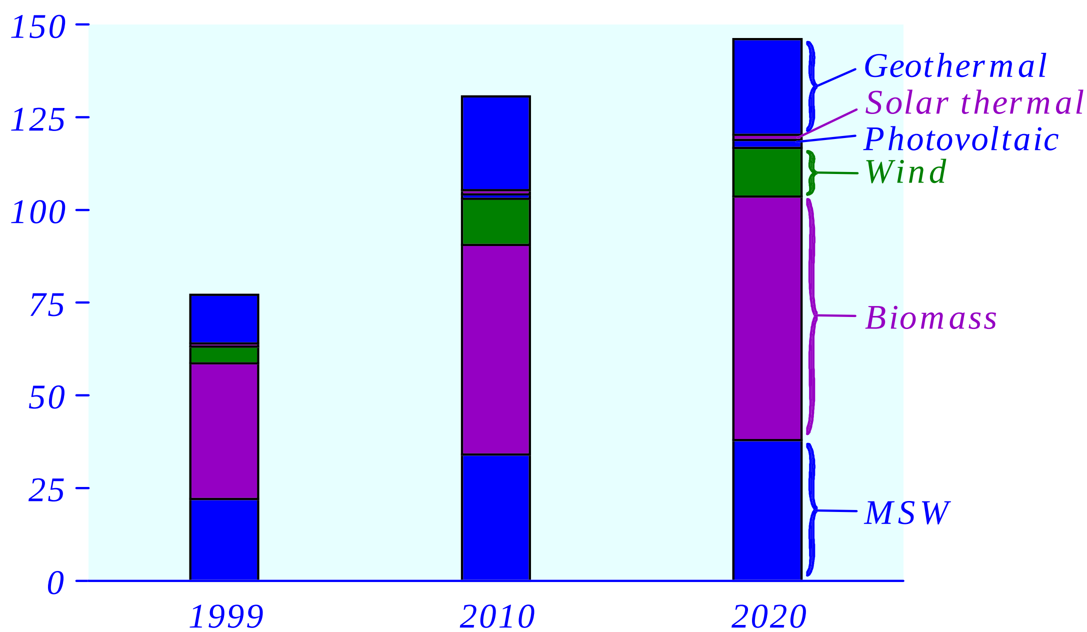

Figure 15. Projected Electricity Generation Costs, 2005 and 2020
(1999 mills per kilowatthour)

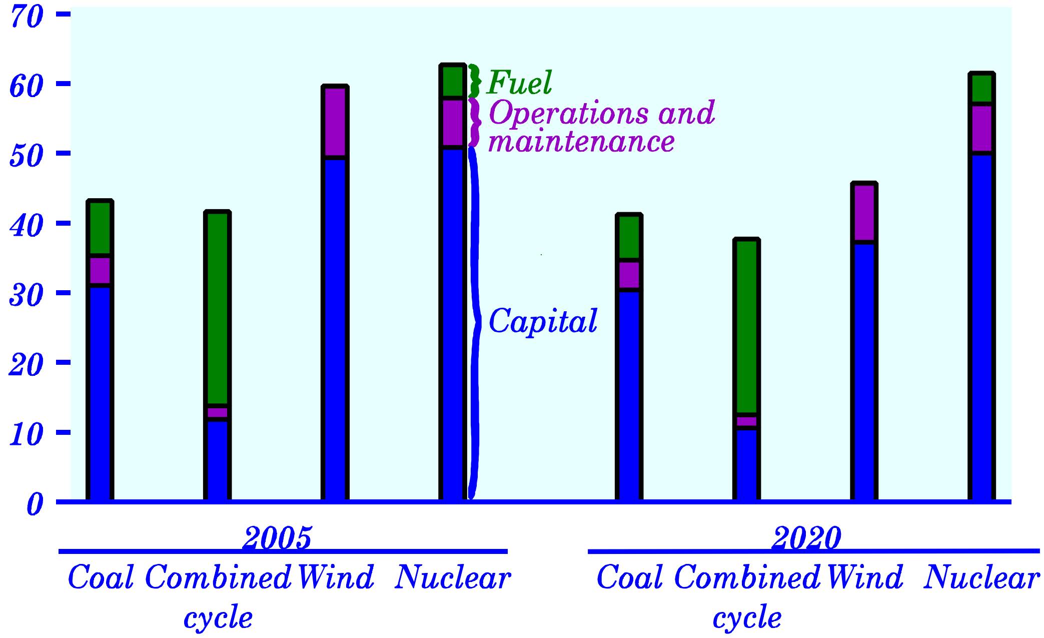

Figure 16. Projected Nonhydroelectric Renewable Electricity Generation by Energy Source in Two Cases, 2020
(billion kilowatthours)

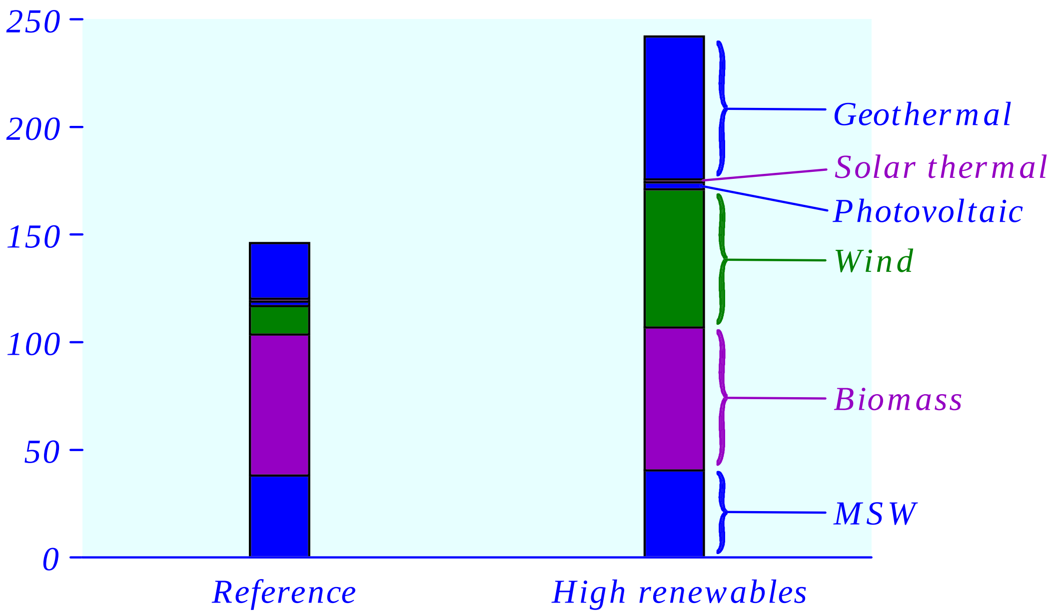

Figure 17. Projected U.S. Energy Intensity in Three Technology Cases, 1990-2020
(thousand Btu per dollar of GDP)

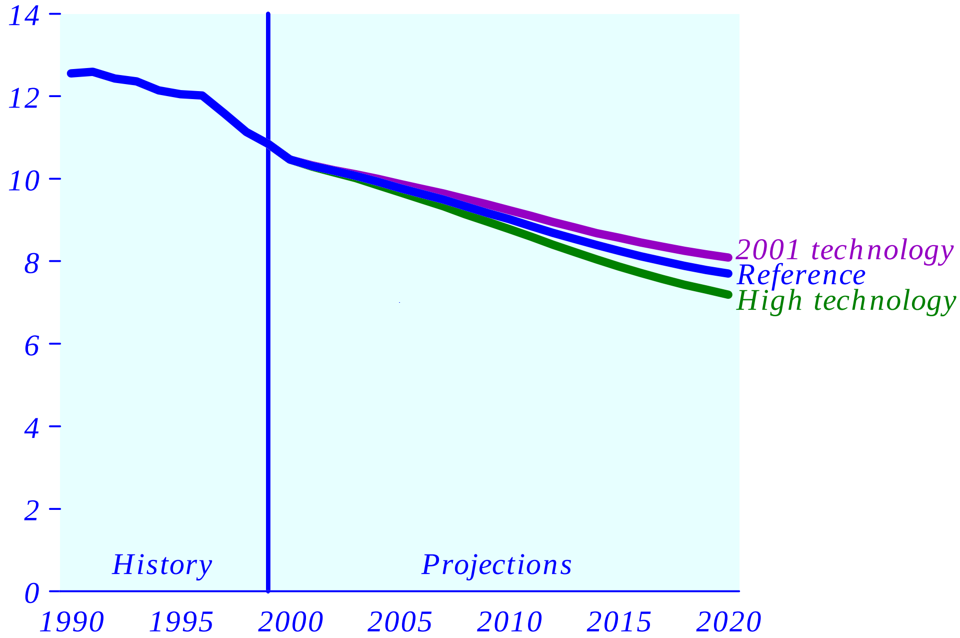

Figure 18. Projected U.S. Energy Consumption in Three Technology Cases, 1990-2020
(quadrillion Btu)

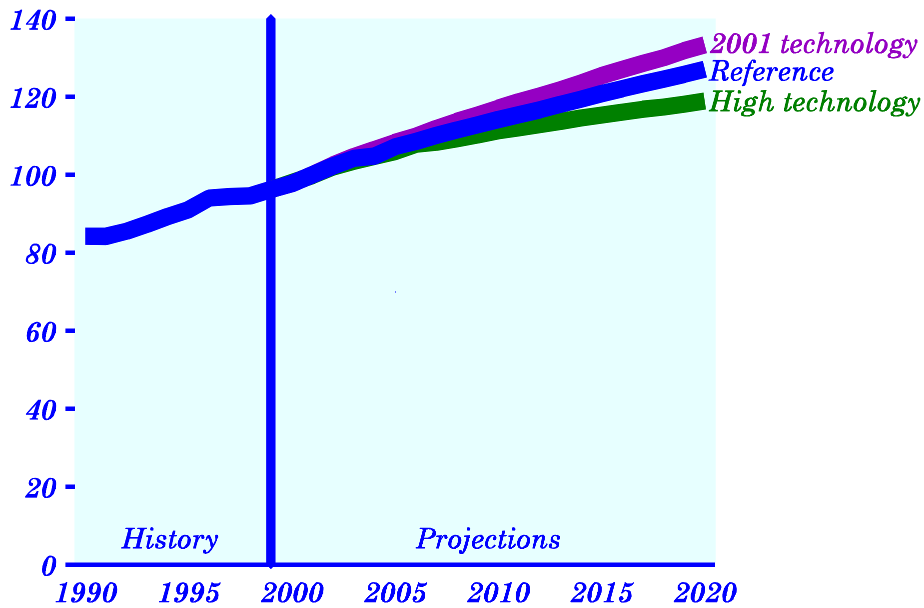

Figure 19. Projected Variation from Reference Case Primary Residential Energy Use in Three Alternative Cases, 2000-2020
(quadrillion Btu)

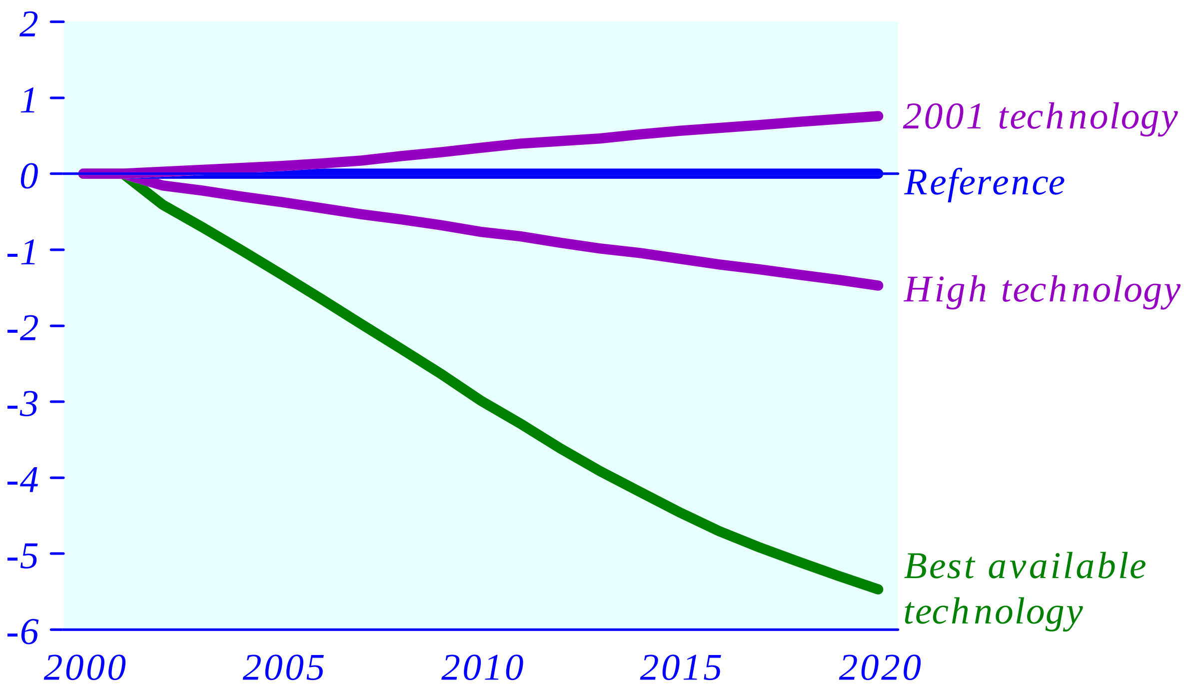

Figure 20. Projected Variation from Reference Case Primary Commercial Energy Use in Three Alternative Cases, 2000-2020
(quadrillion Btu)