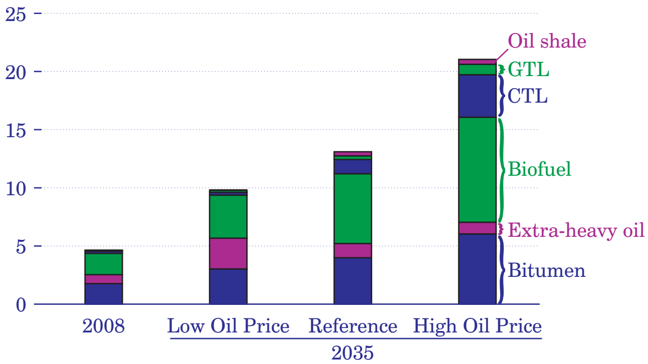
Unconventional liquids gain market share as prices rise

Figure 38. Unconventional resources as a share of total world liquids production in three cases, 2008 and 2035 (percent)



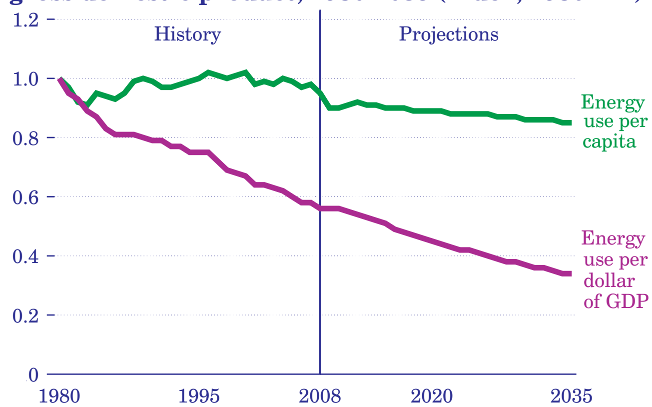
World production of liquid fuels from unconventional resources in 2008 was 4.0 million barrels per day, or about 5 percent of total liquids production. In the *AEO2010* projections, production from unconventional sources grows to about 13, 15, and 19 million barrels per day in 2035 in the Low Oil Price, Reference, and High Oil Price cases, respectively, accounting for about 10, 13, and 21 percent of total world liquids production (Figure 38).

The factors most likely to affect production levels vary for the different types of unconventional liquid. Price is the most important factor for bitumen production from Canadian oil sands, because the fiscal regime and extraction technologies remain relatively constant, regardless of world oil prices. Production of Venezuela's extra-heavy oil depends more on the prevailing investment environment and the assumed government-imposed levels of economic access to resources in the different price cases. In the Low Oil Price case, with more foreign investment in extra-heavy oil, production in 2035 climbs to nearly 3.4 million barrels per day. In the Reference and High Oil Price cases, with growing investment restrictions, extra-heavy oil production is limited to 1.3 and 0.8 million barrels per day, respectively, in 2035.

Production levels for biofuels, CTL, and GTL are driven largely by the needs of consuming nations—particularly, the United States and China, to compensate for restrictions on economic access to conventional liquid resources. In the Low Oil Price and High Oil Price cases, production from those three sources in 2035 totals 5.3 million barrels per day and 12.3 million barrels per day, respectively.

U.S. average energy use per person declines through 2035

Figure 39. Energy use per capita and per dollar of gross domestic product, 1980-2035 (index, 1980 = 1)

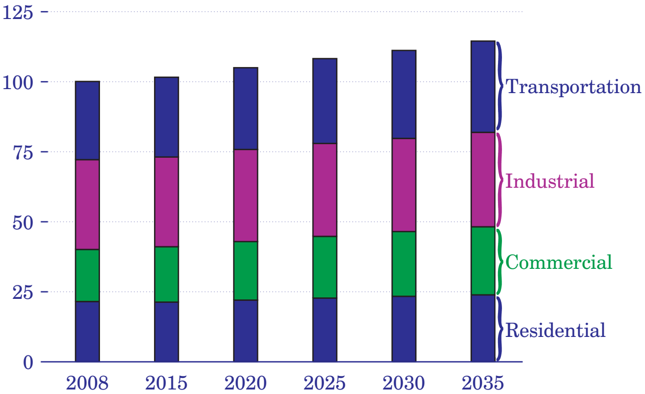


Growth in U.S. energy use is linked to population growth through increases in demand for housing, commercial floorspace, transportation, manufacturing, and services. This affects not only the level of energy use, but also the mix of fuels and consumption by sector. Energy consumption per person has declined sharply during the recent economic recession, and the 2009 level of 310 million Btu per person was the lowest since 1968. In the *AEO2010* Reference case, energy use per capita increases slightly as the economy rebounds, then begins declining in 2013 as higher efficiency standards for vehicles and lighting begin to take effect (Figure 39). From 2013 to 2035, energy use per capita declines by 0.3 percent per year on average, to 293 million Btu in 2035.

Energy intensity (Btu of energy use per dollar of real GDP) also falls as a result of structural changes and efficiency improvements. Since 1990, a growing share of U.S. output has come from services and less from manufacturing. In 1990, 74 percent of the total value of output came from services, 6 percent from energy-intensive manufacturing industries, and the balance from the non-energy-intensive manufacturing industries (e.g., agriculture, mining, and construction). In 2008, services accounted for 78 percent of total output and energy-intensive manufacturing only 5 percent. Services continue to play a growing role in the Reference case, accounting for 82 percent of total output in 2035, with energy-intensive manufacturing accounting for less than 4 percent. In combination with improvements in energy efficiency, the shift away from energy-intensive industries pushes overall energy intensity down by an average of 1.9 percent per year from 2008 to 2035.

Buildings and transportation sectors lead increases in primary energy use

Figure 40. Primary energy use by end-use sector, 2008-2035 (quadrillion Btu)



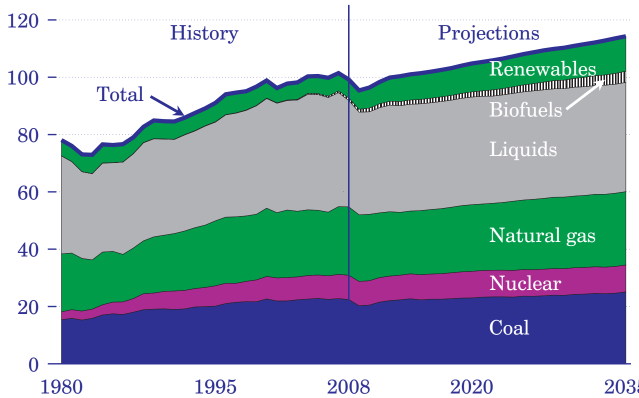
Total primary energy consumption, including fuels for electricity generation, grows by 0.5 percent per year from 2008 to 2035, to 114.5 quadrillion Btu in 2035 in the Reference case (Figure 40). The fastest growth (1.0 percent annually) is in the commercial sector, which currently has the smallest share of end-use energy demand but surpasses the residential sector by the end of the period. Growth in commercial sector energy use is propelled by growth in population (0.9 percent per year) and commercial floorspace (1.3 percent per year), but it is constrained somewhat by tightening efficiency standards.

Energy use for transportation grows by 0.6 percent per year in the Reference case. LDVs have accounted for more than 16 percent of total U.S. energy consumption since 2002; however, their share declines to 15.5 percent in 2020, when the average fuel economy of new LDVs is required by EISA2007 to reach 35.5 mpg. Growth in energy consumption by LDVs averages 0.4 percent per year from 2008 to 2035.

Energy consumption in the industrial sector grows only modestly through 2035, as U.S. output continues to shift toward less energy-intensive industries. Use of liquefied petroleum gas (LPG) feedstocks in the production of ethylene, propylene, and ammonia, which contributes to the small increase, declines after 2020 as output from the chemical industry falls. Energy consumption in the refining sector also grows, as liquids consumption increases and more biofuels are produced to meet the RFS required by EISA2007.

Renewable sources lead rise in primary energy consumption

Figure 41. Primary energy use by fuel, 1980-2035 (quadrillion Btu)



Consumption of all fuels increases in the Reference case, but the aggregate fossil fuel share of total energy use falls from 84 percent in 2008 to 78 percent in 2035 as renewable fuel use grows rapidly (Figure 41). The renewable share of total energy use increases from 8 percent in 2008 to 14 percent in 2035, in response to the EISA2007 RFS, expansion of Federal tax credits for renewable electricity generation and capacity, and State RPS programs.

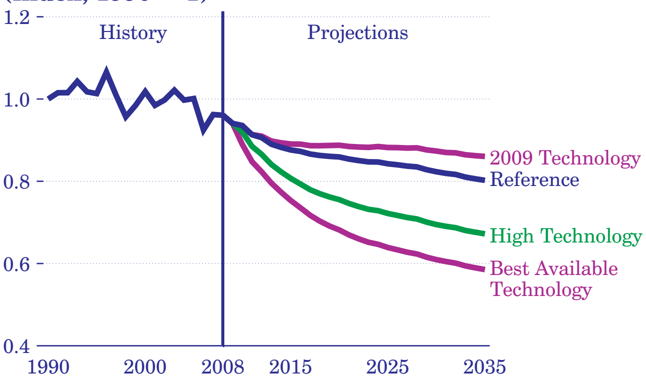
In the transportation sector, where almost all liquid biofuels are used, petroleum's share of liquid fuel use declines as consumption of alternative fuels (biodiesel, E85, and ethanol for blending) increases. Biofuels account for more than 80 percent of the growth in liquid fuel consumption.

Overall, natural gas consumption grows by about 0.2 percent per year from 2008 to 2035, despite declines of about 1.5 percent per year from 2008 through 2014, when coal-fired power plants now under construction or planned begin operation, and Federal tax credits and State RPS programs spur additions of new electricity generation capacity fired by renewable fuels.

Coal consumption increases by 0.4 percent per year in the Reference case. Several coal-fired power plants, with combined capacity totaling 15.6 gigawatts, are planned to come on line by 2012. More coal is consumed for heat and power in the CTL process, offsetting declines in coal consumption for coking and other industrial uses.

Residential energy use per capita varies with technology assumptions

Figure 42. Residential delivered energy consumption per capita in four cases, 1990-2035 (index, 1990 = 1)



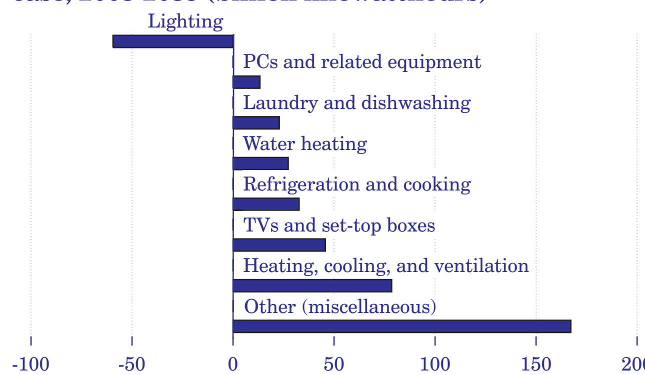
Residential energy use per capita continues declining in the *AEO2010* Reference case, to 16 percent below the 2008 level in 2035 (Figure 42). One cause of the decline is a decrease in energy use for space heating due to a projected shift in State populations from colder to warmer regions. The reduced demand for home heating fuels is offset in part by increased demand for electric air conditioning.

Recent improvements in household energy efficiency have been offset by growth in square footage and the introduction of new electric appliances. Three alternative cases show the potential role of energy-efficient technologies in defining household energy use. The 2009 Technology case assumes no change in efficiency for equipment or building shells beyond 2009 levels. The High Technology case assumes more purchases of energy-efficient appliances by consumers, and earlier availability, lower cost, and higher efficiency for some advanced electric devices. The Best Available Technology case limits purchases of new appliances to the most efficient available and assumes that new home construction applies the most energy-efficient criteria among today's common building practices.

In the 2009 Technology case, household energy use per capita falls by 10 percent from 2008 to 2035, as gains in energy efficiency are limited to stock turnover and more efficient new construction. With greater gains for appliances and building shells in the High Technology and Best Available Technology cases, household energy use per capita declines by 30 percent and 39 percent, respectively, from 2008 to 2035.

Miscellaneous uses dominate growth in electricity demand

Figure 43. Change in residential electricity consumption for selected end uses in the Reference case, 2008-2035 (billion kilowatthours)



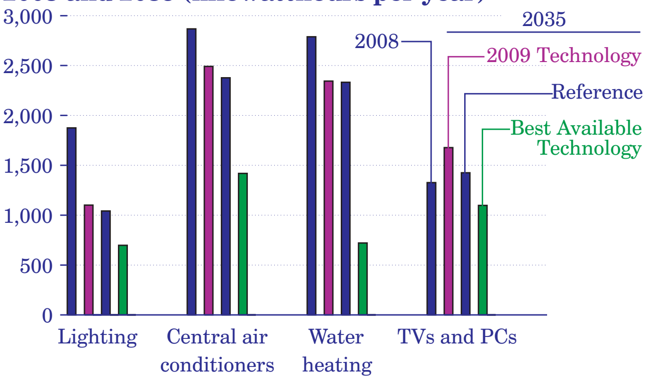
Electricity accounted for 41 percent of total residential delivered energy consumption in 2008, and in the *AEO2010* Reference case that portion increases to 48 percent in 2035. The increase in electricity consumption results from a proliferation of new electric devices. Comparatively few new devices powered by natural gas or liquids have emerged in recent decades, and few are anticipated in the Reference case. Electric appliances have become increasingly prevalent, and that trend continues as demand grows for large-screen televisions (TVs) and other electric devices.

Electricity use for TV sets and set-top boxes surpasses that for refrigerators in 2010. Set-top boxes, including digital video recorders, are needed to decode digital signals from cable or satellite providers and to convert digital signals for older analog TVs. TVs on the market today vary significantly with respect to power draw, depending on technology and screen size. The technology continues to evolve, and improvements in efficiency are expected with the introduction of light-emitting diode (LED) backlighting for TV screens and with new efficiency standards adopted in California.

Other electrically powered services include a range of appliances and devices whose consumption, while small individually, is significant in the aggregate (Figure 43). Electricity use for "other" devices—including microwave ovens, video and audio equipment, game systems, spas, security systems, and coffee makers—increases on average by 1.9 percent per year in the Reference case—slightly more than the 1.6-percent annual growth in residential floorspace.

New approaches to energy efficiency standards show potential for gains

Figure 44. Energy intensity for selected end uses of electricity in the residential sector in three cases, 2008 and 2035 (kilowatthours per year)



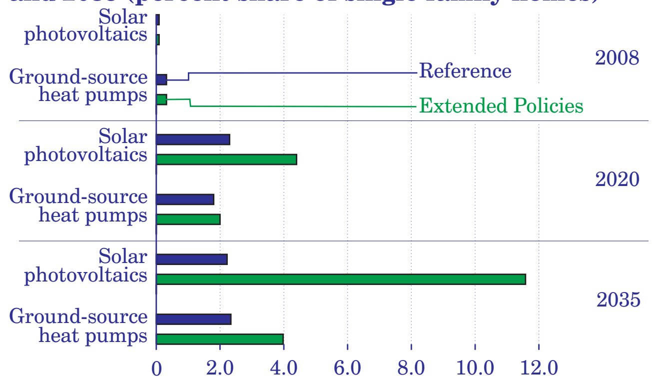
The energy efficiency of residential appliances plays a key role in determining the amount of energy used in buildings. In recent years, the implementation of Federal standards has fallen behind legislated schedules, leading States and other groups to become more active in promoting residential energy efficiency. In 2009, industry and efficiency advocate groups agreed on a set of regional standards to supplant the national standards currently in place. The new standards would divide the Nation into three regions based on climate characteristics for furnaces, heat pumps, and central air conditioners [*80*].

The absence of appliance standards has implications for energy use. Neither televisions nor set-top boxes are covered by Federal standards today, although some efficiency gains have been realized through voluntary programs, such as Energy Star. In the absence of standards, electricity use for personal computers and related equipment (e.g., printers, modems, and routers) grows at roughly the same rate as population in the Reference case.

The potential effects of new efficiency standards are most evident for lighting (Figure 44). Federal standards included in EISA2007 will require general-service lighting to use about 30 percent less electricity by 2014 for the same level of light output. In 2020, the standard is tightened further, requiring general-service lighting to use 60 percent less electricity than today's incandescent bulbs. Overall, in the *AEO2010* Reference case, electricity use for lighting per household in 2035 is 44 percent lower than in 2008.

Tax credits encourage installation of renewable technologies

Figure 45. Residential market saturation by renewable technologies in two cases, 2008, 2020, and 2035 (percent share of single-family homes)



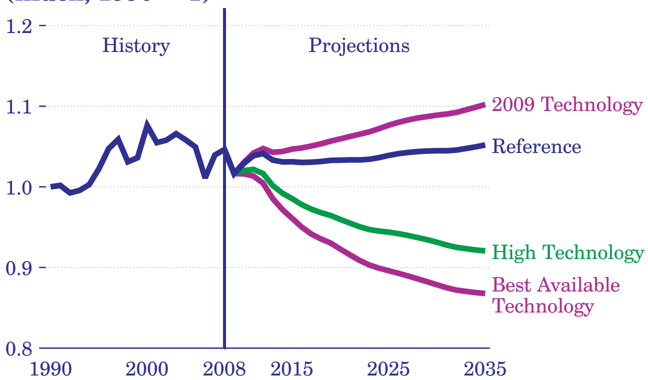
More than one-half of the States have either binding RPS or nonbinding voluntary targets for renewable energy generation. The recent enactment of Federal ITCs for distributed renewable technologies through 2016 provides the greater assurance necessary for market development that will help States achieve their renewable energy goals.

The *AEO2010* Reference case assumes that Federal tax credits for distributed renewable technologies will expire as scheduled. The Extended Policies case shows the implications of extending the tax credits indefinitely. Whereas total installed PV capacity reaches 9.5 gigawatts in 2035 in the Reference case, it grows to 60.5 gigawatts in 2035 in the Extended Policies case. The comparatively smaller distributed wind turbine market is similarly affected, with 8.1 gigawatts installed in the Extended Policies case, as compared with 1.7 gigawatts in the Reference case, in 2035.

Ground-source heat pumps are more energy efficient—but also more expensive—than conventional technologies. In the Reference case, implementation of current incentives increases the number of installations from 47,000 units in 2008 to an average of more than 150,000 units per year through 2016, when the Federal tax credit expires. Even with the increase in installations, however, the market share of ground-source heat pumps is only 2.3 percent in 2035 in the Reference case, up from 0.3 percent in 2008 (Figure 45). In the Extended Policies case—with the tax credit extended through 2035—the market share nearly doubles, to 4 percent in 2035.

Efficiency improvements could lower projected consumption growth

Figure 46. Commercial delivered energy consumption per capita in four cases, 1990-2035 (index, 1990 = 1)

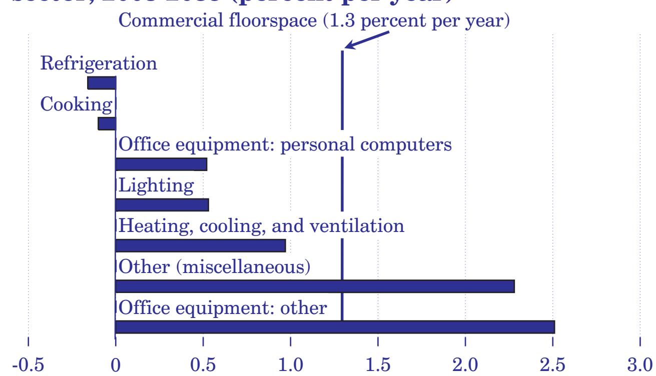


Growth in commercial floorspace averages 1.3 percent per year from 2008 to 2035 in the *AEO2010* Reference case, exceeding the 0.9-percent average for population growth over the period. Delivered commercial energy use per person remains virtually constant, however, as efficiency improvements largely offset the increase in commercial floorspace (Figure 46). Recently updated standards for lighting and refrigeration account for much of the efficiency improvement. More stringent building codes in ARRA further improve building efficiency in the long term.

Three alternative cases show the effects of different assumptions about technology and energy efficiency on energy consumption per capita. The 2009 Technology case limits equipment and building shell technologies to the options available in 2009. The High Technology case assumes lower costs, higher efficiencies for equipment and building shells, and earlier availability of some advanced equipment than in the Reference case, as consumers place greater importance on the value of future energy savings. The Best Available Technology case assumes more improvement in the efficiency of building shells than in the High Technology case and limits future equipment choices to a technology menu that includes only the most efficient model for each type of technology available in a particular year, regardless of cost. In 2035, commercial energy consumption per capita is 4.8 percent higher in the 2009 Technology case than in the Reference case, and in the High Technology and Best Available Technology cases it is 12.5 percent and 17.5 percent lower than in the Reference case, respectively.

Electricity leads expected growth in commercial energy use

Figure 47. Average annual growth rates for selected electricity end uses in the commercial sector, 2008-2035 (percent per year)



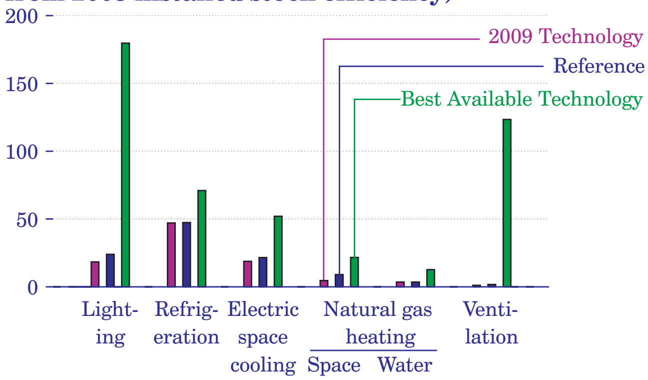
Purchased electricity use accounts for 59 percent of all commercial delivered energy consumption in 2035 in the Reference case, up from 54 percent in 2008. Despite growth in natural gas use for CHP, the natural gas and liquids share of commercial energy use declines as the efficiency of building and equipment stocks improves and demand for new electronic equipment continues to grow.

Major commercial end uses, such as space heating and cooling, water heating, and lighting, are covered by Federal and State efficiency standards, limiting growth in consumption to rates less than the 1.3-percent annual growth in commercial floorspace (Figure 47). Other electric end uses, some of which are not subject to Federal standards, account for most of the growth in commercial electricity consumption.

Although the number of computers and related devices (such as monitors and printers) grows more rapidly than floorspace, with increasing purchases and use of Energy Star equipment their electricity use grows at less than half the rate of floorspace. As reliance on the Internet for information and data transfer increases, electricity use for "other" office equipment—including servers and mainframe computers—surpasses that for commercial refrigeration in 2018. Refrigeration is one of the few commercial end uses for which electricity use declines in the Reference case, primarily as a result of new efficiency standards. Electricity demand for other miscellaneous end uses (e.g., video displays and medical devices) increases by an average of 2.3 percent per year and, in 2035, accounts for 40 percent of end-use electricity consumption in the commercial sector.

Technology provides potential energy savings in the commercial sector

Figure 48. Efficiency gains for selected commercial equipment in three cases, 2035 (percent change from 2008 installed stock efficiency)



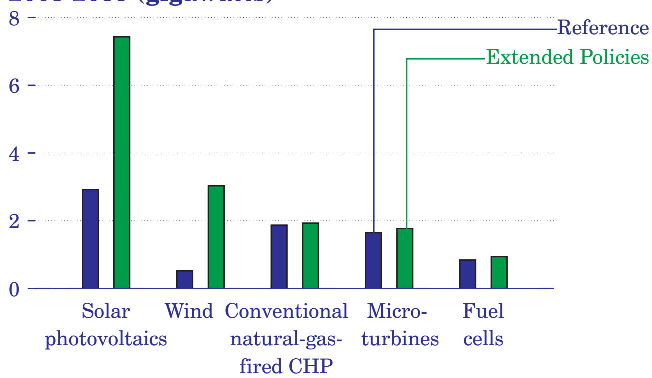
Delivered energy consumption for space heating, cooling, and water heating grows at an average annual rate of 0.4 percent in the Reference case, as compared with 1.3-percent annual growth in commercial floorspace. The remaining end uses in the commercial sector grow by 1.2 percent per year as a group in the Reference case, but by only 0.5 percent in the Best Available Technology case.

Lighting improvements have consistently been a source of efficiency gains, as standards for fluorescent lamps and ballasts, incandescent reflector lamps, and metal halide lamp fixtures have reduced their electricity consumption. Incandescent bulbs, which already are less common in the commercial sector, are nearly eliminated by 2014 as compliance with EISA2007 lighting standards increases. Significant potential for further improvement remains, as shown by the Best Available Technology case (Figure 48); however, many of those best available technologies, such as LED lighting, currently are too costly to be practical in many commercial applications.

The energy efficiency of refrigeration equipment improves significantly in each of the cases, as a result of EPACT2005 and EISA2007 standards, which are in place for a wide range of commercial equipment that accounts for a significant share of the sector's total electricity use for refrigeration. Additional efficiency improvements could come from the actions of States applying their own equipment standards for end uses not covered by Federal mandates. In addition, at the Federal level, new research and development funding from ARRA may lead to efficiency improvements in communication and information technology devices.

Tax credits, advanced technologies could boost distributed generation

Figure 49. Additions to electricity generation capacity in the commercial sector in two cases, 2008-2035 (gigawatts)



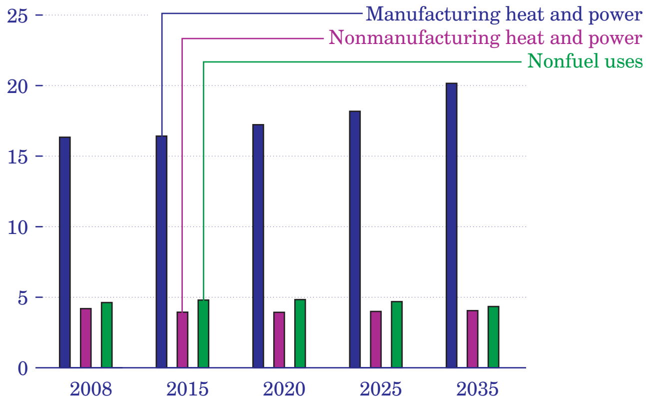
Recent legislation has extended or increased the ITCs for distributed generation technologies and removed the cap on credits for wind-powered generation. In the Reference case, tax credits boost the near-term expansion of distributed generation in the commercial sector, and its growth remains strong in later years as technology costs decline, conversion efficiency improves, and electricity prices increase.

PV capacity benefits from a 30-percent ITC through 2016 and reverts to a 10-percent credit thereafter (Figure 49). Conventional natural-gas-fired turbines and engines account for the next-largest capacity increase, followed by microturbines and fuel cells. Wind power also benefits from the ITC, growing by 8.7 percent per year. Conventional CHP technology receives a 10-percent tax credit through 2016. Comparatively expensive fuel cells receive a 30-percent ITC capped at $3,000 per kilowatt.

In the Reference case, commercial distributed generating capacity grows from 2 gigawatts in 2008 to almost 10 gigawatts in 2035. In the Extended Policies case, which assumes that the ITC provisions are extended through 2035, total commercial generating capacity increases by 17 gigawatts. PV technology benefits the most from the extension of the ITC provisions in the Extended Policies case, with installed capacity in 2035 that is 125 percent higher than in the Reference case. After 2016, with the extension of the ITC, wind power capacity in the commercial sector grows the fastest, averaging more than 16 percent per year from 2016 to 2035.

Heat and power energy consumption increases in manufacturing industries

Figure 50. Industrial delivered energy consumption by application, 2008-2035 (quadrillion Btu)



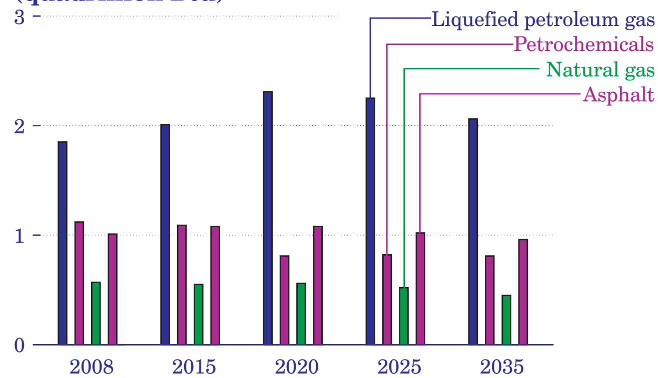
Industrial delivered energy consumption increases by 8 percent from 2008 to 2035 in the *AEO2010* Reference case—despite a 44-percent increase in industrial shipments—as a result of slow growth or declines in energy-intensive manufacturing output and strong growth in high-value (but less energy-intensive) industries, such as computers and electronics. In the chemical industry, output declines by nearly 10 percent from 2008 to 2035 in the face of rising energy prices and pressure from overseas competition.

In 2008, about two-thirds of delivered energy consumption in the industrial sector was used for heat and power in manufacturing; that share increases to three-quarters in 2035 (Figure 50). Heat and power consumption in the nonmanufacturing industries (agriculture, mining, and construction) remains constant over the projection, accounting for about one-sixth of total industrial energy consumption. The remaining consumption consists of nonfuel uses of energy products, primarily as feedstocks in chemical manufacturing and asphalt for construction.

The rise in manufacturing heat and power consumption in the *AEO2010* Reference case can be attributed primarily to a relatively large 36-percent increase in total energy use for the refining industry (although the value of shipments produced by the refining industry grows by only 11 percent over the same period). The strong growth in fuel use for refining results from higher industrial demand for lighter feedstocks, changes in the production mix as demand for diesel fuels increases, a shift by refineries from lighter to heavier crude oils, and growth in biofuels production.

Use of fuels as feedstocks declines in the chemical industry

Figure 51. Industrial consumption of fuels for use as feedstocks by fuel type, 2008-2035 (quadrillion Btu)



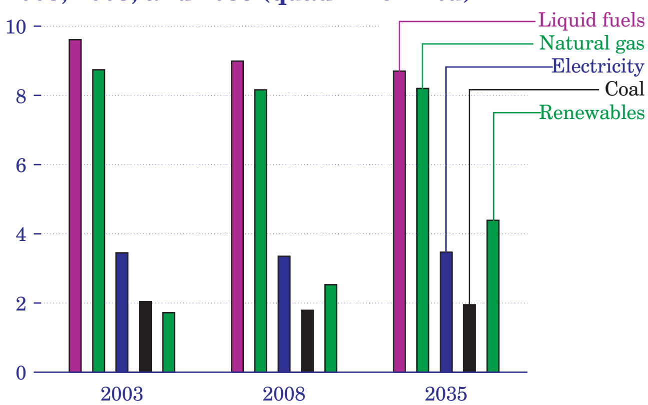
The use of fuels for feedstock in the industrial sector involves the consumption of fuels as raw materials for the production of various chemicals, as well as the consumption of asphalt and road oil for the building of roads in the construction industry. Most of the consumption of fuel-based feedstocks occurs in the chemical industry, primarily for the production of ethylene, propylene, and butadiene—three chemicals that are basic to the production of a variety of plastic products.

Feedstock consumption trends in the *AEO2010* Reference case reflect a switch from petrochemical feedstocks (naphtha and gas oils) to LPG feedstocks (ethane, butane, and propane) and a decline in basic chemical production. The shift occurs because of a growing divergence between more rapidly rising crude oil prices, which are the basis for petrochemical feedstock prices, and the slow pace of increase in natural gas prices—the primary basis for LPG prices.

From 2008 to 2035, total energy use as a feedstock declines by 6 percent in the industrial sector (Figure 51). Virtually all the decline is in the use of natural gas feedstocks, which drops by 21 percent as domestic production of ammonia, hydrogen, and methanol slows. Domestic ammonia production falls by 6 percent as a result of slow growth in agricultural production and foreign competition in the ammonia industry. Domestic outputs of hydrogen and methanol decline even more, by 74 percent and 32 percent, respectively. Consumption of asphalt and road oil remains flat in the Reference case, reflecting slow growth in the construction industry.

Over time, more fuels are brought into the mix of industrial energy use

Figure 52. Industrial energy consumption by fuel, 2003, 2008, and 2035 (quadrillion Btu)



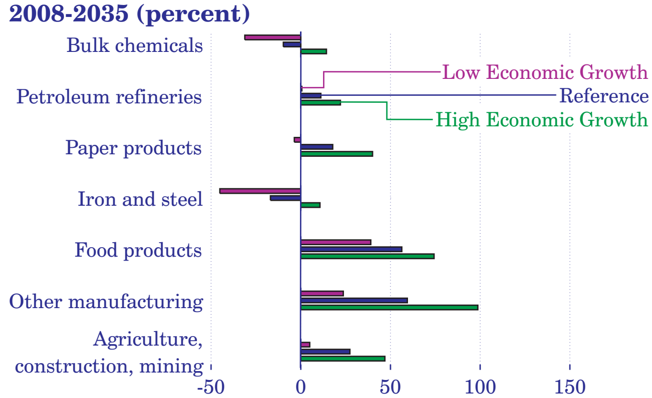
Liquid fuels and natural gas currently account for about two-thirds of industrial delivered energy use, and electricity, coal, and renewables make up the remainder (Figure 52). With fuel-switching opportunities often limited to boilers, kilns, and some feedstocks, changes in fuel shares tend to reflect long-term transitions among the mix of industries and capital investment. Although their use is declining, liquid fuels and natural gas are the leading industrial fuel sources throughout the projections. Almost one-half of industrial liquid fuel consumption is for use as a feedstock for the production of petrochemicals. Another large portion (28 percent) is generated as by-product fuel and consumed at refineries. The decline in industrial use of liquid fuels and natural gas reflects a drop in chemical production, which accounted for a large share of industrial use of the two fuels (excluding natural gas lease and plant fuel) in 2008.

Increased coal use for CTL production more than offsets a decline in traditional industrial applications of coal, such as steam generation and coke production, largely because of environmental concerns about emissions from coal-fired boilers, along with improvements in manufacturing efficiency that reduce the need for process steam. Metallurgical coal use also declines, reflecting a decline in steel industry output and the greater penetration of electric arc furnaces.

The flat outlook for industrial electricity use reflects efficiency gains in many industries, due in part to motor efficiency standards. In addition, consumption of renewable energy in the industrial sector expands with expected growth in the lumber, paper, and other industries that consume biomass-based byproducts.

Output growth is strongest for food and non-energy-intensive industries

Figure 53. Cumulative growth in value of shipments by industrial subsector in three cases, 2008-2035 (percent)



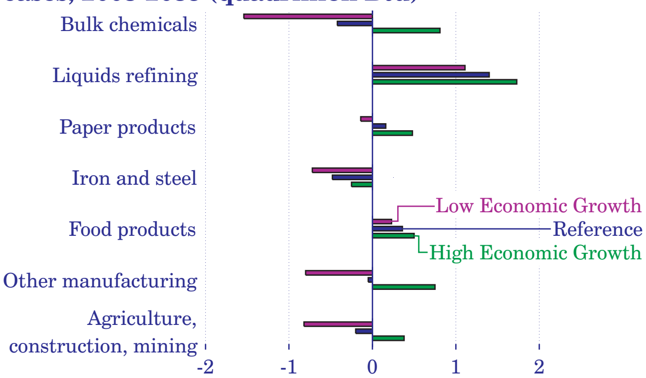
Industrial shipments vary across the *AEO2010* economic growth cases, both in aggregate and by industry. Total industrial shipments grow by 44 percent from 2008 to 2035 in the Reference case, as compared with 16 percent in the Low Economic Growth case and 74 percent in the High Economic Growth case. Near-term industrial activity is slowed by the economic recession, however, with shipments from 2008 to 2011 lower for most industries and in particular for iron and steel, cement, aluminum, transportation equipment, and machinery.

A few energy-intensive manufacturing industries account for a large share of total industrial energy consumption. Ranked by their 2008 total energy use, the top five energy-consuming industries—bulk chemicals, refining, paper, steel, and food—accounted for about 60 percent of total industrial energy consumption but only 22 percent of total value of shipments. From 2008 to 2035, four of those top five industries (with food products being the exception), as well as the other energy-intensive industries (glass, cement, and aluminum) grow more slowly than the non-energy-intensive industries (Figure 53).

The relatively slow growth of energy-intensive manufacturing industries in the Reference case results from increased foreign competition, reduced domestic demand for the raw materials and basic goods they produce, and movement of investment capital to more profitable areas of the economy.

Energy consumption growth varies widely across industry sectors

Figure 54. Change in delivered energy consumption for industrial subsectors in three cases, 2008-2035 (quadrillion Btu)



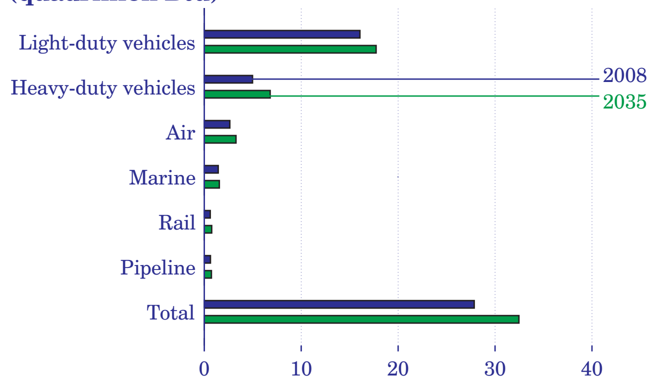
The projections for industrial energy consumption vary by industry (Figure 54) and are subject to considerable uncertainty. Industrial delivered energy consumption grows by 8 percent from 2008 to 2035 in the Reference case, declines by 9 percent in the Low Economic Growth case, and increases by 25 percent in the High Economic Growth case.

In absolute terms, the most significant changes in energy use are in the three largest energy-consuming industries: bulk chemicals, iron and steel, and refining. For the first two, declines in energy use in most cases reflect changes in competition from countries with access to less expensive energy sources, as well as changes in product mix. Energy consumption in the refining industry *increases*—despite a relatively flat trend in overall petroleum demand—given the industry's needs to process heavier crude oils, comply with low-sulfur fuel standards, and produce biofuels as mandated in EISA2007. Energy use also increases in the food and paper and pulp industries, where rising shipments reverse recent declines. For the cement, aluminum, and "other nonmanufacturing" industries, delivered energy consumption declines, primarily as a result of relatively slow output growth and long-term changes in production technology.

Aggregate industrial energy intensity, or consumption per real dollar of shipments, declines in all three cases. When a higher rate of economic growth is assumed the decline is more rapid, because non-energy-intensive output grows relatively more rapidly: 1.4 percent in the High Economic Growth case, as compared with 1.2 percent in the Reference case and 1.0 percent in the Low Economic Growth case.

Growth in transportation energy use slows relative to historical trend

Figure 55. Delivered energy consumption for transportation by mode, 2008 and 2035 (quadrillion Btu)



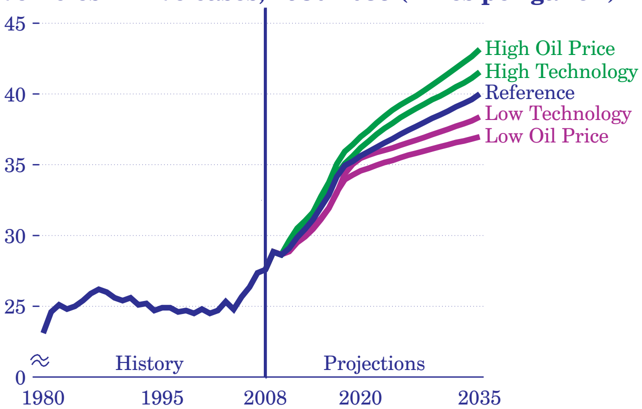
From 2008 to 2035, transportation sector energy consumption grows at an average annual rate of 0.6 percent (from 27.9 quadrillion Btu to 32.5 quadrillion Btu), slower than the 1.3-percent average rate from 1980 to 2008. The slower growth is a result of changing demographics, improved fuel economy, and increased saturation of personal travel demand.

Energy demand for LDVs increases by 10 percent, or 1.7 quadrillion Btu (0.8 million barrels per day), from 16.7 quadrillion Btu in 2008 (Figure 55). Slower growth in fuel prices compared with recent history and rising real disposable income combine to increase annual VMT. Delivered energy consumption by LDVs is tempered by fuel economy improvements that result from more stringent standards for vehicle fuel economy and CO_2 emissions. Energy demand for heavy-duty vehicles (including freight trucks and buses) increases by 37 percent, as a result of only slow improvement in fuel economy and modest increases in industrial output.

Energy demand for air travel increases by 24 percent, or 0.6 quadrillion Btu (0.3 million barrels per day), from 2.6 quadrillion Btu in 2008. Growth in personal air travel is driven by increases in income per capita and relatively low fuel costs; however, gains in aircraft fuel efficiency and slow growth in air freight movement (caused by slow growth in imports) combine to slow the increase in fuel use by aircraft. Energy consumption for marine and rail travel increases slightly as industrial output rises and demand for coal transport grows. Energy use for pipelines increases as growing volumes of natural gas and biofuels are transported.

New CAFE and emissions standards boost vehicle fuel efficiency

Figure 56. Average fuel economy of new light-duty vehicles in five cases, 1980-2035 (miles per gallon)



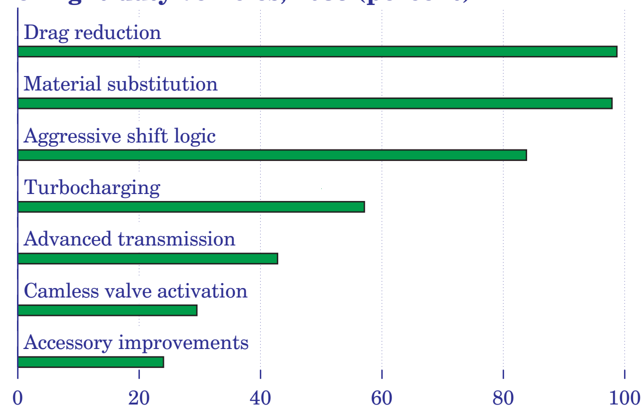
Light trucks (pickups, SUVs, and vans) have claimed a rising share of U.S. LDV sales since the 1970s, peaking at over 55 percent of new LDV sales in 2004 before dropping to just over 47 percent in 2009 [*81*]. Thus, despite technology improvements, average fuel economy for new LDVs ranged between 24 and 26 mpg from 1995 to 2006 after peaking at 26.2 mpg in 1987, then rose to 26.6 mpg in 2007 with higher fuel prices and introduction of tighter fuel economy standards.

NHTSA and EPA have proposed attribute-based CAFE and emissions standards for MY 2012 to 2016. In the Reference case, the average fuel economy of new LDVs (including credits for AFVs and banked credits) rises from 29 mpg in 2011 to 34 mpg in 2016 and 35.6 mpg in 2020, averaging 3.1 percent per year from 2011 to 2016 and 1.2 percent per year from 2016 to 2020 (Figure 56). EISA2007 requires an average of 35 mpg in 2020.

LDV sales in 2035 are about 19 million units in all the *AEO2010* cases, but the mix of cars and light trucks varies. In the Reference case, cars represent 66 percent of sales in 2035, and LDV fuel economy averages 40 mpg. In the High Oil Price case, cars are 69 percent of sales in 2035, and LDV fuel economy averages 43 mpg. In the Low Oil Price case, cars are 57 percent of sales in 2035, and LDV fuel economy averages 37 mpg. Economics of fuel-saving technologies improve in the High Technology and High Oil Price cases, and consumers buy more efficient vehicles. But average fuel economy improves modestly, because the CAFE standards assumed in the two cases already require significant improvement in fuel economy performance and the penetration of advanced technologies.

New technologies promise better vehicle fuel efficiency

Figure 57. Market penetration of new technologies for light-duty vehicles, 2035 (percent)



In the *AEO2010* Reference case, the fuel economy of new LDVs improves from 27.6 mpg in 2008 to 40.0 mpg in 2035. Market adoption of advanced technologies facilitates the improvement in fuel economy that will be needed to meet new, more stringent CAFE standards (Figure 57).

In 2035, advanced drag reduction, which provides significant fuel economy improvements by reducing vehicle air resistance at higher speeds, is implemented in nearly 99 percent of new LDVs. With the adoption of light-weight materials that reduce vehicle mass, the average weight of new cars declines from 3,264 pounds in 2008 to 3,112 pounds in 2035, providing significant improvements in fuel economy. In addition, adoption of advanced transmission technologies, such as continuous variable and automated manual transmissions, grows from 5 percent of the LDV market in 2008 to 43 percent in 2035.

Camless valve activation, which reduces engine friction and allows for infinitely variable valve timing and lift, increases engine efficiency by approximately 14 percent. After its introduction in 2020, camless valve activation is implemented in 30 percent of the LDVs marketed by 2035. Other technologies that improve fuel economy—including turbocharging, supercharging, and cylinder deactivation—increase from a 5-percent share of new LDV sales in 2008 to 57 percent in 2035. Improvements in accessories, such as the replacement of mechanical pumps with electric pumps that increase fuel economy by up to 1.5 percent, are implemented in 24 percent of new LDV sales in 2035, as compared with 0.1 percent of new LDV sales in 2008.