Annual Energy Outlook 2020

with projections to 2050

U.S. Energy Information Administration

#AEO2020

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Key Takeaways from U.S. Energy Information Administration's *Annual Energy Outlook 2020*

- In the U.S. Energy Information Administration's (EIA) *Annual Energy Outlook 2020* (AEO2020) Reference case, U.S. energy consumption grows more slowly than gross domestic product throughout the projection period (2050) as U.S. energy efficiency continues to increase. This decline in the energy intensity of the U.S. economy continues through 2050.

- The electricity generation mix continues to experience a rapid rate of change, with renewables the fastest-growing source of electricity generation through 2050 because of continuing declines in the capital costs for solar and wind that are supported by federal tax credits and higher state-level renewables targets. With slow load growth and increasing electricity production from renewables, U.S. coal-fired and nuclear electricity generation declines; most of the decline occurs by the mid-2020s.

- The United States continues to produce historically high levels of crude oil and natural gas. Slow growth in domestic consumption of these fuels leads to increasing exports of crude oil, petroleum products, and liquefied natural gas.

- After falling during the first half of the projection period, total U.S. energy-related carbon dioxide emissions resume modest growth in the 2030s, driven largely by increases in energy demand in the transportation and industrial sectors; however, by 2050, they remain 4% lower than 2019 levels.

The Annual Energy Outlook explores long-term energy trends in the United States

- The value of the projections in the AEO2020 is not that they are predictions of what will happen, but rather, they are modeled projections of what may happen given certain assumptions and methodologies. By varying those assumptions and methodologies, AEO2020 can illustrate important factors in future energy production and use in the United States.

- Energy market projections are subject to much uncertainty because many of the events that shape energy markets—as well as future developments in technologies, demographics, and resources—cannot be foreseen with certainty. To illustrate the importance of key assumptions, AEO2020 includes a Reference case and side cases that systematically vary important underlying assumptions.

- EIA develops the AEO with the National Energy Modeling System (NEMS), an integrated model that captures interactions of economic changes and energy supply, demand, and prices.

- More information about the assumptions EIA used to develop these projections will be available on the AEO website shortly after the release of the AEO2020.

- The AEO is published to satisfy the Department of Energy Organization Act of 1977, which requires the Administrator of the U.S. Energy Information Administration to prepare annual reports on trends and projections for energy use and supply.

What is the AEO2020 Reference case?

- The AEO2020 Reference case represents EIA's best assessment of how U.S. and world energy markets will operate through 2050, based on key assumptions intended to provide a base for exploring long-term trends.
- The AEO2020 Reference case should be interpreted as a reasonable baseline case that can be compared with the cases that include alternative assumptions.
- EIA based the economic and demographic trends reflected in the Reference case on the current views of leading economic forecasters and demographers. For example, the Reference case projection assumes improvement in known energy production, delivery, and consumption technologies.
- The Reference case generally assumes that current laws and regulations that affect the energy sector, including laws that have end dates, are unchanged throughout the projection period. This assumption makes it possible for us to use the Reference case as a benchmark to compare policy-based modeling.
- The potential effects of proposed legislation, regulations, or standards are not included in the AEO2020 cases.

What are the side cases?

- Oil prices in the future will be driven by global market balances that are primarily influenced by factors that are not modeled in NEMS. In the AEO2020 High Oil Price case, the price of Brent crude oil, in 2019 dollars, reaches $183 per barrel (b) by 2050, compared with $105/b in the Reference case and $46/b in the Low Oil Price case.
- Compared with the Reference case, the High Oil and Gas Supply case reflects lower costs and greater U.S. oil and natural gas resource availability, which allows more production at lower prices. The Low Oil and Gas Supply case assumes fewer resources and higher costs.
- The effects of economic assumptions on the energy consumption modeled in the AEO2020 are addressed in the High Economic Growth and Low Economic Growth cases, which assume compound annual growth rates for U.S. gross domestic product of 2.4% and 1.4%, respectively, from 2019 to 2050, compared with 1.9% per year growth in the Reference case.
- AEO2020 introduces two cases to examine the sensitivities surrounding capital costs for electric power generating technologies. Capital cost reduction for an electric power generating technology is assumed to occur from learning by doing. In the High Renewables Cost case, no cost reduction from learning is assumed for any renewable technologies. The Low Renewables Cost case assumes higher learning for renewable technologies through 2050, resulting in a cost reduction of about 40% from the Reference case by 2050.

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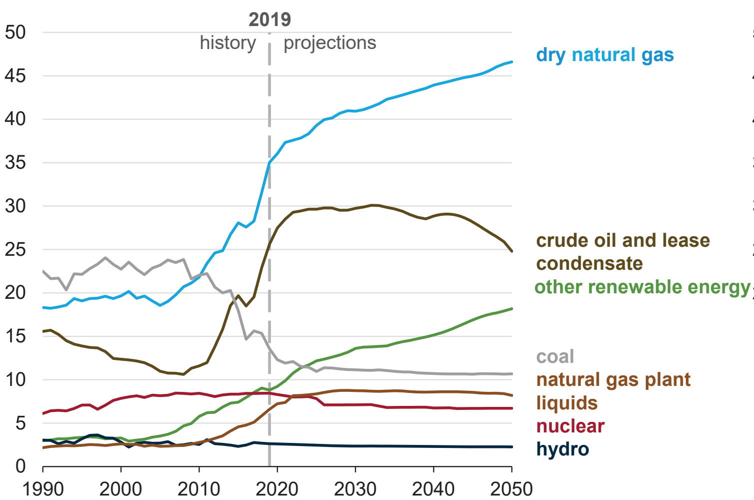
Overview of energy markets

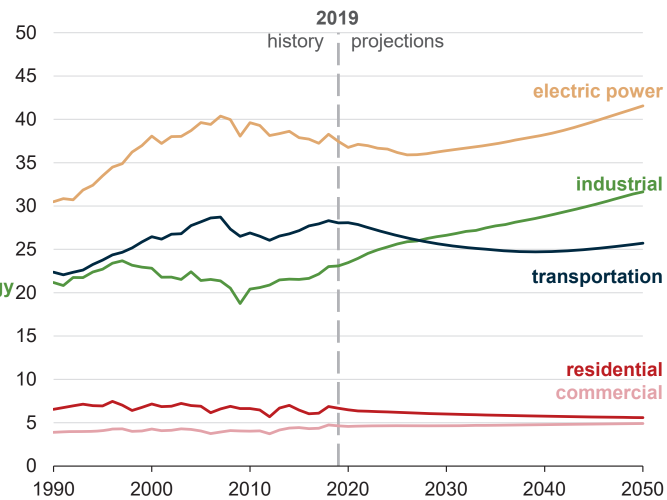
In the Reference case, strong domestic energy production coupled with slow growth in domestic energy demand leads the United States to remain a net energy exporter through 2050. Energy-related carbon dioxide emissions, driven by changes in the electricity generation fuel mix and increasing activity in the transportation and industrial sectors, experience modest growth in the later part of the projection period after falling in the 2020s.

U.S. energy production grows significantly, but consumption grows moderately under the AEO2020 Reference case assumption of current laws and regulations

Energy production (AEO2020 Reference case)
quadrillion British thermal units

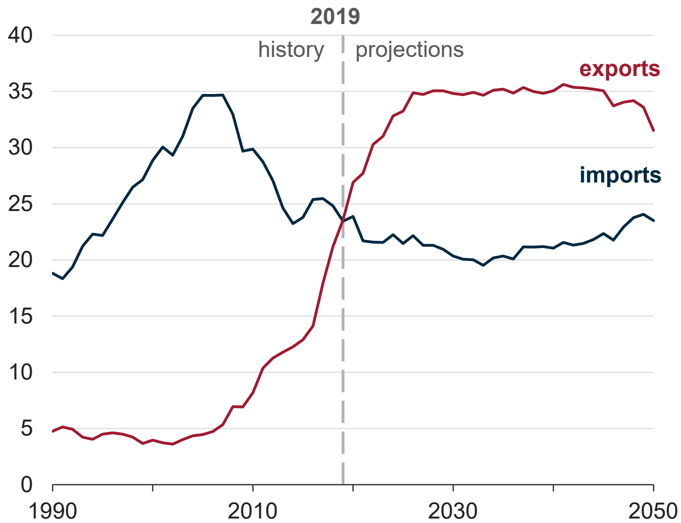


Energy consumption by sector (AEO2020 Reference case)
quadrillion British thermal units

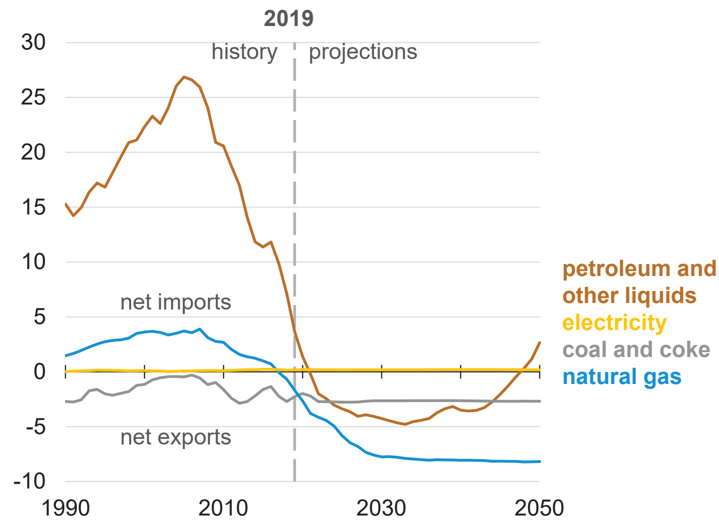


The United States becomes a net energy exporter on an annual basis by 2020 in the AEO2020 Reference case—

Gross energy trade (AEO2020 Reference case)
quadrillion British thermal units



Net energy imports (AEO2020 Reference case)
quadrillion British thermal units



—but the United States continues to import and export energy throughout the projection period

- The United States imported more energy than it exported annually since 1953, but continued growth in petroleum and natural gas exports results in the United States becoming a net energy exporter in 2020 in all AEO2020 cases.

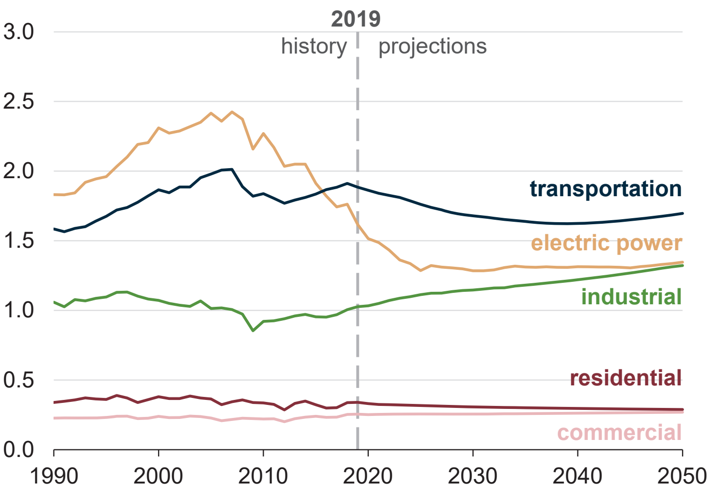
- In the AEO2020 Reference case, the United States exports more petroleum and other liquids than it imports annually starting in 2020 as U.S. crude oil production continues to increase and domestic consumption of petroleum products decreases. Near the end of the projection period, the United States returns to importing more petroleum and other liquids than it exports on an energy basis as a result of increasing domestic gasoline consumption and falling domestic crude oil production after 2047.

- The United States became a net natural gas exporter on an annual basis in 2017 and continued to export more natural gas than it imported in 2018 and in 2019. In the AEO2020 Reference case, liquefied natural gas (LNG) exports to more distant destinations will increasingly dominate the U.S. natural gas trade, and the United States is projected to remain a net natural gas exporter through 2050.

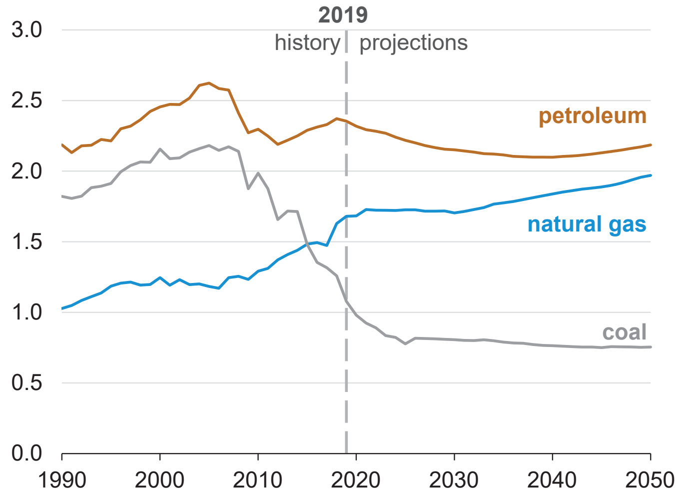
- The United States continues to be a net exporter of coal (including coal coke) through 2050 in the AEO2020 Reference case, but coal exports remain at the same level because of competition from other global suppliers that are closer to major world consumers.

AEO2020 energy-related carbon dioxide emissions increase in the industrial sector, increase as a result of natural gas consumption, but remain relatively flat in other sectors and fuels through 2050

Energy-related CO2 emissions by energy sector (AEO2020 Reference case)
billion metric tons



Energy-related CO2 emissions by fuel (AEO2020 Reference case)
billion metric tons



Critical drivers and model updates

Many factors influenced the results presented in AEO2020, including model improvements, new and existing laws and regulations since AEO2019, and varying assumptions about global oil prices, macroeconomic growth, domestic energy resources and production technology, and technology costs for renewable electricity generation.

Critical drivers and uncertainty

- Future oil prices are highly uncertain and are subject to international market conditions influenced by factors outside of the National Energy Modeling System. The High Oil Price and Low Oil Price cases represent international conditions that could drive prices to extreme, sustained deviations from the Reference case price path. In the High Oil Price case, non-U.S. demand for petroleum and other liquids is higher and non-U.S. supply of liquids is lower; in the Low Oil Price case, the opposite is true.

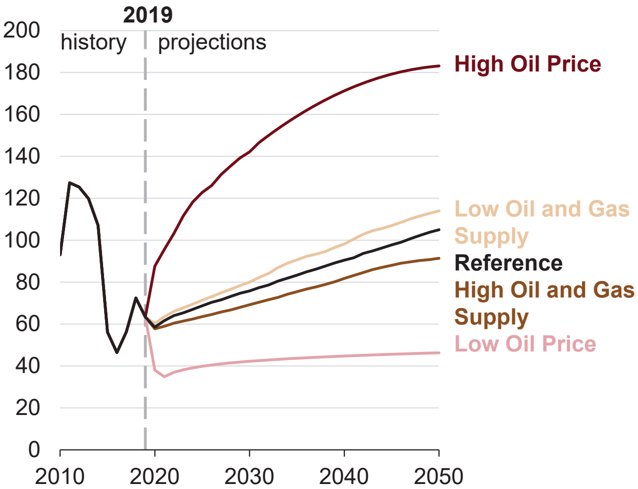
- Projections of tight oil and shale gas production are uncertain because large portions of known formations have relatively little or no production history and extraction technologies and practices continue to evolve rapidly. In the High Oil and Gas Supply case, lower production costs and higher resource availability allow higher production at lower prices. In the Low Oil and Gas Supply case, EIA applied assumptions of lower resources and higher production costs. EIA did not extend these assumptions to outside the United States.

- Economic growth drives energy consumption. The High Economic Growth and Low Economic Growth cases address these effects by modifying population growth and productivity assumptions throughout the projection period to yield higher or lower compound annual growth rates for U.S. gross domestic product (GDP).

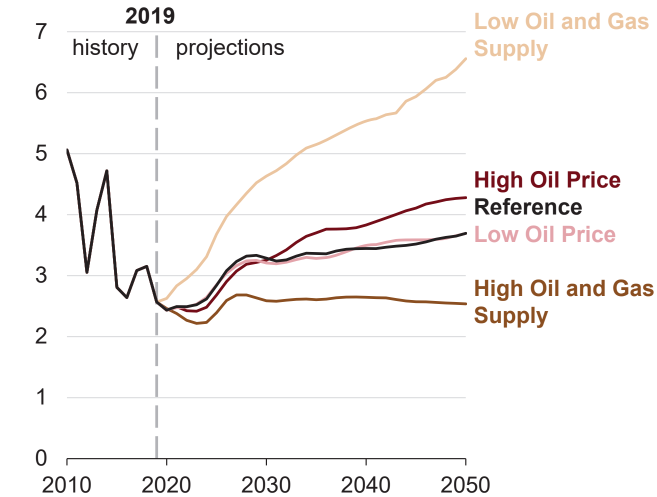
- Costs for renewables such as wind and solar have continued to decline as experience is gained with more builds. How long these high cost reduction rates can be sustained is highly uncertain. The High Renewables Cost case assumes no further cost reduction for renewables, and the Low Renewables Cost case assumes a sustained high rate of cost reduction. The Reference case assumes that cost reduction rates gradually taper off.

EIA develops oil and natural gas price assumptions by considering international supply and demand and the development of U.S. shale resources—

AEO2020 North Sea Brent crude oil price
2019 dollars per barrel



AEO2020 natural gas price at Henry Hub
2019 dollars per million British thermal unit



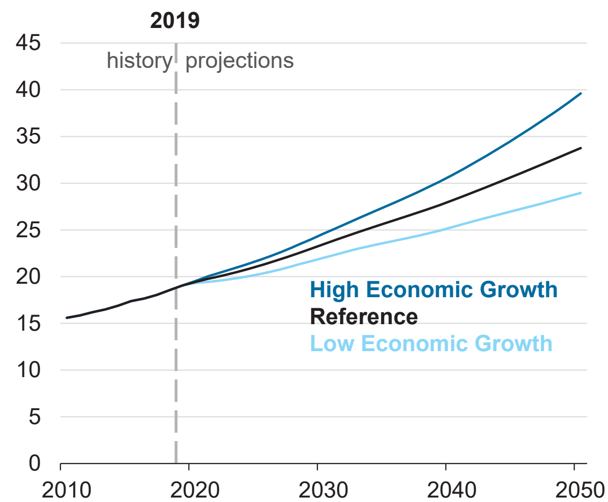
—however, global conditions are more important for oil prices and assumptions about resource and technology are more important for natural gas prices

- EIA's assumed crude oil prices in AEO2020 are influenced more by assessments of international markets than by assumptions about domestic resources and technological advances. In the High Oil Price case, EIA projects the price of Brent crude oil in 2019 dollars to reach $183 per barrel (b) by 2050 compared with $105/b in the Reference case and $46/b in the Low Oil Price case.

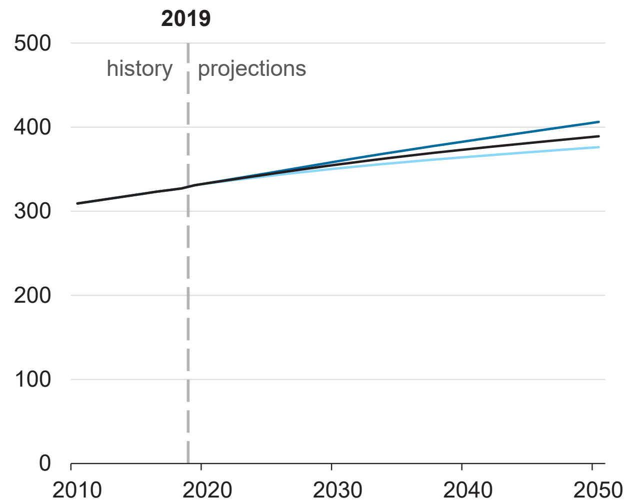
- Natural gas prices are highly sensitive to factors that drive supply, such as domestic resource and technology assumptions, and are less dependent on the international conditions that drive oil prices. In the High Oil and Gas Supply case, Henry Hub natural gas prices remain lower than $3 per million British thermal units ($/MMBtu) throughout the projection period, but in the Low Oil and Gas Supply case, they rise to more than $6/MMBtu during the same period.

Economic growth side cases explore the uncertainty in macroeconomic assumptions inherent in future economic growth trends—

AEO2020 gross domestic product assumptions
trillion 2012 dollars



AEO2020 U.S. population assumptions
millions

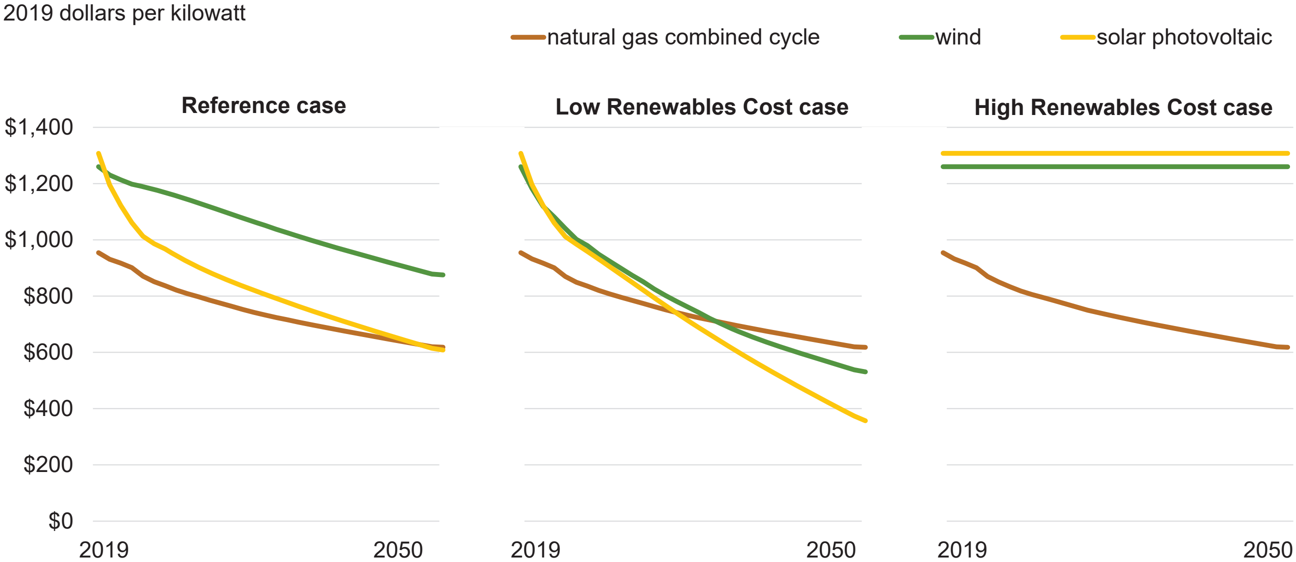


—which also affect important drivers of energy demand growth

- The AEO2020 Reference, High Economic Growth, and Low Economic Growth cases illustrate three possible paths for U.S. economic growth. In the High Economic Growth case, average annual growth in real GDP during the projection period is 2.4%, compared with 1.9% in the Reference case. The Low Economic Growth case assumes a lower rate of annual growth in real GDP of 1.4%.
- Differences among the cases reflect different assumptions for growth in the labor force, capital stock, and productivity. These changes affect capital investment decisions, household formation, industrial activity, and amount of travel.
- All three economic growth cases assume smooth economic growth and do not anticipate business cycles or large economic shocks.

The High Renewables Cost and Low Renewables Cost cases assume different rates of cost reduction for renewable technologies compared with the Reference case; non-renewables assume the same rates

AEO2020 overnight installed cost by technology
2019 dollars per kilowatt

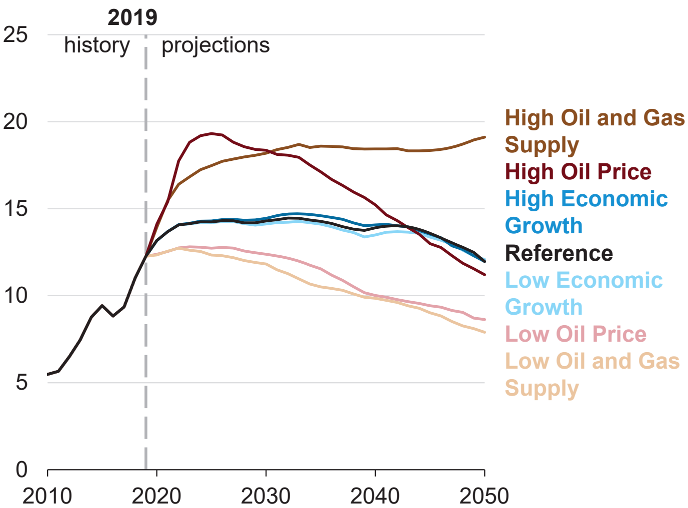


Petroleum and other liquids

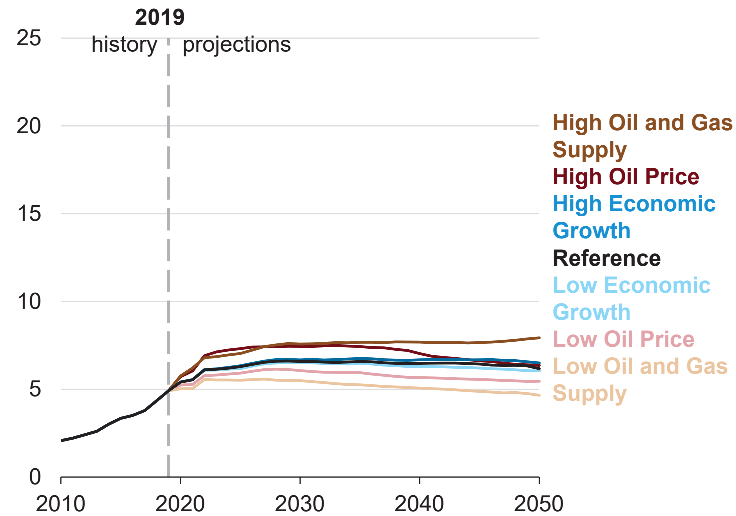
Growth in production of U.S. crude oil and natural gas plant liquids generally continues through 2025, mainly as a result of the continued development of tight oil resources. During the same period, domestic consumption falls, making the United States a net exporter of liquid fuels in the AEO2020 Reference case and in many of the side cases.

Production of U.S. crude oil and natural gas plant liquids continues to grow through 2025 in the AEO2020 Reference case—

AEO2020 U.S. crude oil production
million barrels per day



AEO2020 U.S. natural gas plant liquids production
million barrels per day



—and natural gas plant liquids comprise nearly one-third of cumulative U.S. liquids production during the projection period

- In the AEO2020 Reference case, U.S. crude oil production reaches 14.0 million barrels per day (b/d) by 2022 and remains near this level through 2045 as tight oil development moves into less productive areas and well productivity declines.

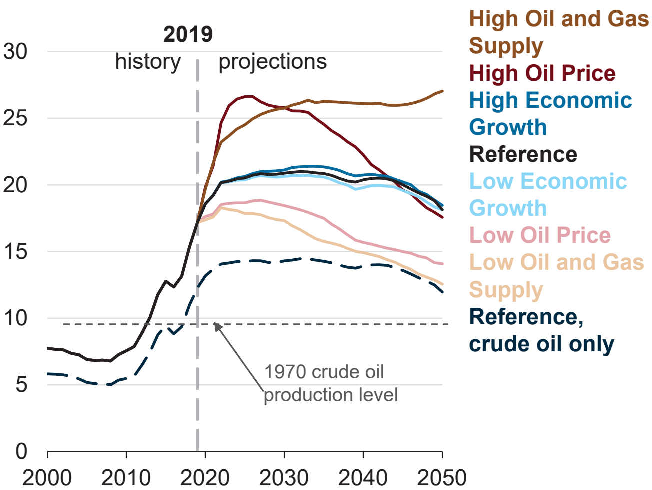
- The continued development of tight oil and shale gas resources in the AEO2020 Reference case supports growth in natural gas plant liquids (NGPL) production, which reaches 6.6 million b/d by 2028. NGPLs are light hydrocarbons predominantly found in natural gas wells and are diverted from the natural gas stream by natural gas processing plants. These hydrocarbons include ethane, propane, normal butane, isobutane, and natural gasoline.

- In the AEO2020 Reference case, NGPL production grows by 26% during the projection period as a result of demand increases by the global petrochemical industry. Most NGPL production growth in the AEO2020 Reference case occurs before 2025 as producers focus on natural gas plant liquids-rich plays, where NGPL-to-gas ratios are highest and increased demand spurs greater ethane recovery.

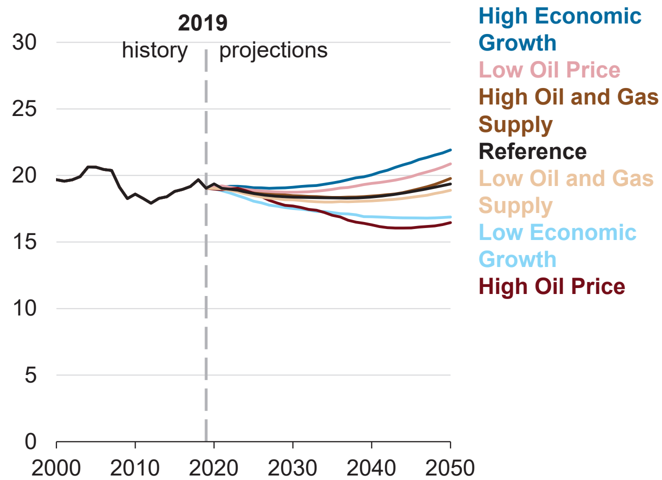
- In the AEO2020 cases, NGPL production is sensitive to changes in resource and technology assumptions, as well as oil price assumptions. In the High Oil and Gas Supply case, which has faster rates of technological improvement, higher recovery estimates, and additional tight oil and shale gas resources, NGPL production grows by 61% during the projection period. In the High Oil Price case, high crude oil prices lead to more drilling in the near term, but cost increases and fewer easily accessible resources decrease production of crude oil and NGPLs later in the forecast period.

Although production continues to grow through 2025, consumption of petroleum and other liquids remains lower than its 2004 peak level through 2050 in most cases

AEO2020 U.S. crude oil and natural gas plant liquids production
million barrels per day

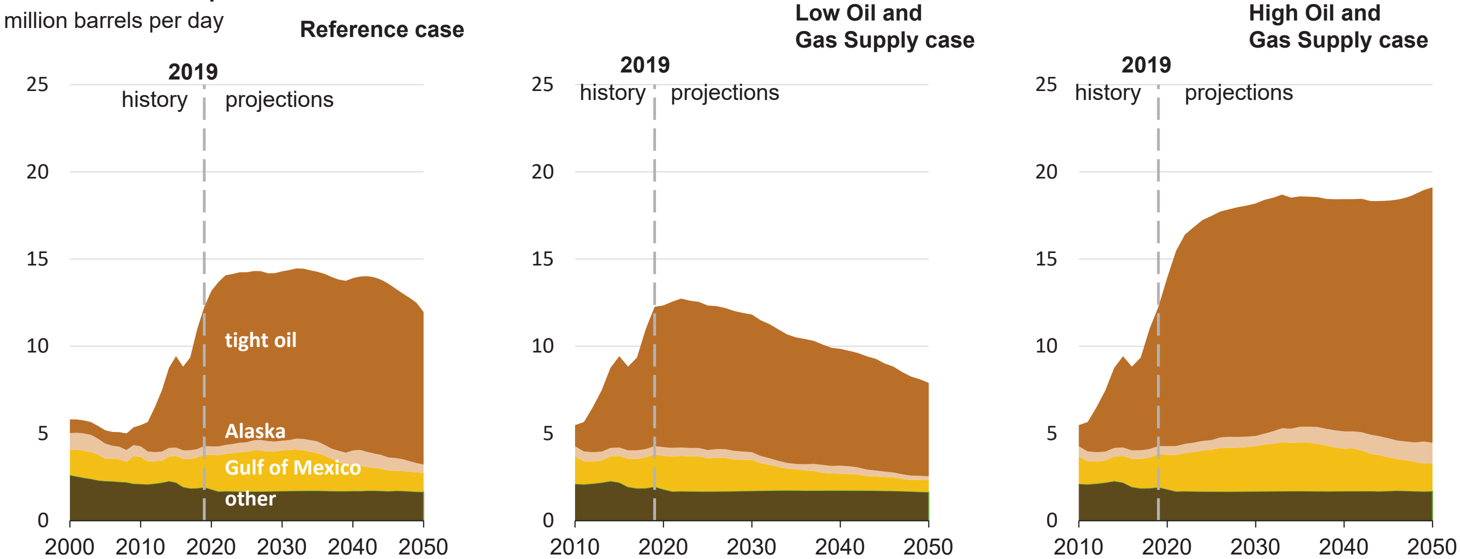


AEO2020 petroleum and other liquids consumption
million barrels per day



Tight oil development drives U.S. crude oil production during the AEO2020 projection period—

AEO2020 crude oil production

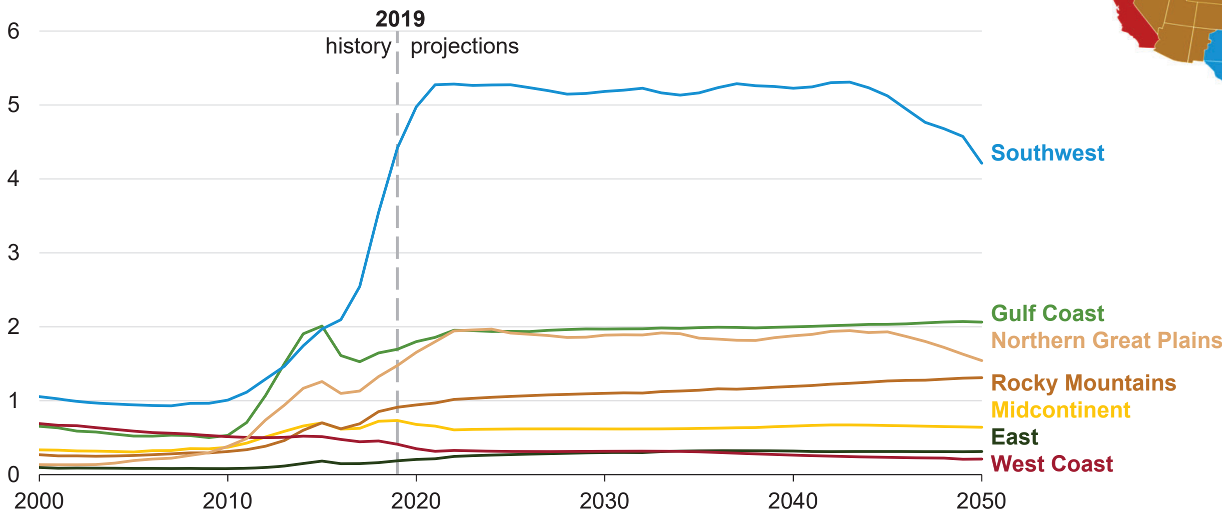


—which is consistent across all AEO2020 side cases

- Onshore tight oil development in the Lower 48 states continues to be the main driver of total U.S. crude oil production, accounting for about 70% of cumulative domestic production in the AEO2020 Reference case during the projection period.
- In the AEO2020 Reference case, deepwater discoveries of oil and natural gas resources in the Gulf of Mexico lead offshore production in the Lower 48 states to reach a record 2.4 million b/d in 2026. Many of these discoveries occurred during exploration that took place before 2015, when oil prices were higher than $100 per barrel, and they are being developed as oil prices rise. Offshore production increases through 2035 before generally declining through 2050 as a result of new discoveries only partially offsetting declines in legacy fields.
- Alaska crude oil production generally increases through 2041, driven primarily by the development of fields in the National Petroleum Reserve–Alaska (NPR-A) before 2030, and after 2030, by the development of fields in the 1002 Section of the Arctic National Wildlife Refuge (ANWR). Exploration and development of fields in ANWR is not economical in the Low Oil Price case.

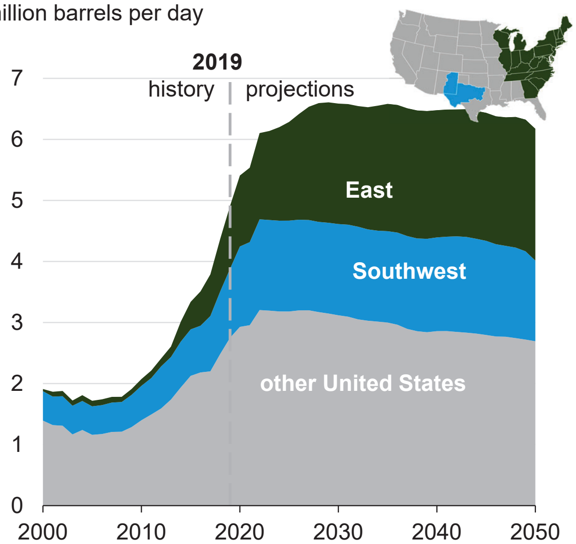
The Southwest region leads onshore crude oil production in the United States in the AEO2020 Reference case

Onshore crude oil production in the Lower 48 states (AEO2020 Reference case)
million barrels per day

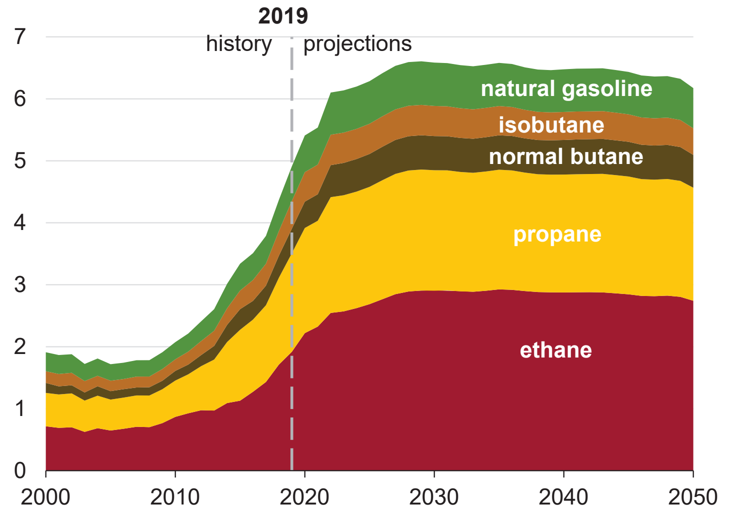


The East and Southwest regions lead production of natural gas plant liquids in the AEO2020 Reference case—

U.S. natural gas plant liquids production by region (Reference case)
million barrels per day



U.S. natural gas plant liquids production by type (Reference case)
million barrels per day



—as development focuses on tight plays with low production costs and easy access to markets

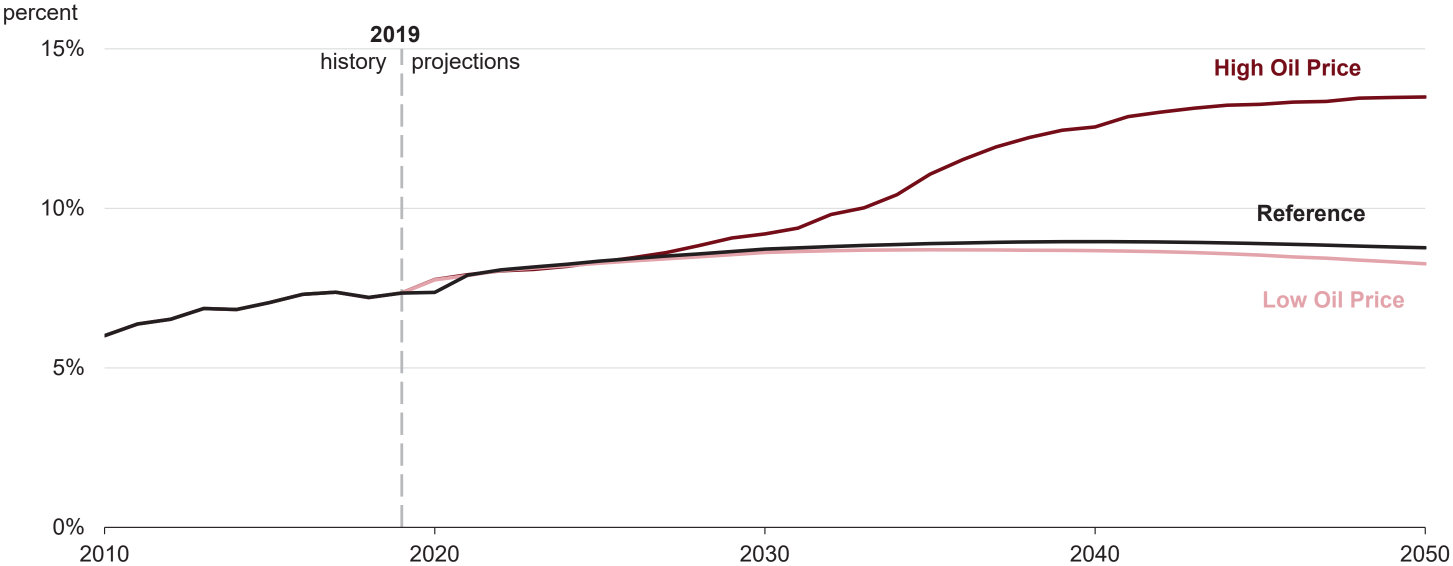
- NGPL production in the AEO2020 Reference case increases during the next 10 years in the East (Marcellus and Utica plays) and Southwest (Permian plays) regions because the development of crude oil and natural gas resources is driven in part by the increased economic favorability of coproducing these products. By 2050, the Southwest and East regions account for nearly 60% of total U.S. NGPL production.

- NGPLs are used in many different ways in the United States. Ethane is used almost exclusively for petrochemicals. About 40% of propane is used for petrochemicals, and the remainder is used for heating, grain drying, and transportation. About 60% of butanes and natural gasoline is used for blending with motor gasoline and fuel ethanol, and the remainder is used for petrochemicals and solvents.

- The shares of NGPL components in the AEO2020 Reference case are relatively stable during the entire projection period. Ethane and propane contribute about 44% and 30%, respectively, to the total volume.

Biofuels as a percentage of gasoline, diesel, and jet fuel consumption increase in the AEO2020 Reference case projection—

AEO2020 projected biofuel percentage of gasoline, distillate, and jet fuel consumption



—and biofuels adoption accelerates in the AEO2020 High Oil Price case as biofuels become more competitive

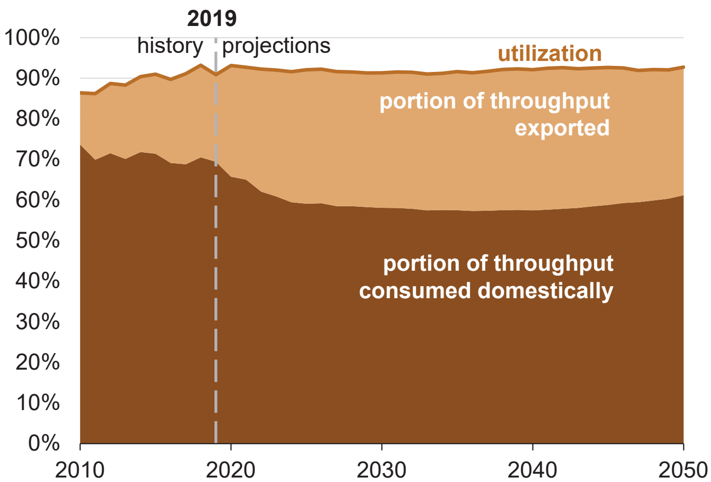
- EIA projects that the percentage of biofuels (ethanol, biodiesel, renewable diesel, and biobutanol) blended into U.S. gasoline, diesel, and jet fuel in the AEO2020 Reference case will increase from 7.3% in 2019 to peak at 9.0% in 2040.

- The share of biofuels consumed in the United States rises more in the AEO2020 High Oil Price case as higher prices for gasoline, diesel, and jet fuel make biofuels more competitive. In that case, the biofuels share rises to 13.5% in 2050.

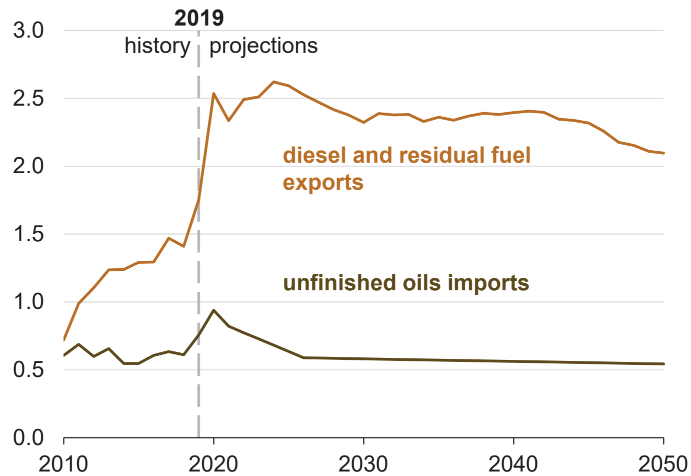
- In the AEO2020 Low Oil Price case, the share of biofuels consumed in the United States is relatively unchanged compared with the Reference Case because of federal and state regulations. Regulations such as the Renewable Fuel Standard and Low Carbon Fuel Standard support biofuels consumption when prices of petroleum-based product are low and biofuels are less competitive.

Utilization of U.S. refineries remains near recent levels throughout the projection period in the Reference case as U.S. refineries remain competitive in the global market—

U.S. refinery utilization (Reference case)
percent



U.S. diesel and residual fuel exports and unfinished oils imports (Reference case)
million barrels per day



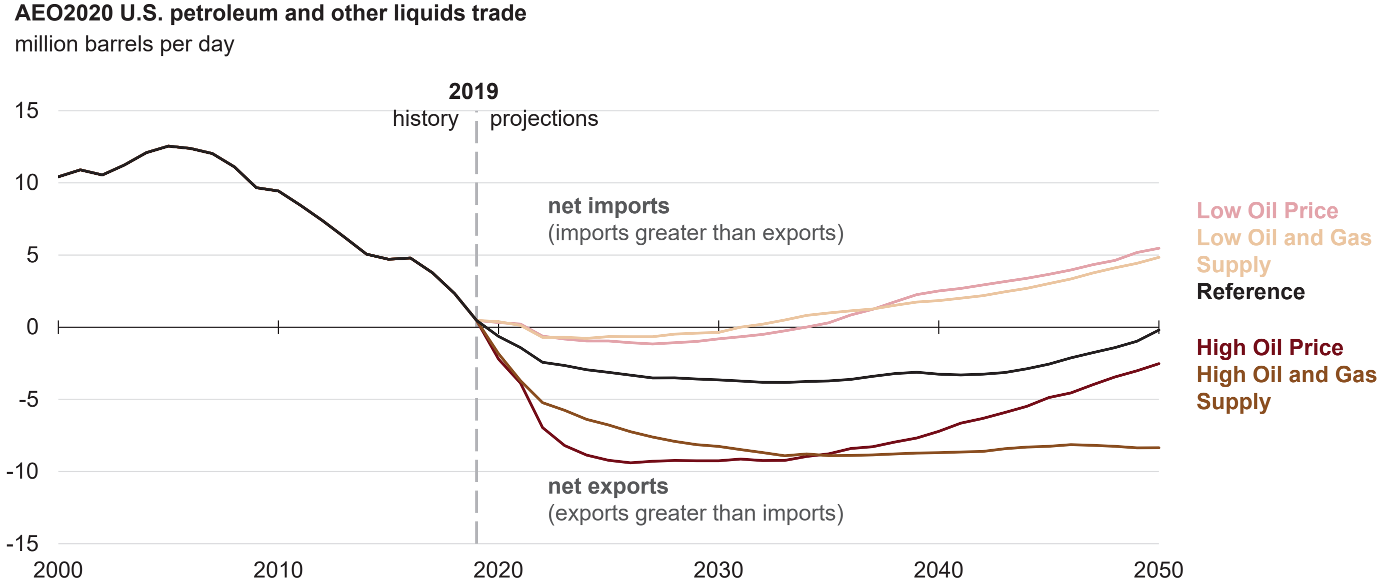
—and U.S. exports of low-sulfur diesel and residual fuel oil increase in 2020 as a result of international sulfur emissions regulations on the marine sector

- The share of U.S. refinery throughput that is exported increases in the AEO2020 Reference case as domestic consumption of refined products decreases, leaving more petroleum product available to export from 2020 to 2041. The trend reverses after 2041 when domestic consumption (especially of gasoline) gradually increases.

- The global competitiveness of the U.S. refining sector and the ability of the United States to increase exports as domestic consumption falls keep domestic refinery utilization near recent levels, between 90% and 93%, during the projection period in the Reference case.

- Imports of unfinished oils peak in 2020 as U.S. refineries take advantage of the increased discount of the heavy, high-sulfur residual fuel oil available on the global market. Exports of diesel and residual fuel (especially low-sulfur residual fuel) increase to 2.5 million barrels per day in 2020 because U.S. refineries are well -positioned to supply some of the increase in global demand for low-sulfur fuels as a result of the International Maritime Organization's new limits on sulfur content in marine fuels.

In the AEO2020 Reference case, the United States exports more petroleum on a volume basis than it imports from 2020 to 2050—

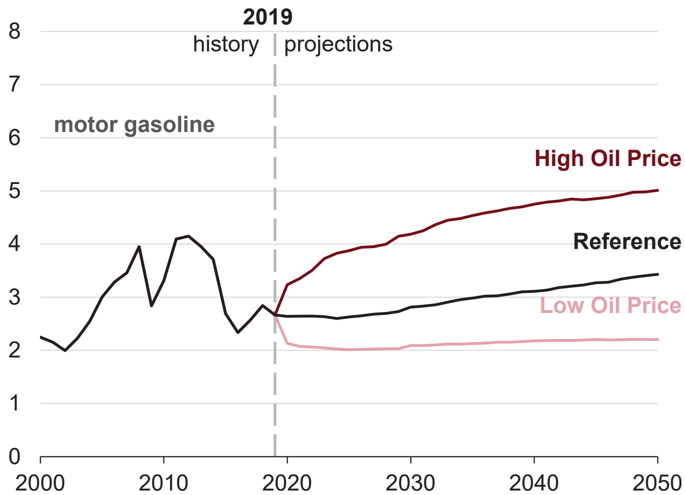


—but side case results vary significantly as shifts in U.S. domestic petroleum consumption and crude oil production drive changes to net imports

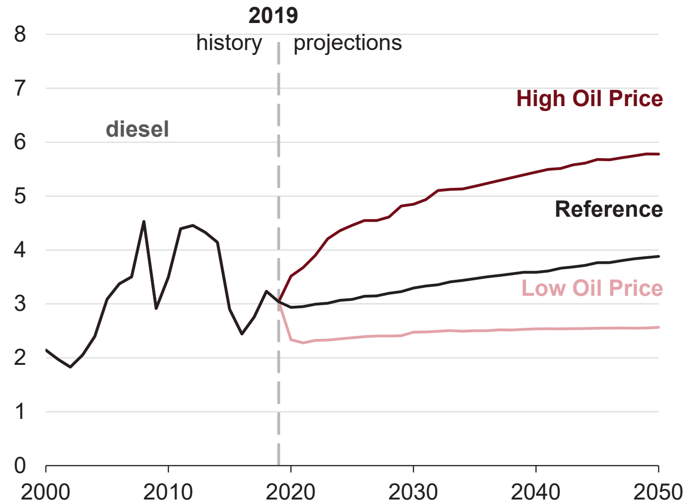
- In the AEO2020, strong production growth and decreasing domestic demand drive the United States to export higher volumes of crude oil and liquid fuels than it imports, resulting in growing levels of net exports from 2020 to 2033.
- In the AEO2020 Reference case, net exports of U.S. petroleum and other liquids peak at more than 3.8 million barrels per day (b/d) in the early 2030s before gradually declining as domestic consumption rises. The United States continues to export more petroleum and other liquids than it imports. Net exports of petroleum and other liquids reach 0.2 million b/d in 2050 as domestic consumption slowly increases but remains 1.2 million b/d below the peak levels recorded in 2004.
- Additional resources and higher levels of technological improvement in the AEO2020 High Oil and Gas Supply case result in more U.S. crude oil production and exports; net exports reach a high of 8.9 million b/d in the mid-2030s. Projected net exports reach a high of 9.6 million b/d in the mid-2020s in the High Oil Price case as a result of higher prices that support more domestic production.
- In the AEO2020 Low Oil Price case, by the mid-2020s, the United States exports 1.1 million b/d more than it imports before rising consumption leads the United States to become a net importer, importing 5.5 million b/d more than it exports in 2050.
- All AEO2020 cases except the Low Oil and Gas Supply and Low Oil Price cases project that the United States will export more petroleum and other liquids than it imports through 2050.

Prices for gasoline and diesel fuel rise throughout the Reference case projection period and primarily follow the price of crude oil in the High Oil Price and Low Oil Price cases

AEO2020 retail prices of motor gasoline
2019 dollars per gallon



AEO2020 retail prices of diesel
2019 dollars per gallon

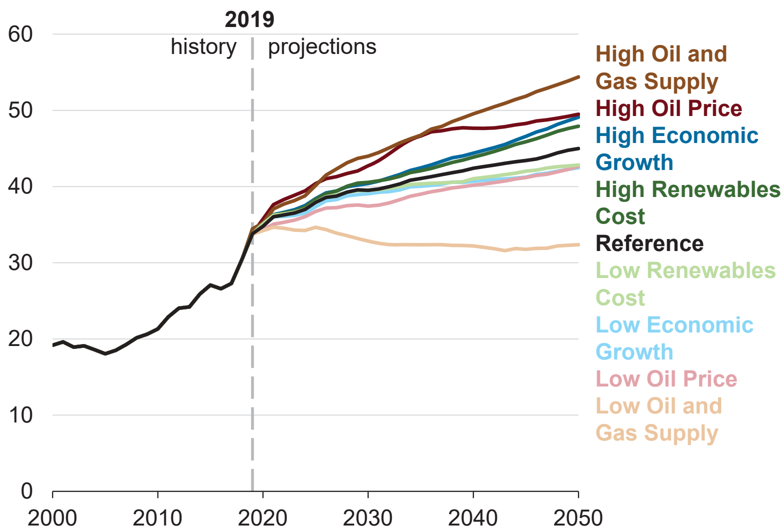


Natural gas

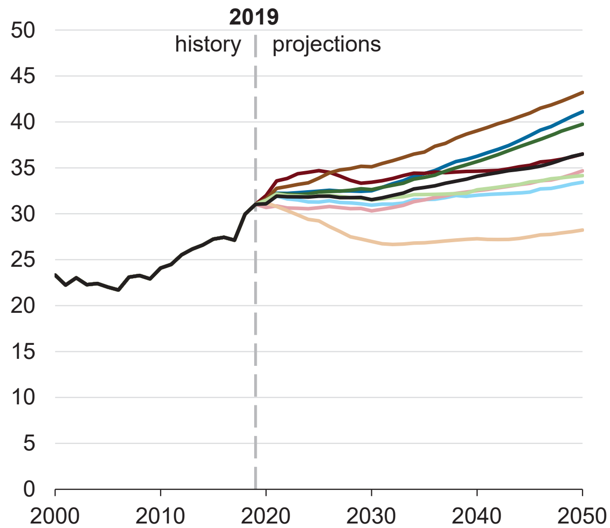
Natural gas production increases in most cases, supporting higher levels of domestic consumption and natural gas exports. However, AEO2020 projections are sensitive to resource and technology assumptions.

U.S. dry natural gas production and consumption increase in most AEO2020 cases—

AEO2020 U.S. dry natural gas production
trillion cubic feet



AEO2020 U.S. natural gas consumption
trillion cubic feet

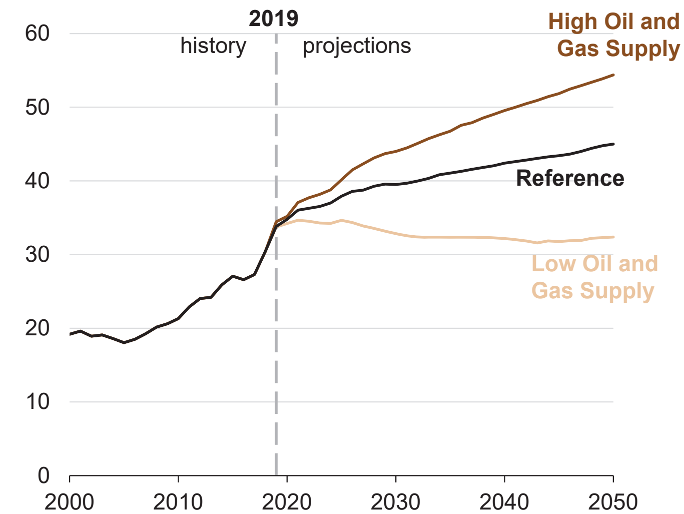


—and natural gas production growth outpaces consumption in most cases

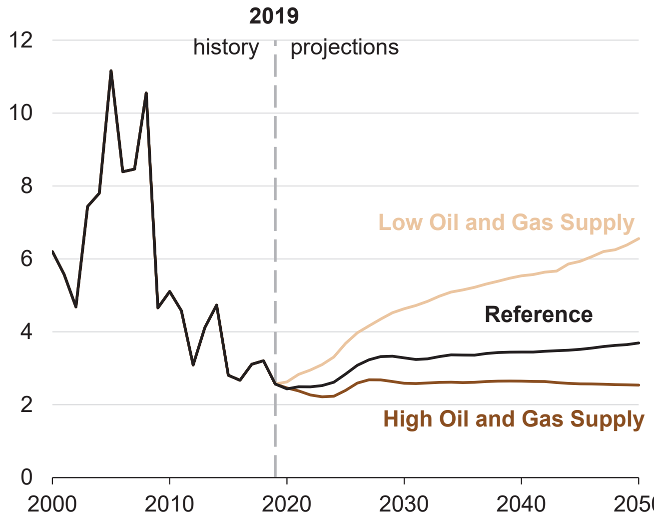
- Natural gas dry production in the AEO2020 Reference case grows 1.9% per year from 2020 to 2025, which is considerably slower than the 5.1%-per-year average growth rate from 2015 to 2020.
- U.S. natural gas consumption in the Reference case slows after 2020 and remains relatively flat through 2030 because of slower industrial sector growth. Consumption also declines in the electric power sector during this period. After 2030, consumption growth rises almost 1% per year on average as natural gas use in the electric power and industrial sectors increases.
- U.S. natural gas production grows at a faster rate than consumption in most cases after 2020, leading to an increase in U.S. exports of natural gas. The exception is in the AEO2020 Low Oil and Gas Supply case, where production and consumption remain relatively flat as a result of higher production costs.

AEO2020 natural gas prices depend on resource and technology assumptions—

AEO2020 dry natural gas production
trillion cubic feet



AEO2020 natural gas spot price at Henry Hub
2019 dollars per million British thermal units



—and Henry Hub prices in the AEO2020 Reference case remain lower than $4 per million British thermal units throughout the projection period

- In the AEO2020 Reference case, growing demand in domestic and export markets leads to increasing natural gas spot prices at the U.S. benchmark Henry Hub through 2050 despite continued technological advances that support increased production.

- To satisfy the growing demand for natural gas, U.S. natural gas production expands into less prolific and more expensive-to-produce areas, putting upward pressure on production costs.

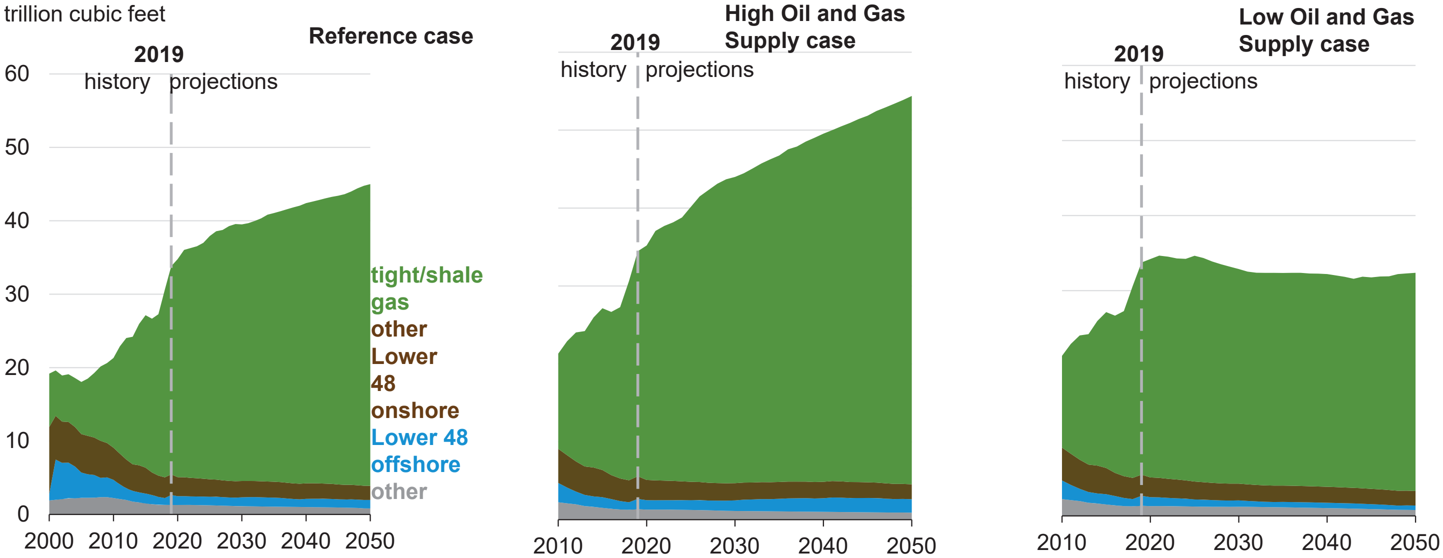
- Natural gas prices in the AEO2020 Reference case remain lower than $4 per million British thermal units (MMBtu) through 2050 because of an abundance of lower cost resources, primarily in tight oil plays in the Permian Basin. These lower cost resources allow higher production levels at lower prices during the projection period.

- The AEO2020 High Oil and Gas Supply case--which reflects lower finding, development, and production costs and greater resource availability--shows an increase in U.S. natural gas production and lower prices relative to the Reference case. In the Low Oil and Gas Supply case, high prices, which result from higher costs and fewer available resources, result in less domestic consumption and exports during the projection period.

U.S. dry natural gas production in AEO2020 increases as a result of continued development of tight and shale resources—

AEO2020 dry natural gas production by type

trillion cubic feet



—which account for more than 90% of dry natural gas production in 2050 in the Reference case

- Natural gas production from shale gas and tight oil plays continues to grow, both as a share of total U.S. natural gas production and in absolute volume, in the AEO2020 Reference case. This growth is a result of the size of the associated resources, which extend over nearly 500,000 square miles, and improvements in technology that allow development of these resources at lower costs.

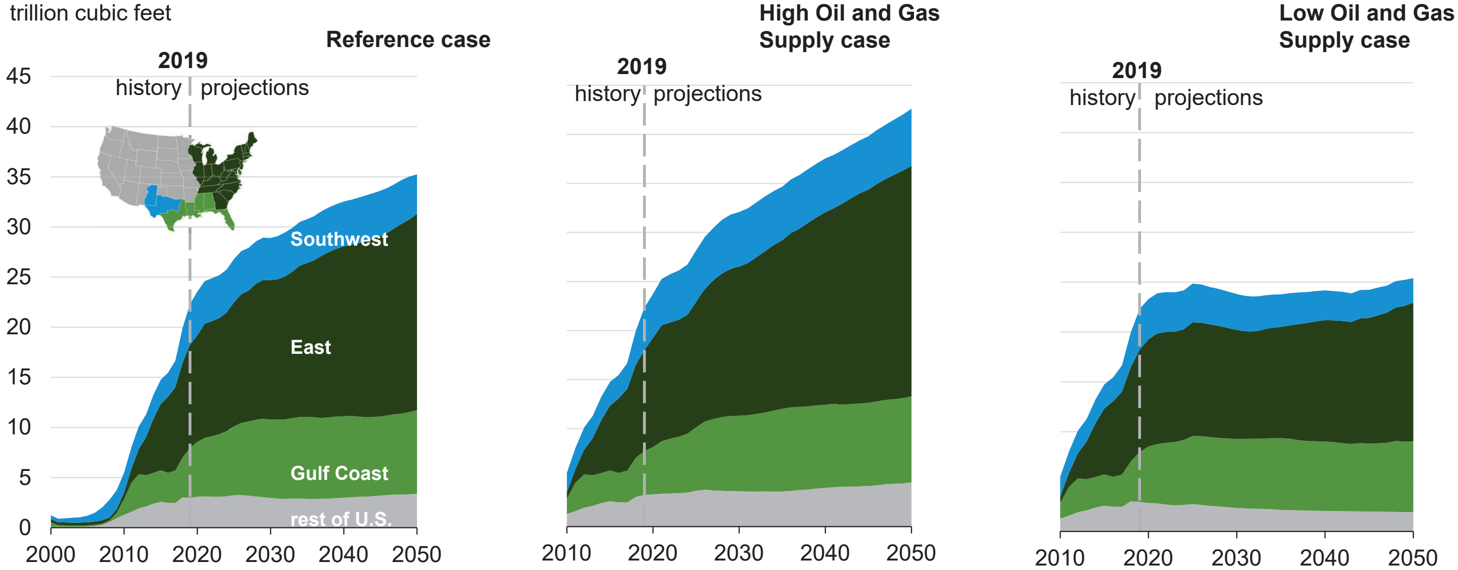
- In the High Oil and Gas Supply case, which has more optimistic assumptions regarding resource size and recovery rates, cumulative production from shale gas and tight oil is 14% higher than in the Reference case. Conversely, in the Low Oil and Gas Supply case, cumulative production from those resources is 20% lower than in the Reference case.

- Across all AEO2020 cases, onshore production of natural gas from sources other than tight oil and shale gas, such as coalbed methane, generally continues to decline through 2050 because of unfavorable economic conditions for producing these resources.

- Offshore natural gas production in the United States remains relatively flat during the projection period in all cases, driven by production from new discoveries that generally offsets declines in legacy fields.

Eastern U.S. production of natural gas from shale resources leads growth in the AEO2020 Reference case—

AEO2020 dry shale gas production by region
trillion cubic feet

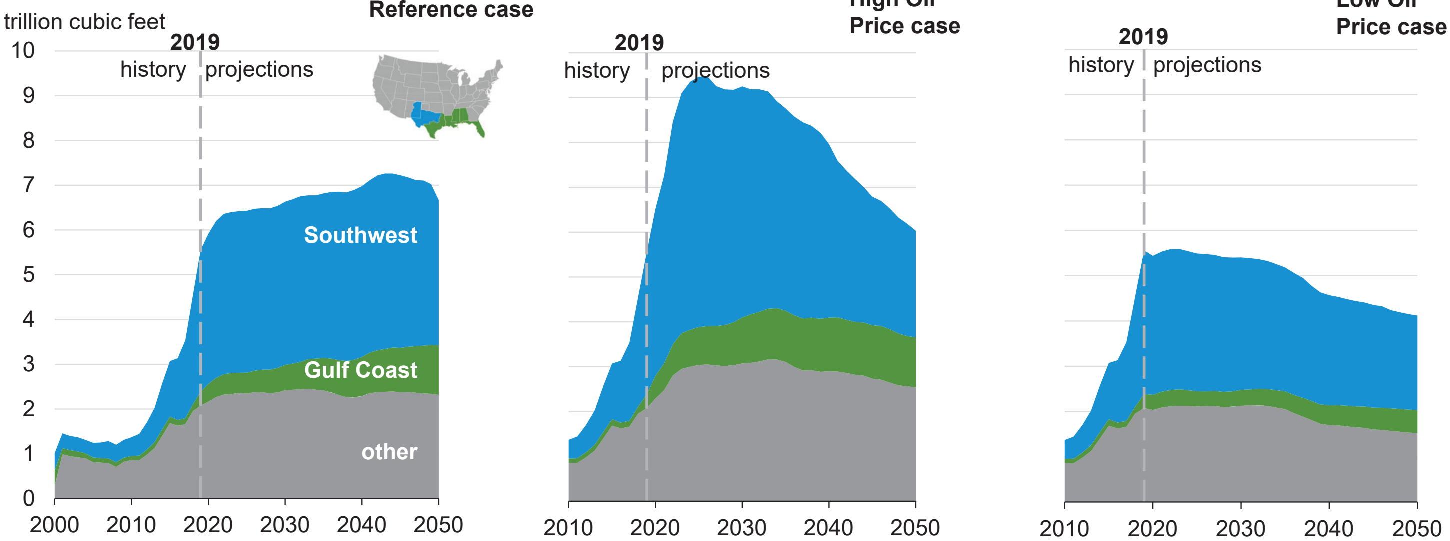


—followed by growth in Gulf Coast onshore production

- Total U.S. natural gas production across most AEO2020 cases is driven by the continued development of the Marcellus and Utica shale plays in the East.
- Natural gas from the Eagle Ford (coproduced with oil) and the Haynesville plays in the Gulf Coast region also materially contributes to domestic dry natural gas production.
- Natural gas production associated with tight oil in the Permian Basin in the Southwest region greatly increases until 2022 but remains relatively flat afterwards to 2050.
- Technological advancements and improvements in industry practices lower production costs in the Reference case and increase the volume of oil and natural gas recovery per well. These advancements have a significant cumulative effect in plays that extend over wide areas and that have large undeveloped resources (for example, Marcellus, Utica, and Haynesville).
- Natural gas production from regions with shale and tight resources shows higher levels of variability across the AEO2020 supply side cases compared with the Reference case because assumptions in those cases target those resources.

The United States continues to produce large volumes of natural gas from oil formations—

AEO2020 dry natural gas production from oil formations

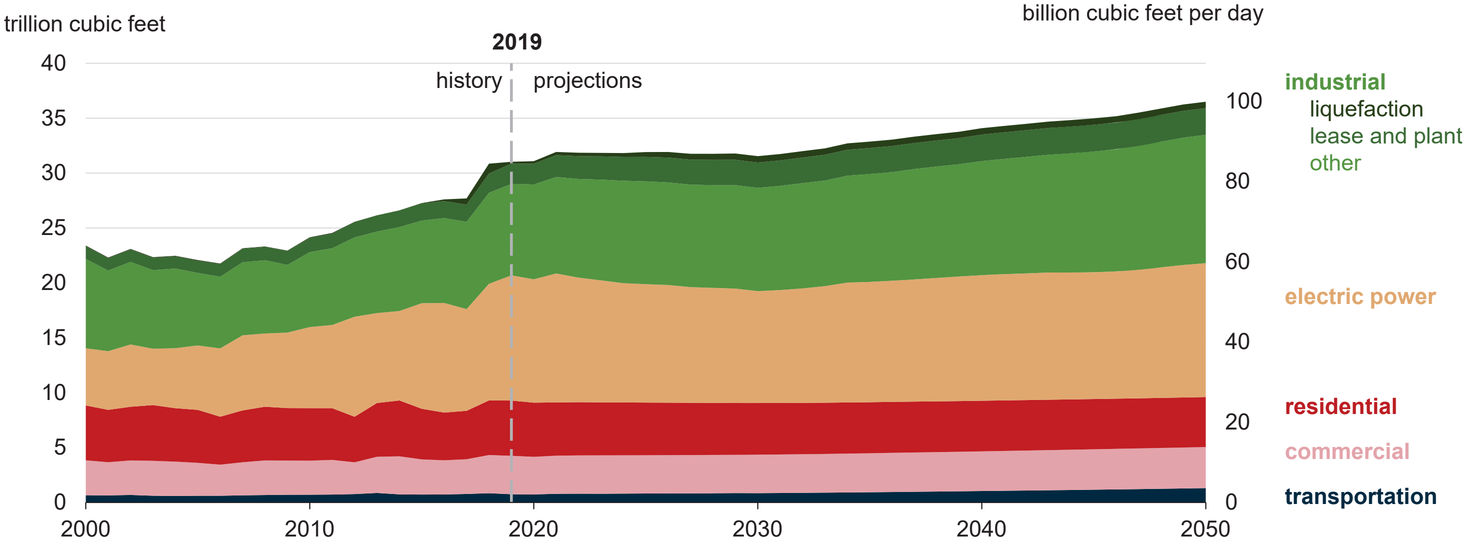


—even though relatively low oil prices put downward pressure on natural gas prices

- The percentage of dry natural gas production from oil formations in the United States increased from 8% in 2013 to 15% in 2018 and remains near this percentage through 2050 in the AEO2020 Reference case.
- Increased drilling in the Southwest, particularly in the Wolfcamp formation in the Permian Basin, is the main driver of growth in natural gas production from tight oil formations.
- The AEO2020 Low Oil Price case (which reflects a U.S. crude oil benchmark West Texas Intermediate price at $56 per barrel or lower) is the only case in which U.S. natural gas production from oil formations is lower in 2050 than current levels.
- The level of drilling in oil formations primarily depends on crude oil prices rather than natural gas prices. Increased natural gas production from oil-directed drilling puts downward pressure on natural gas prices throughout the projection period.

Industrial and electric power demand drives U.S. natural gas consumption growth—

Natural gas consumption by sector (AEO2020 Reference case)



—but consumption in the residential and commercial sectors remains relatively flat across the projection period in the AEO2020 Reference case

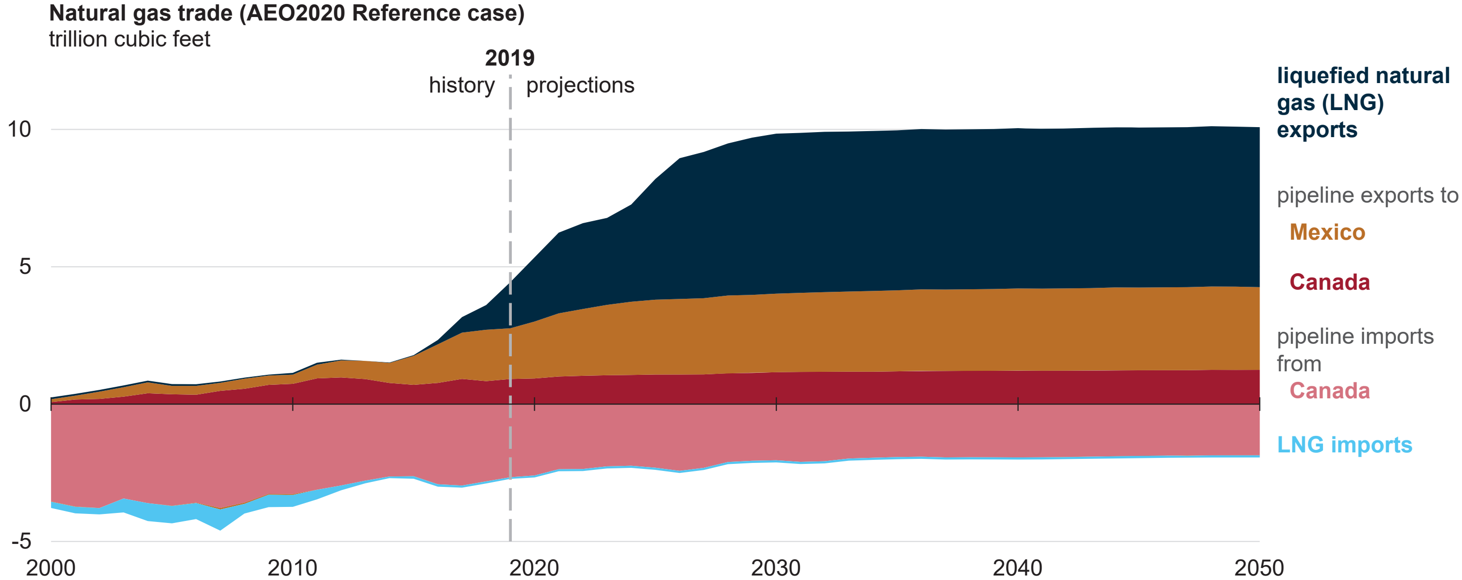
- Relatively low U.S. natural gas prices in the AEO2020 Reference case lead to continued growth in natural gas consumption in the near term, particularly in the electric power sector. However, through 2050, only the industrial sector shows markedly increased natural gas consumption.

- The industrial sector, which includes fuel used for liquefaction at export facilities and in lease and plant operations, consumes more natural gas than any other sector in the United States after 2021. Major natural gas consumers in this sector include the chemical industry (where natural gas is used as a feedstock to produce methanol and ammonia), manufacturing heat and power, and lease and plant fuel.

- Natural gas used for U.S. electric power generation peaks in 2021 as relatively low natural gas prices, new natural gas-fired combined-cycle capacity, and coal-fired capacity retirements drive increases in natural gas-fired generation in the short term. However, strong growth in renewables and efficiency improvements in the remaining coal-fired fleet lead to declining amounts of natural gas consumed in the electric power sector through 2030. Natural gas consumption then slowly rises to reach its 2021 level again in the late 2040s.

- Natural gas consumption in the residential and commercial sectors remains largely flat because of efficiency gains and population shifts to warmer regions that counterbalance population growth. Although natural gas consumption rises in the transportation sector--particularly for freight trucks, rail, and marine shipping--it remains a small share of both transportation fuel demand and total natural gas consumption.

The United States continues to export more natural gas than it imports in the AEO2020 Reference case—



—because near-term growth in liquefied natural gas export capacity delivers domestic production to global markets

- In the AEO2020 Reference case, pipeline exports to Mexico and liquefied natural gas (LNG) exports to world markets increase moderately until 2025, after which pipeline export growth to Mexico slows. LNG exports continue to rise through 2030 before remaining relatively flat for the remainder of the projection period.

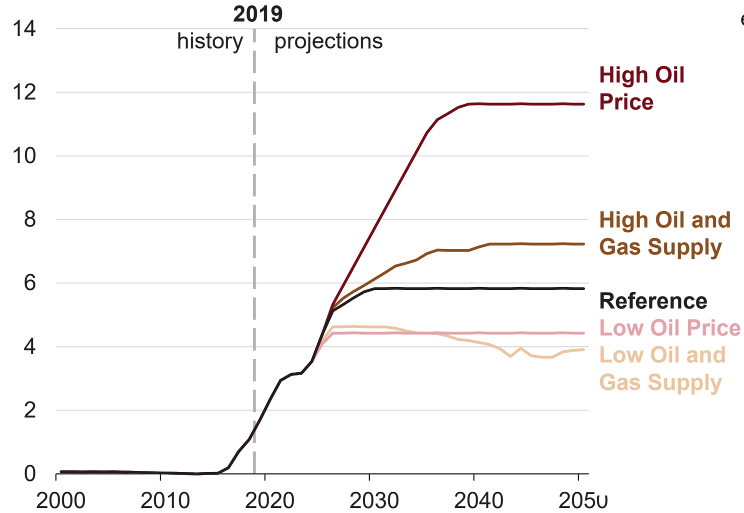
- Increasing natural gas exports to Mexico are a result of more pipeline infrastructure to and within Mexico, allowing for increased natural gas-fired power generation. By 2030, Mexico's domestic natural gas production begins to displace U.S. exports.

- Three more LNG-export facilities became operational in the Lower 48 states in 2019, bringing the total number to six. Two new LNG projects reached final investment decisions and started construction in 2019. All LNG-export facilities and expansions currently under construction are expected to be completed by 2025. U.S. LNG-export capacity will continue to serve growing global LNG demand, particularly in emerging Asian markets as long as U.S. natural gas prices remain competitive. As U.S.-sourced LNG becomes less competitive in world markets after 2030, export volumes level off.

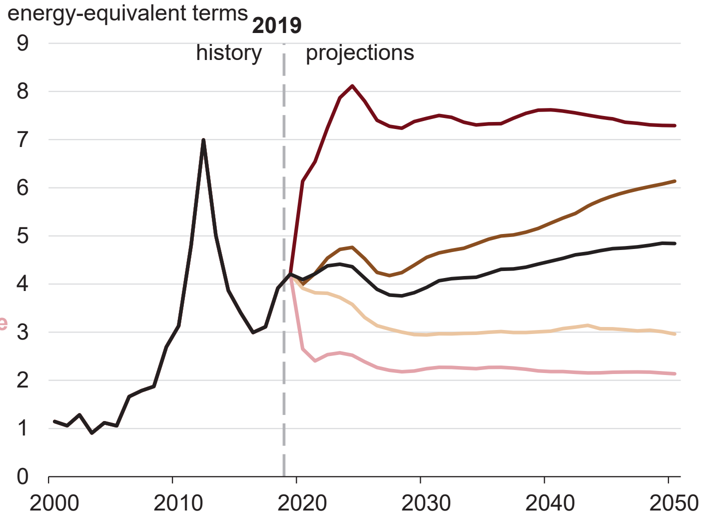
- U.S. imports of natural gas from Canada, primarily from its prolific western region, continue to generally decline from historical levels. U.S. exports of natural gas to eastern Canada continue to increase because of eastern Canada's proximity to U.S. natural gas resources in the Marcellus and Utica plays and new pipeline infrastructure. However, this export growth slows in the mid-2020s as Canada's demand for natural gas begins to decline, particularly in the electric power sector, as Canada begins transitioning to more renewables in its generation mix.

Liquefied natural gas (LNG) exports are sensitive to both oil and natural gas prices—

AEO2020 liquefied natural gas exports
trillion cubic feet



Ratio of Brent crude oil price to natural gas price at Henry Hub in AEO2020
energy-equivalent terms



—resulting in a wide range of U.S. LNG-export levels across cases

- Historically, most LNG was traded under long-term contracts linked to crude oil prices because the regional nature of natural gas markets prevented the development of a natural gas price index that could be used globally. In addition to providing a liquid global pricing benchmark, crude oil, to some degree, can act as a substitute for natural gas in industry and for power generation.

- As more natural gas is traded via short-term contracts or traded on the spot market, the link between LNG and oil prices weakens over time, making U.S. LNG exports less sensitive to the crude oil-to-natural gas price ratio and more responsive to the global LNG supply-natural gas demand dynamics. This shift causes growth in U.S. LNG exports to slow in all cases.

- When the crude oil-to-natural gas price ratio is highest, such as in the High Oil Price case, U.S. LNG exports are at their highest levels. U.S. LNG supplies are priced based on relatively low domestic spot prices instead of oil-linked contracts. In addition, demand for LNG increases, in part, as a result of consumers moving away from petroleum products.

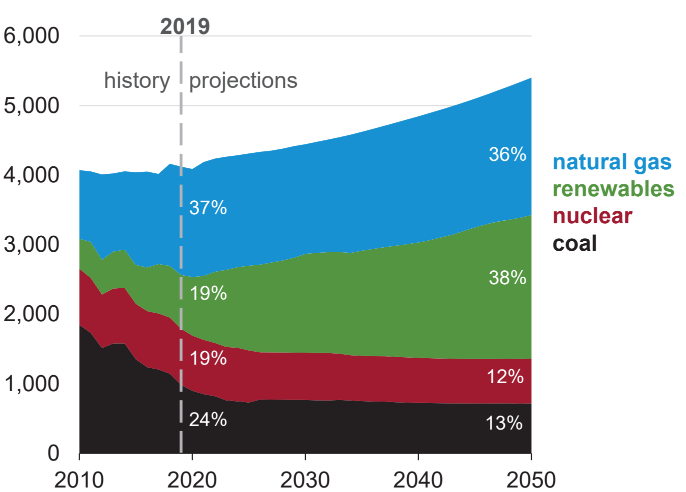
- In the High Oil and Gas Supply case, low U.S. natural gas prices make U.S. LNG exports competitive relative to other suppliers. Conversely, higher U.S. natural gas prices in the Low Oil and Gas Supply case result in lower U.S. LNG exports.

Electricity

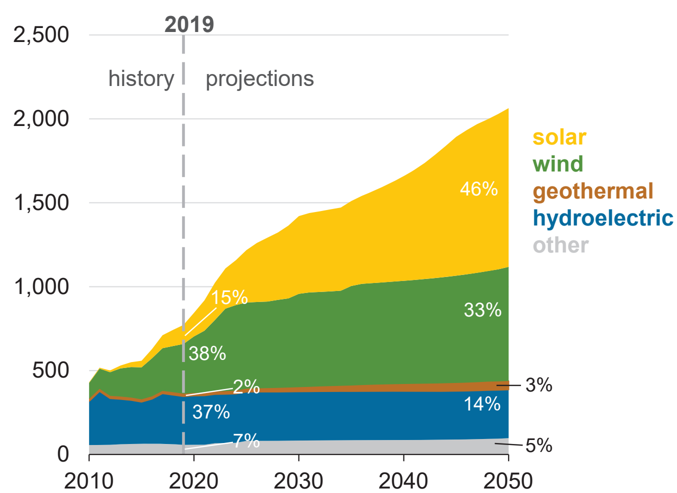
As electricity demand grows modestly, the primary drivers for new capacity in the AEO2020 Reference case are retirements of older, less-efficient fossil fuel units; the near-term availability of renewable energy tax credits; and the continued decline in the capital cost of renewables, especially solar photovoltaic. Low natural gas prices and favorable costs for renewables result in natural gas and renewables as the primary sources of new generation capacity through 2050. The future generation mix is sensitive to the price of natural gas and growth in electricity demand.

Electricity generation from natural gas and renewables increases as a result of lower natural gas prices and declining costs of solar and wind renewable capacity, making these fuels increasingly competitive

Electricity generation from selected fuels (AEO2020 Reference case)
billion kilowatthours

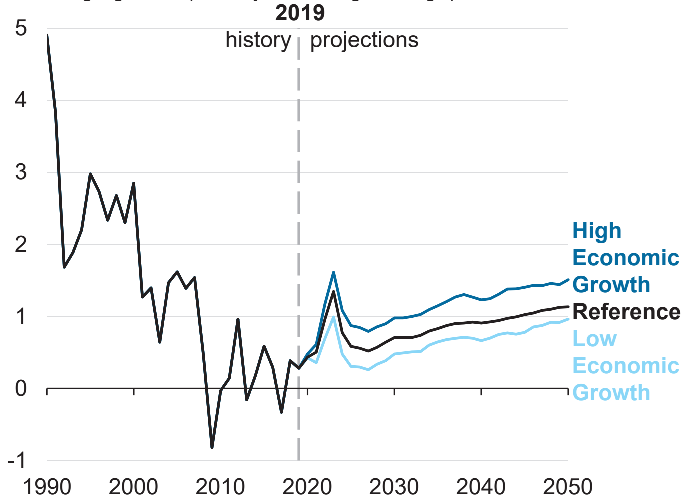


Renewable electricity generation, including end use (AEO2020 Reference case)
billion kilowatthours

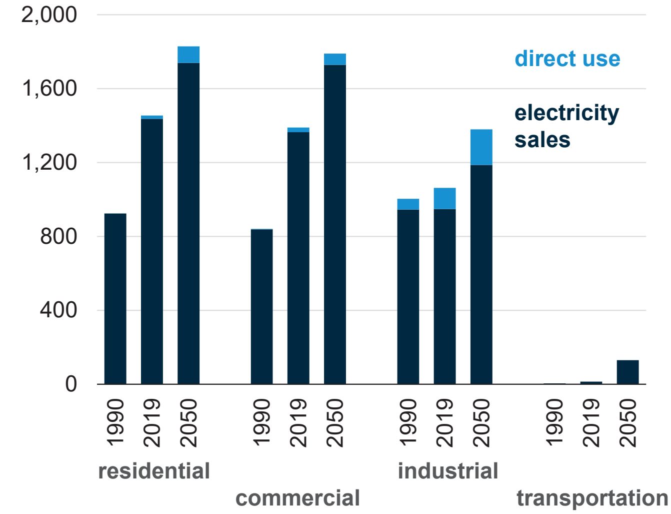


Electricity demand grows slowly through 2050 in the AEO2020 Reference case—

AEO2020 Electricity use growth rate
percentage growth (three-year rolling average)



Electricity use by end-use sector (AEO2020 Reference case)
billion kilowatthours



—with increases occurring across all end-use sectors

- Although near-term electricity demand may fluctuate as a result of year-to-year changes in weather, trends in long-term demand tend to be driven by economic growth offset by increases in energy efficiency. The annual growth in electricity demand averages about 1% throughout the projection period (2019-2050) in the AEO2020 Reference case.

- Historically, although the economy has continued to grow, growth rates for electricity demand have slowed as new, efficient devices and production processes that require less electricity have replaced older, less-efficient appliances, heating, ventilation, cooling units, and capital equipment.

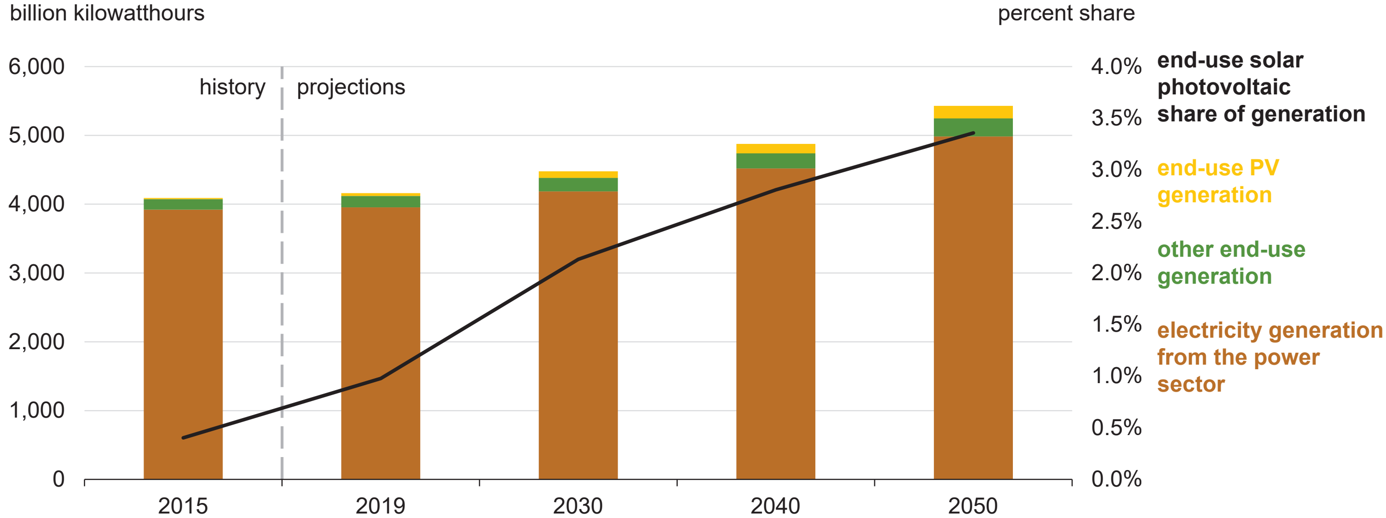
- Average electricity growth rates in the AEO2020 High Economic Growth and Low Economic Growth cases vary the most from the Reference case. Electricity use in the High Economic Growth case grows 0.3 percentage points faster on average, and electricity use in the Low Economic Growth case grows 0.2 percentage points slower.

- The growth in projected electricity sales during the projection period would be higher if not for significant growth in generation from rooftop photovoltaic (PV) systems, primarily on residential and commercial buildings, and combined-heat-and-power systems in industrial and some commercial applications. By 2050, end-use solar photovoltaic accounts for 4% of U.S. generation in the AEO2020 Reference case.

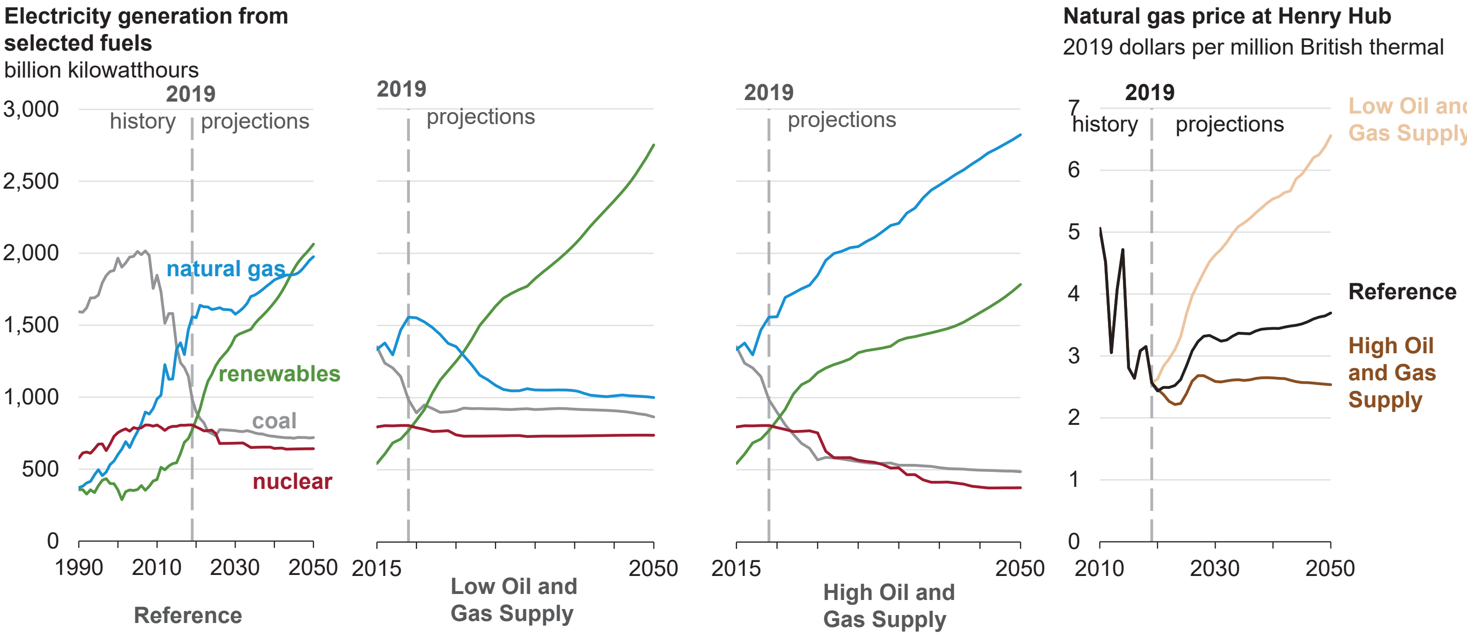
- Electric power demand from the transportation sector is a very small percentage of economy-wide demand because electric vehicles (EVs) still represent a developing market. Given the lack of market evidence to date that would indicate a significant increase in U.S. consumer preference for EVs, EIA's AEO2020 projections reflect the dependence of the EV market on regulatory policies. Both vehicle sales and utilization (miles driven) would need to increase substantially for EVs to raise electric power demand growth rates by more than a fraction of a percentage per year.

An increasing share of total electricity demand is met with customer-owned generation, including rooftop solar photovoltaic

Electricity generation, end-use solar photovoltaic share (AEO2020 Reference case)



Declining costs for new wind and solar projects support the growing renewables share of the generation mix across a wide range of assumptions—



—although the results are sensitive to natural gas resource and price assumptions

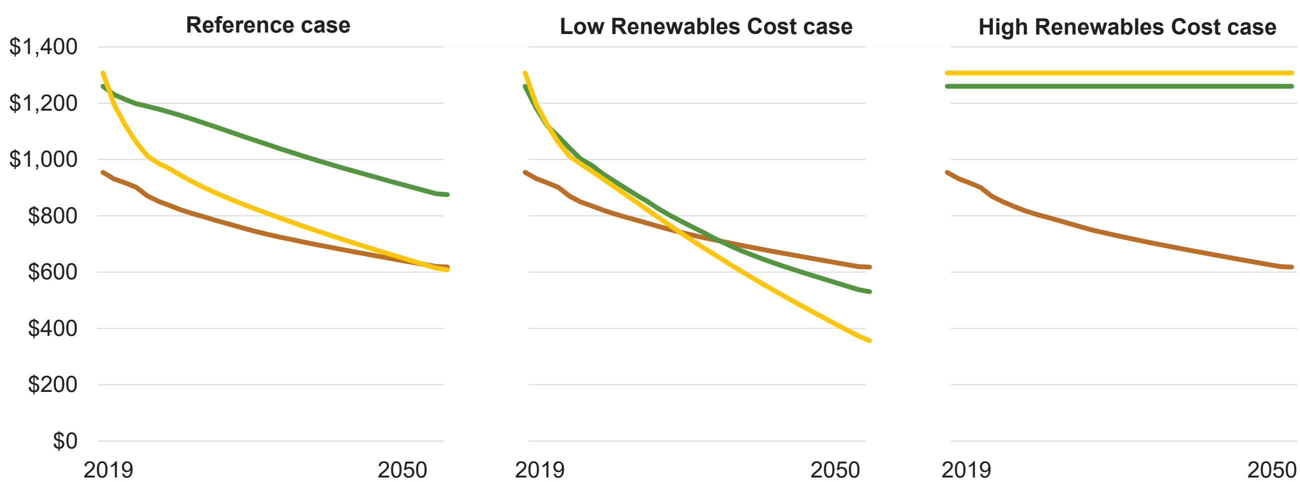
- Because of declining capital costs and higher renewable portfolio standards (RPS) targets in some states, AEO2020 projects that the relatively sharp growth in renewables seen during the past 10 years will continue through the projection period. Total renewable generation exceeds natural gas-fired generation after 2045 in the AEO2020 Reference case. Renewable generation grows faster than overall electricity demand.

- Although coal-fired and nuclear generation decline through the mid-2020's as a result of retirements, generation from these sources stabilizes over the longer term as the more economically viable plants remain in service. At projected Reference case prices, natural gas-fired generation is the marginal fuel source to fulfill incremental demand and increases in the later projection years, averaging 0.8% growth per year through 2050.

- As a result of projected lower natural gas prices in the High Oil and Gas Supply case, natural gas-fired generation increases 1.9% per year through the projection period, reaching a 51% share of the generation mix by 2050. In contrast, under the projected higher natural gas prices in the Low Oil and Gas Supply case, natural gas-fired generation declines 1.4% per year through 2050, reaching a 19% share of the generation mix by 2050.

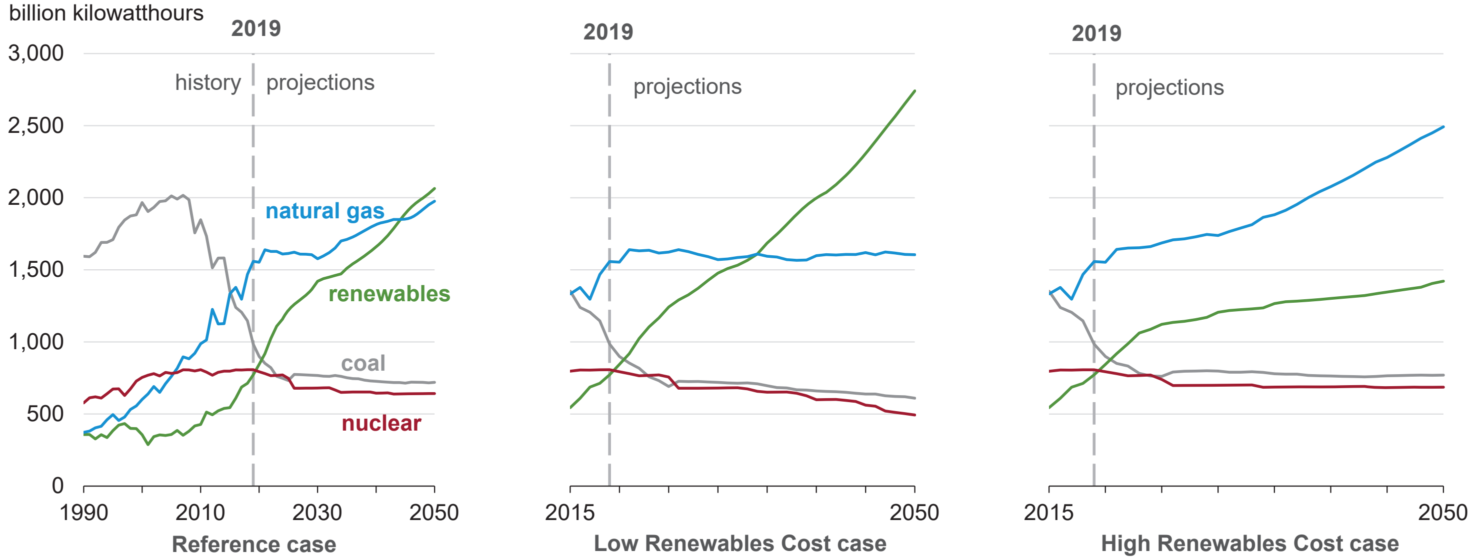
The High Renewables Cost and Low Renewables Cost cases assume different rates of cost reduction for renewable technologies compared with the Reference case; non-renewables assume the same rates

AEO2020 overnight installed cost by technology
2019 dollars per kilowatt



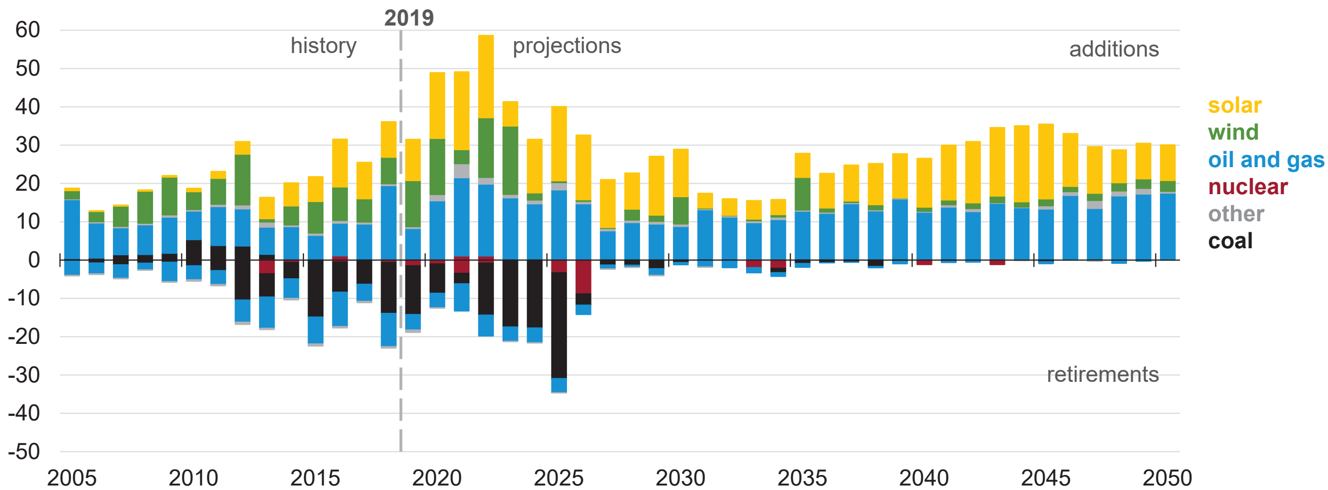
Changes in cost assumptions for new wind and solar projects result in significantly different projected fuel mixes for electricity generation

AEO2020 electricity generation from selected fuels
billion kilowatthours



Expected requirements for new generating capacity will be met by renewables and natural gas in the AEO2020 Reference case—

Annual electricity generating capacity additions and retirements (Reference case)
gigawatts



—as a result of competitive natural gas prices and declining costs for renewables

- In the AEO2020 Reference case, the United States adds 117 gigawatts (GW) of new wind and solar capacity between 2020 and 2023, which is the result of tax credits, increasing RPS targets, and declining capital costs.

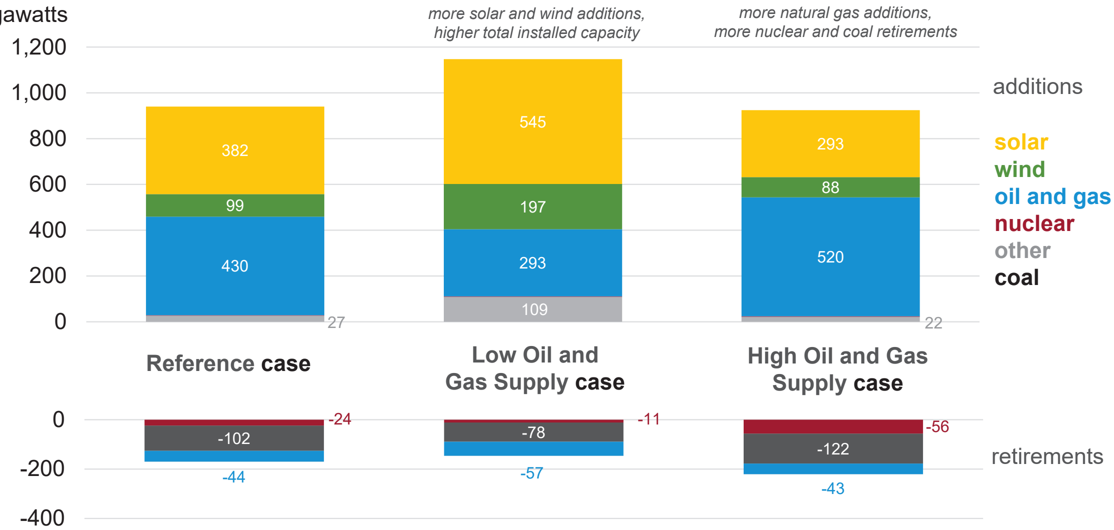
- New wind capacity additions continue at much lower levels after production tax credits expire in the early 2020s, but the growth in solar capacity continues through 2050 for both the utility-scale and small-scale applications because the cost of solar PV declines throughout the projection period.

- Natural gas-fired combined-cycle generation capacity is also added steadily throughout the projection period to meet rising demand.

- Most of the electric generation capacity retirements assumed in the AEO2020 Reference case occur by 2025. Although the final schedule will depend upon state-level implementation plans, in AEO2020 EIA assumes that coal-fired plants must either invest in heat rate improvement technologies by 2025 or retire to comply with the Affordable Clean Energy (ACE) rule. Heat rate improvement technologies increase the efficiency of power plants. The remaining coal plants are more efficient and continue to operate throughout the projection period. Low natural gas prices in the early years also contribute to the retirements of coal-fired and nuclear plants because both coal and nuclear generators are less profitable in these years.

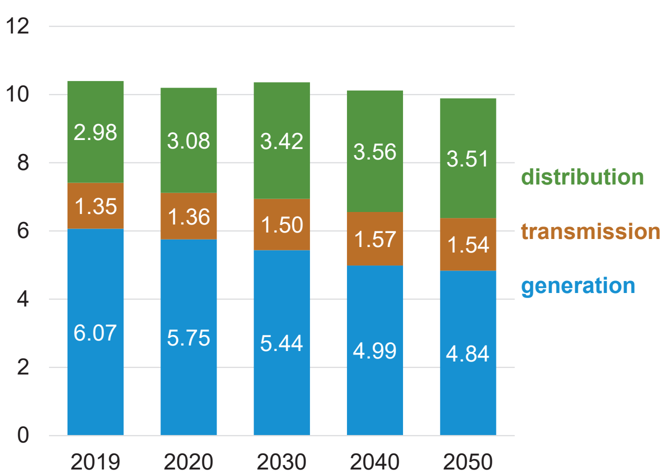
AEO2020’s long-term trends in electricity generation are dominated by solar and natural gas-fired capacity additions; coal, nuclear, and less efficient natural gas generators contribute to capacity retirements

AEO2020 cumulative electricity generating capacity additions and retirements (2020–2050)

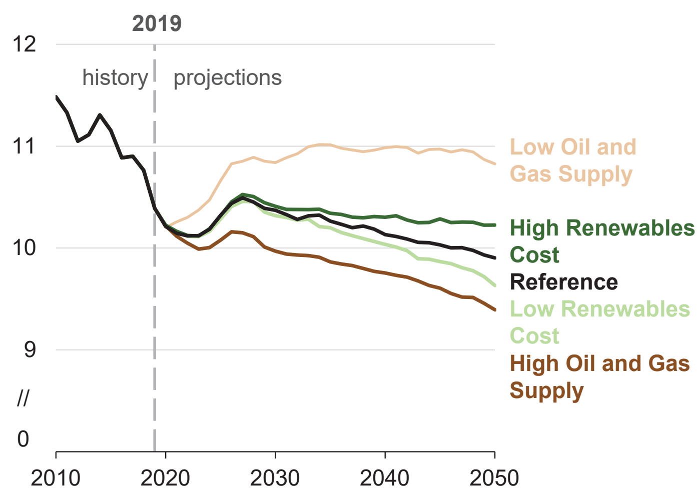


AEO2020 Reference case electricity prices fall slightly; declining generation costs are offset by rising transmission and distribution costs

Electricity prices by service category (AEO2020 Reference case)
2019 cents per kilowatthour

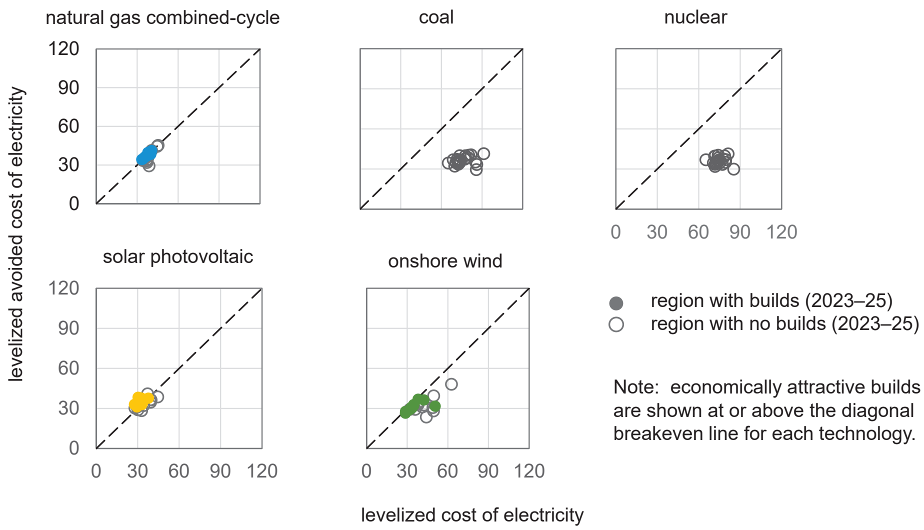


AEO2020 average electricity price
2019 cents per kilowatthour



In the AEO2020 Reference case, combined-cycle and solar photovoltaic are the most economically competitive generating technologies—

AEO2020 levelized cost of electricity and levelized avoided cost of electricity by technology and region, 2025
2019 dollars per megawatthour



—when considering the overall cost to build and operate and the value of the plant to the grid

- The levelized cost of electricity (LCOE) reflects the cost to build and operate a power plant per unit of generation, annualized over a cost recovery period. When compared with the levelized avoided cost of electricity (LACE), or expected average revenue realized by that plant, we can estimate the economic competitiveness for that generating technology.

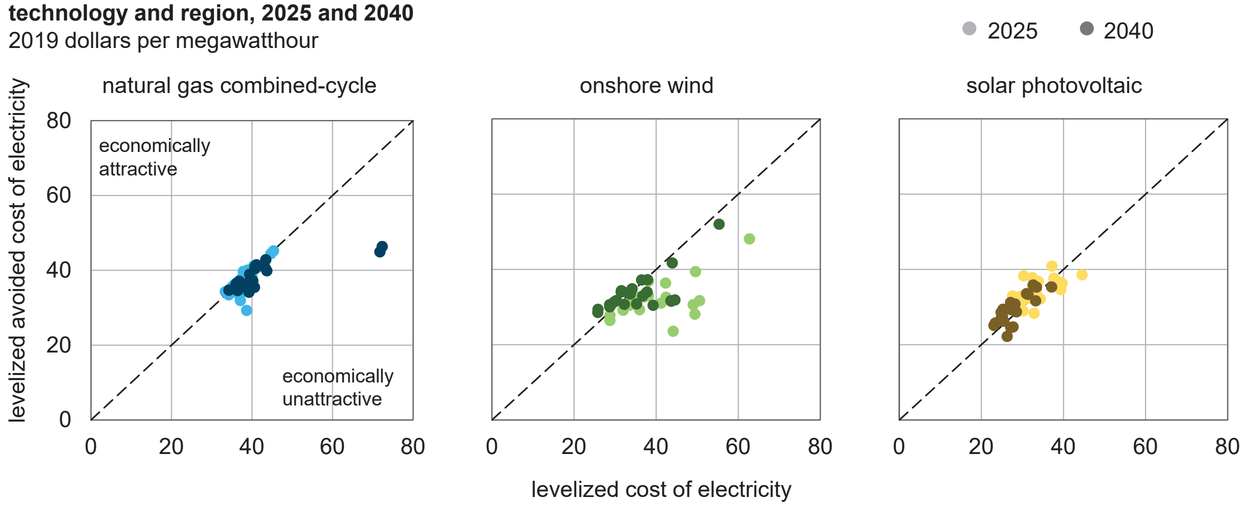
- The solid, colored circles on the figure indicate that projects tend to be built in regions where revenue (LACE) exceeds costs (LCOE). In the AEO2020 Reference case, expected revenues from electric generation for both natural gas-fired combined-cycle and solar photovoltaic with single axis tracking are generally greater than or equal to projected costs across the most electricity market regions in 2025. Correspondingly, these two technologies show the greatest projected growth through the middle of the 2030s.

- The value of wind approaches its cost in nearly half of the regions. These regions see new wind capacity builds in the AEO2020 Reference case, primarily in advance of the phase-out of the production tax credit (PTC), through the early part of the next decade.

- LACE accounts for both the variation in daily and seasonal electricity demand in the region where a new project is under consideration and the characteristics of the existing generation fleet where the new capacity will be added. The prospective new generation resource is compared with the mix of new and existing generation and capacity that it would displace. For example, a wind resource that would primarily displace existing natural gas-fired generation will usually have a different value than one that would displace existing coal-fired generation.

Onshore wind will become more competitive over time, while natural gas-fired combined-cycle and solar photovoltaic maintain their current competitive positions—

AEO2020 Reference case levelized cost of electricity (LCOE) and levelized avoided cost of electricity (LACE) by technology and region, 2025 and 2040
2019 dollars per megawatthour



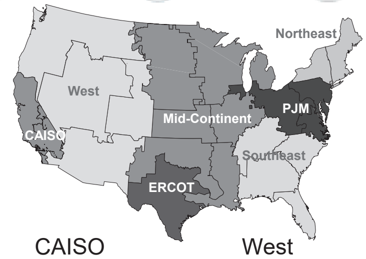
—as LCOE declines through learning-induced cost reductions and LACE increases with rising demand and natural gas prices

- Changes in AEO2020 electricity generation costs over time reflect a number of factors, sometimes working in different directions. For both solar photovoltaic (PV) and onshore wind, LCOE increases in the near term with the phase-out and expiration of the investment tax credit (ITC) and PTC, respectively. However, LCOE eventually declines over time because technological improvements tend to reduce LCOE through lower capital cost or improved performance (as measured by heat rate for natural gas combined-cycle plants or capacity factor for onshore wind or solar PV plants), partly offsetting the loss of the tax credits.

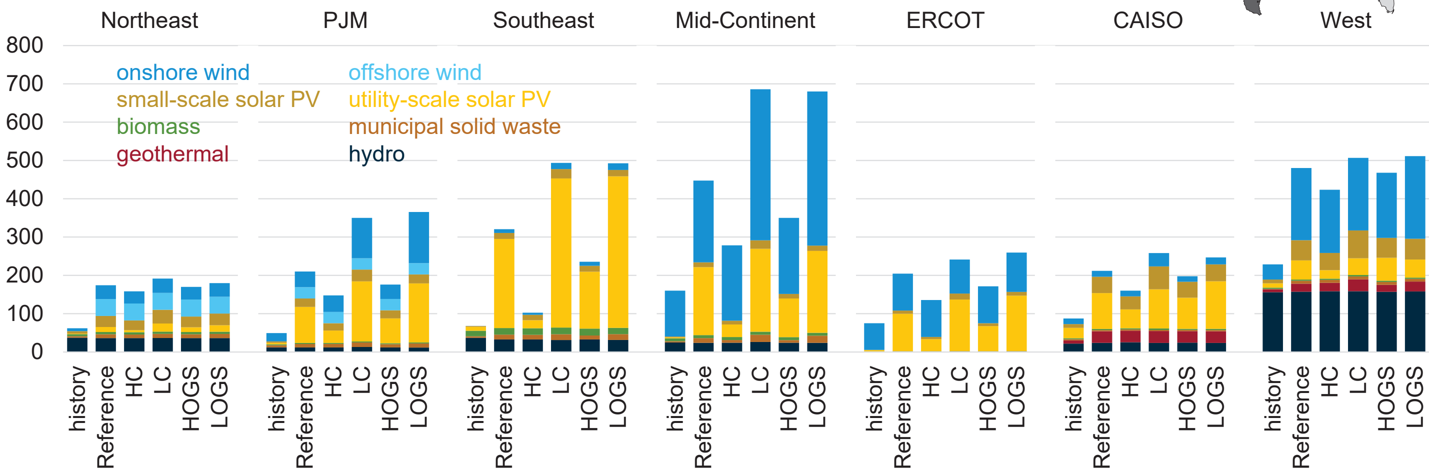
- Natural gas-fired combined-cycle plants with online years of 2025 and 2040 in the AEO2020 projection have similar LCOE because the technology has reached market maturity, judging from the build patterns throughout the projection years across all regions. The two outliers in the 2040 LCOE projection are attributed to the increase in variable operations and in maintenance costs for plants in California as a result of the state's phase-out of fossil fuel-fired generation starting in 2030.

- Solar may show strong daily generation patterns within any given region; therefore, AEO2020 LACE for solar PV declines over time as the market becomes saturated with generation from resources with similar hourly generation patterns. LACE for onshore wind is generally lower than other technologies because most of the generation at these plants occurs at night or during fall and spring seasons when the demand for and the value of electricity is typically lower. Solar PV plants produce most of their energy during the middle of the day when higher demand increases the value of electricity, resulting in higher LACE.

Solar and wind lead the growth in renewables generation in most regions across all cases in AEO2020



Total renewables generation (all sectors), 2018 and 2050
billion kilowatthours



Note: HC = High Renewables Cost, LC = Low Renewables Cost, HOGS = High Oil and Gas Supply, LOGS = Low Oil and Gas Supply, PV= photovoltaic

—but its penetration rate differs by regional resource and generation mix

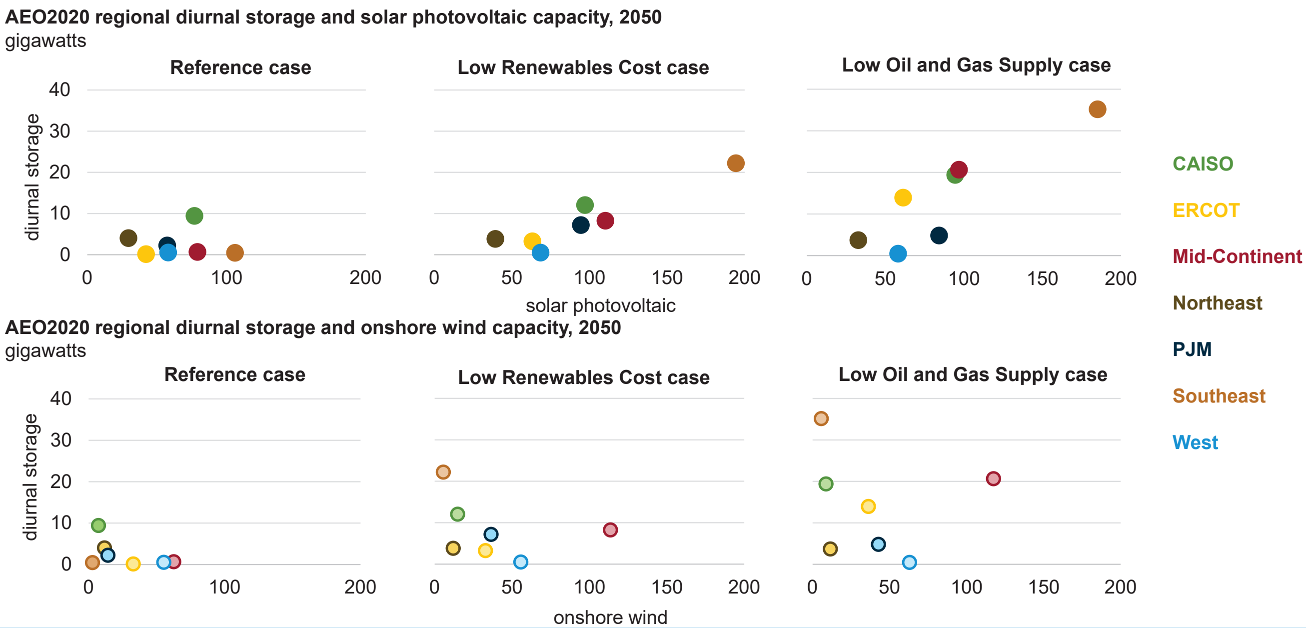
- The AEO2020 projects that generation from renewable sources will rise from 18% of total generation in 2018 to 38% by 2050 in the Reference case. Solar photovoltaic (PV) contributes the most to the growth in renewable generation, increasing from 13% of total renewable generation in 2018 to 46% by 2050. Although onshore wind generation more than doubles during the projection period, its share of renewable generation declines slightly from 37% to 29% between 2018 and 2050.

- Solar PV generation grows the most in Southeast and Mid-Continent regions in nearly all cases. On average, these two regions have higher-than-average delivered U.S. natural gas prices, making natural gas generation a more expensive option to replace retired coal or nuclear generation. Because solar PV generates mostly during daytime hours, it can readily substitute natural gas generation during periods of higher demand. Regions with existing wind capacity continue to install new wind capacity between 2018 and 2050.

- When natural gas prices are higher, as in the Low Oil and Gas Supply case, onshore wind becomes the incremental generation source in the Mid-Continent region, where wind resources are abundant. Wind generation for the region is 189 billion kilowatthours (BkWh) higher (89% increase) in 2050 than in the Reference case, and all-sector solar PV generation is 37 BkWh higher (20% increase).

- The Northeast, ERCOT (Electric Reliability Council of Texas), CAISO (California Independent System Operator), and West regions have relatively small variations in results across the alternative cases. The small variations are most likely a result of the regions' current small shares of existing coal generation capacity that may need to be replaced over the projection period. The share of renewables is also comparatively large in these regions.

Growth in utility-scale battery storage in AEO2020 follows growth in solar in most regions in high renewable penetration scenarios—



—but does not benefit from wind growth, which has more unpredictable generation patterns

- The AEO2020 Reference case projects that the United States will have 17 GW of battery storage capacity in 2050. Storage capacity takes advantage of times when an oversupply of electricity occurs, which generally happens in areas that have a high penetration of non-dispatchable renewable resources such as wind and solar. Limitations in the time a battery can store electricity make batteries more suitable for solar, which has more predictable generation patterns than wind.

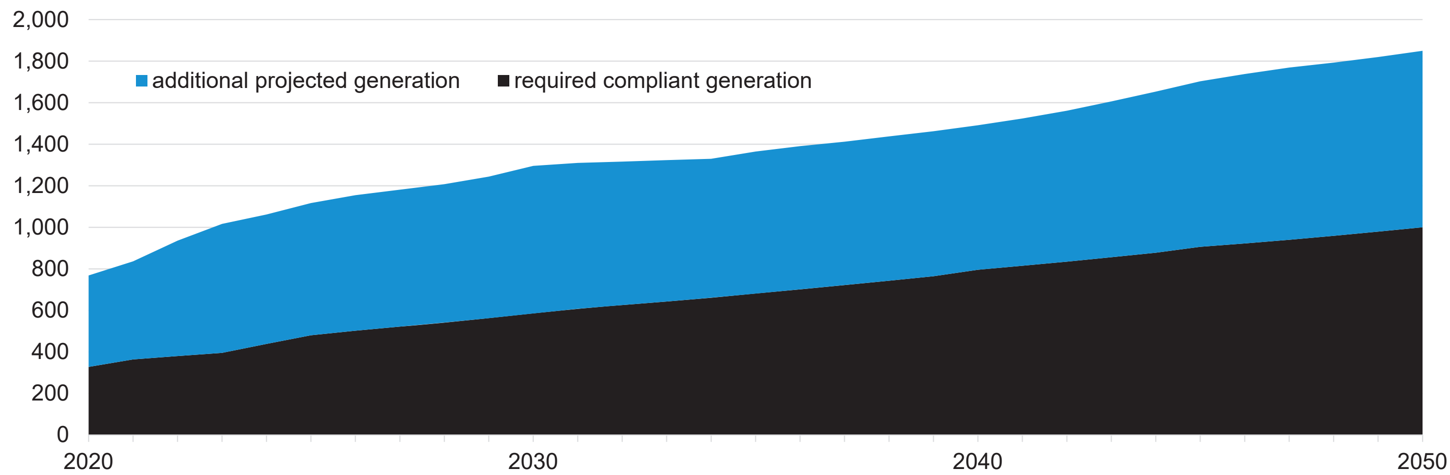
- The large number of combustion turbine (CT) additions in the West and Mid-Continent regions correspond the large number of wind additions in these regions. Because wind energy is less predictable and fluctuates in intensity for long periods, current limitations in the length of time a battery can store or generate power make batteries an inadequate backup for wind power. Therefore, CTs, which have no duration limit as long as natural gas fuel is available, fill the gap. CTs in the West region are also supported by its large hydropower resources.

- Storage growth is stronger in AEO2020 scenarios that have a high penetration of renewables, such as the Low Renewables Cost and Low Oil and Gas Supply cases. The Low Renewables Cost case projects 57 GW of storage by 2050, and the Low Oil and Gas Supply case projects 98 GW of storage by 2050.

- In both the Low Renewables Cost and Low Oil and Gas Supply cases, the Southeast and California regions see high amounts of solar capacity in 2050, minimal amounts of wind capacity, and concurrently large amounts of battery storage. The Northeast, the West, and the PJM regions have relatively low solar capacity and lower storage capacity.

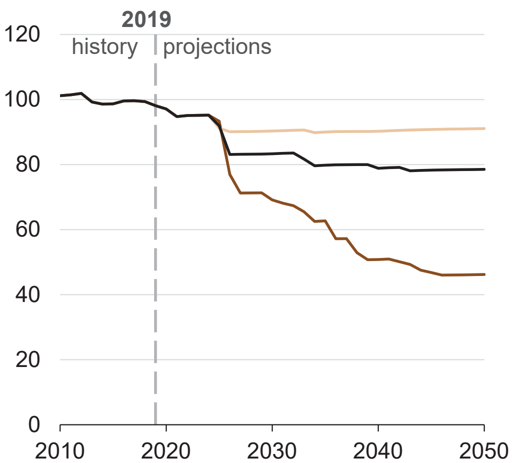
Even with recent increases in several states' renewable portfolio standards, renewable generation that exceeds requirements allows for full compliance in the AEO2020 Reference case by 2050

AEO2020 Reference case total qualifying renewables generation required for combined state renewable portfolio standards and projected total generation from compliant technologies, 2020–2050
billion kilowatthours

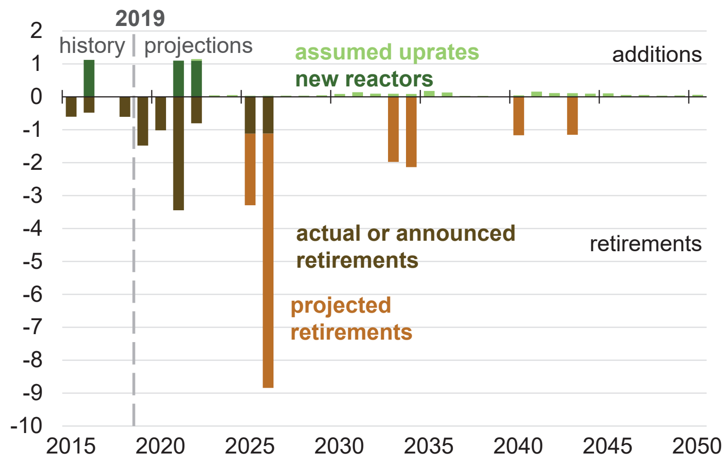


Lower natural gas prices throughout the AEO2020 projection period accelerate nuclear capacity retirements—

AEO2020 nuclear electricity generating capacity
gigawatts



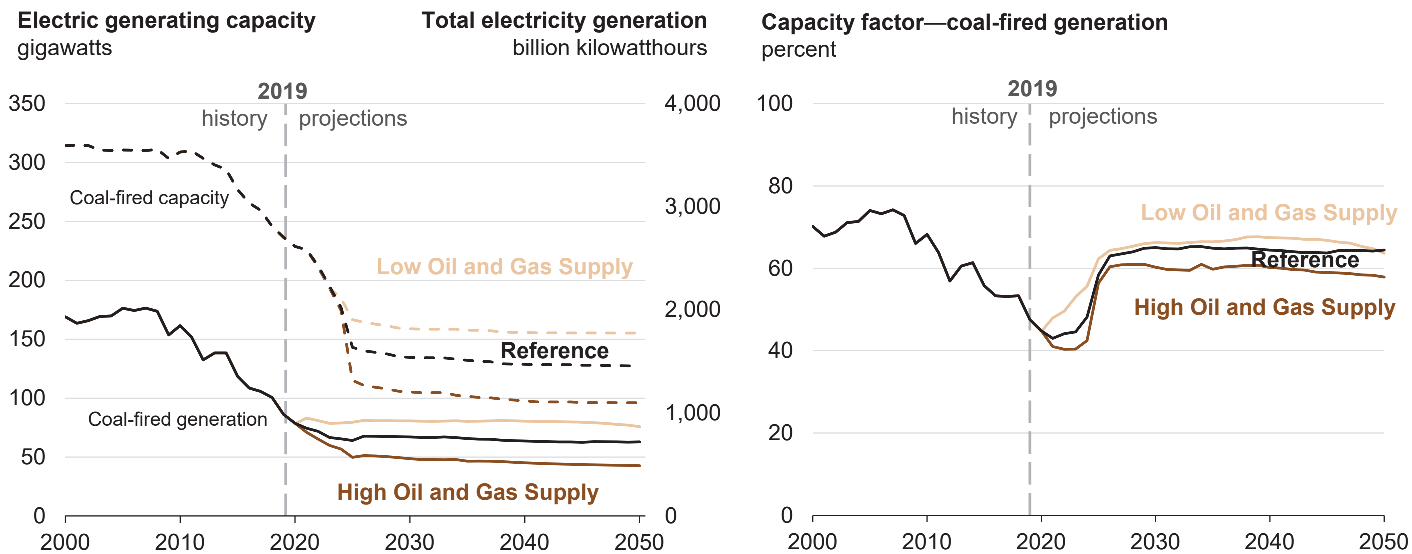
Year-over-year nuclear capacity changes (AEO2020 Reference case)
gigawatts



—as a result of declining revenue in competitive wholesale power markets

- The AEO2020 Reference case projects a 19% decline in nuclear electric generating capacity from 98 GW in 2019 to 79 GW in 2050. No new plant additions occur beyond 2022, and existing plants have 2 GW of uprates starting in 2022.
- Projected nuclear retirements are driven by declining revenues that result from low growth in electricity load and from increasing competition from low-cost natural gas and declining-cost renewables. Smaller, single-reactor nuclear plants with higher average operating costs are most affected, particularly those plants operating in regions with deregulated wholesale power markets and in states without a zero emission credit policy.
- Lower natural gas prices in the High Oil and Gas Supply case lead to lower wholesale power market revenues for nuclear power plant operators, accelerating an additional 32 GW of nuclear capacity retirements by 2050 compared with the Reference case.
- Higher natural gas prices in the Low Oil and Gas Supply case help increase profitability for nuclear power plant operators, resulting in 13 GW fewer retirements through 2050 compared with the Reference case.

Coal-fired generating capacity retires at a faster pace than total generation in the AEO2020 Reference case—



—as capacity factors increase for the more efficient coal-fired units that remain in service

- In addition to decreases as a result of competitively priced natural gas and increasing renewables generation, coal-fired generating capacity decreases by 109 GW (or 46%) between 2019 and 2025 to comply with the Affordable Clean Energy (ACE) rule before leveling off near 127 GW in the AEO2020 Reference case by 2050.

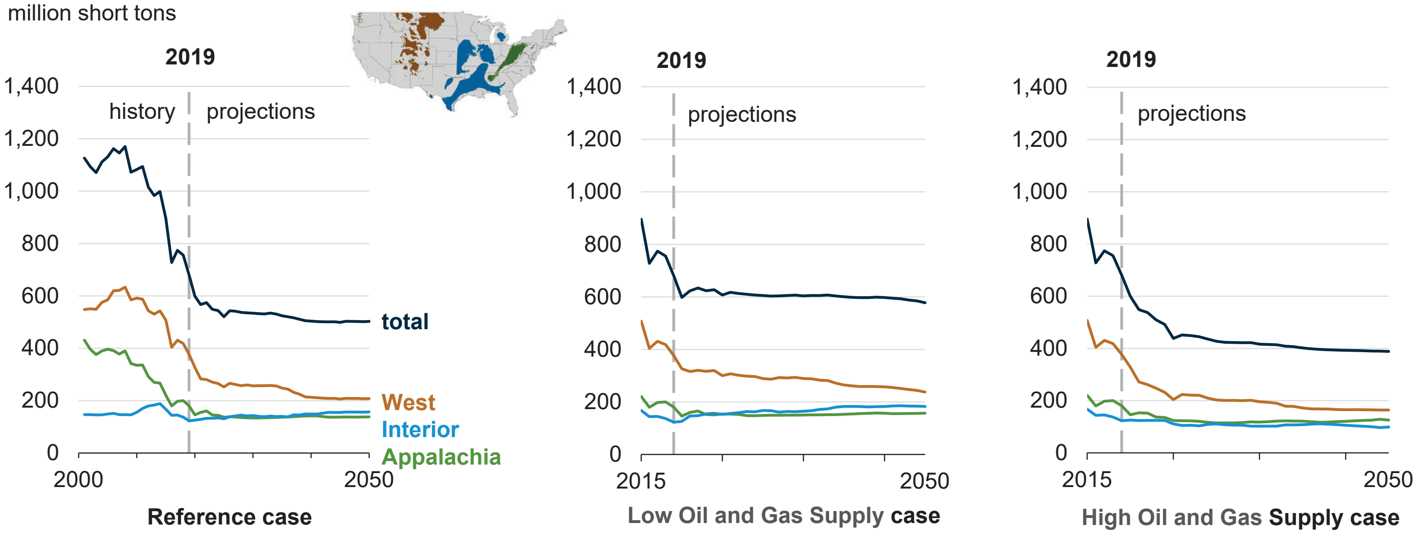
- Average capacity factors for coal-fired generating units improve over time as less-efficient units are retired, as heat rates in the remaining coal fleet improve to comply with the ACE rule, and as natural gas prices increase

- Between 2019 and 2025, coal-fired generation decreases by 26% in the Reference case while natural gas prices increase. By 2030, the utilization rate of the remaining coal-fired capacity returns to 65%, which is slightly less than in the early 2000s. In the High Oil and Gas Supply case, coal-fired generation decreases by 42% between 2019 and 2025, and lower natural gas prices limit the utilization rate of the coal fleet to about 60% in 2030.

- Higher natural gas prices in the Low Oil and Gas Supply case slow the pace of coal power plant retirements by about 23 GW through 2025 compared with the Reference case. The Low Oil and Gas Supply case has 155 GW of coal-fired capacity still in service in 2050. Conversely, lower natural gas prices in the High Oil and Gas Supply case increase coal-fired power plant retirements by 28 GW in 2025, and 96 GW of remaining coal-fired capacity remains by 2050.

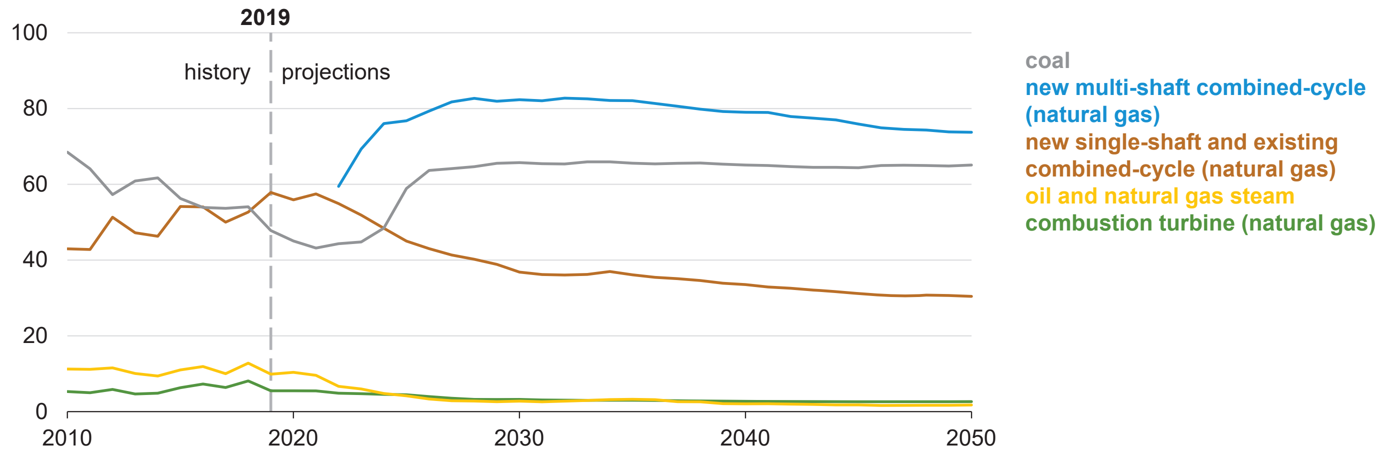
Coal production decreases through 2025 due to retiring coal-fired electric generating capacity, but federal rule compliance and higher natural gas prices lead to coal production leveling off afterwards

AEO2020 coal production by region
million short tons



Lower operating costs and higher efficiencies result in advanced natural gas-fired combined-cycle capacity factors of 80% by 2030 in the AEO2020 Reference case—

Capacity factor for fossil-fired plants (AEO2020 Reference case)
percent



—but then decline over time as natural gas prices increase and renewable generation grows

- Lower natural gas prices and reduced capital costs for new natural gas-fired combined-cycle generating units change fossil fuel electric generation use during the next decade in the AEO2020 Reference Case. Beginning in 2022—the first year of availability—new, multi-shaft (2 x 2 x 1 configuration) combined-cycle natural gas-fired units have the highest projected capacity factors of all technologies, averaging 81% between 2025 and 2035. The currently most common combined-cycle units, with their lower efficiency, and the new single-shaft (1 x 1 x 1 configuration) combined-cycle units decline in utilization as a group, from 56% in 2020 to 36% by 2035.

- After 2035, capacity factors for both combined-cycle technologies decline gradually, in part because large increases in intermittent generation through 2050 alter the dispatch patterns and requirements for fossil fuel-fired generation.

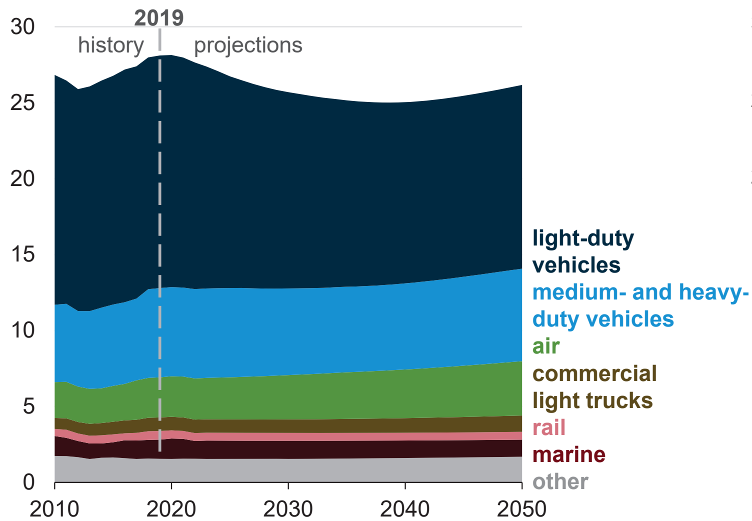
- The utilization rate of coal plants has fallen significantly in recent years as declining natural gas prices have led to a shift in economics between existing coal-fired and natural gas-fired combined-cycle generators. In 2019, the average capacity factor of the U.S. coal-fired fleet was 48% compared with an average natural gas-fired combined-cycle capacity factor of 58%. The low capacity factor for coal plants reflects a certain amount of idled inefficient capacity, which the Reference case projects will retire by 2025 as a result of the ACE rule. After 2025, the installed coal-fired capacity level is much lower because only the most efficient plants remain online. As a result, the average capacity factor for the fleet recovers quickly and stabilizes at about 65%.

Transportation

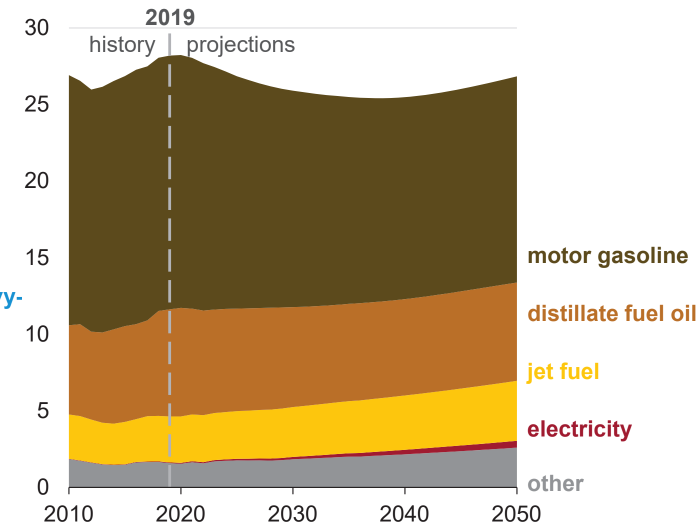
Transportation energy consumption peaks in 2020 in the AEO2020 Reference case because rising fuel efficiency more than offsets the effects of increases in total travel and freight movements, but this trend reverses toward the end of the projection period.

Transportation energy consumption declines through the 2030s in the AEO2020 Reference case—

Transportation sector consumption (by type)
(AEO2020 Reference case)
quadrillion British thermal units



Transportation sector consumption (by fuel)
(AEO2020 Reference case)
quadrillion British thermal units

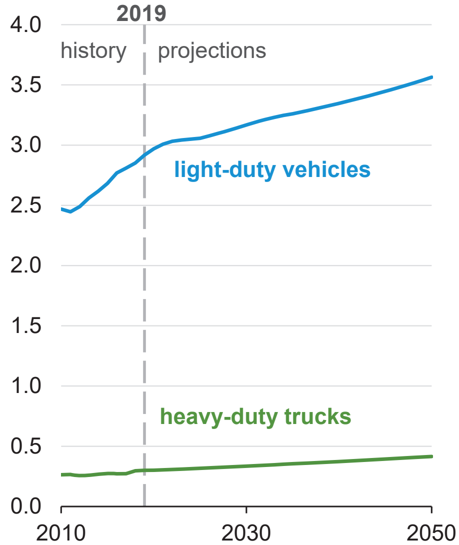


—because increases in fuel economy more than offset growth in vehicle miles traveled

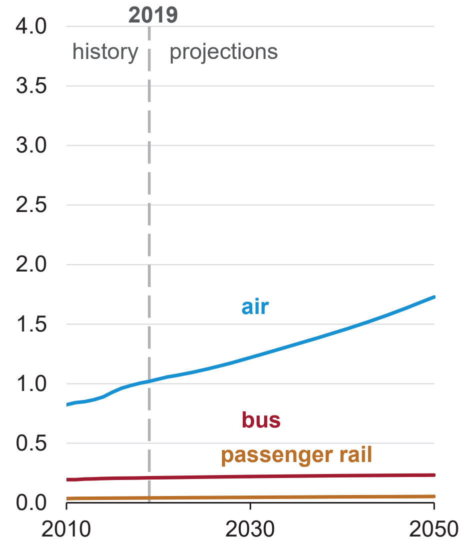
- Increases in fuel economy standards drive the decrease in U.S. motor gasoline consumption, which declines by 19% through 2050.
- Continued growth of on-road travel increases energy use later in the projection period because the travel demand for both light- and heavy-duty vehicles outpaces fuel economy improvements that result from regulatory requirements. Fuel efficiency regulations require no additional efficiency increases for new light-duty vehicles after 2025 and for new heavy-duty vehicles after 2027.
- Although increases in fuel efficiency standards slow growth in heavy-duty vehicle energy consumption and related diesel use, overall energy consumption for heavy-duty vehicles increases 4% through 2050 as a result of rising economic activity that increases demand for freight truck travel.
- Electricity is the fastest-growing energy source in the transportation sector, increasing on average 7.4% per year by 2050 as a result of increased demand for electric light-duty vehicles. Despite this growth, electricity accounts for less than 2% of transportation fuel consumption in 2050.
- Jet fuel consumption also increases through the projection period, rising 31% by 2050 because increases in air transportation outpace increases in aircraft fuel efficiency.
- Motor gasoline and distillate fuel oil's combined share of total transportation energy consumption decreases from 84% in 2019 to 74% in 2050.

Passenger travel increases across all transportation modes in the AEO2020 Reference case through 2050—

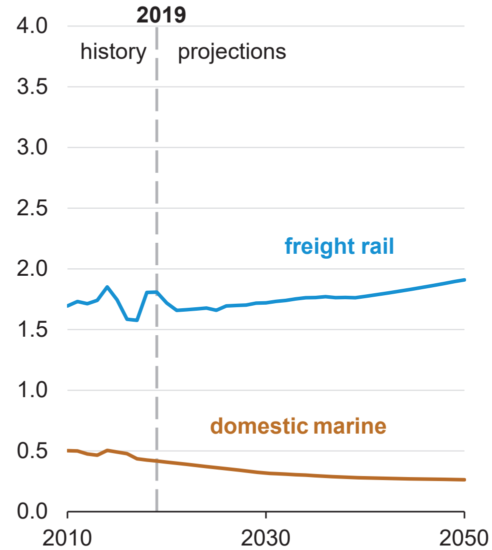
Vehicle travel
(AEO2020 Reference case)
trillion vehicle miles



Passenger travel
(AEO2020 Reference case)
trillion revenue passenger miles



Rail and domestic shipping
(AEO2020 Reference case)
trillion ton-miles traveled



—and freight movement increases across all modes except domestic marine

- Light-duty vehicle miles traveled increase by 22% in the AEO2020 Reference case, growing from 2.9 trillion miles in 2019 to 3.6 trillion miles in 2050 as a result of rising incomes and growing population.

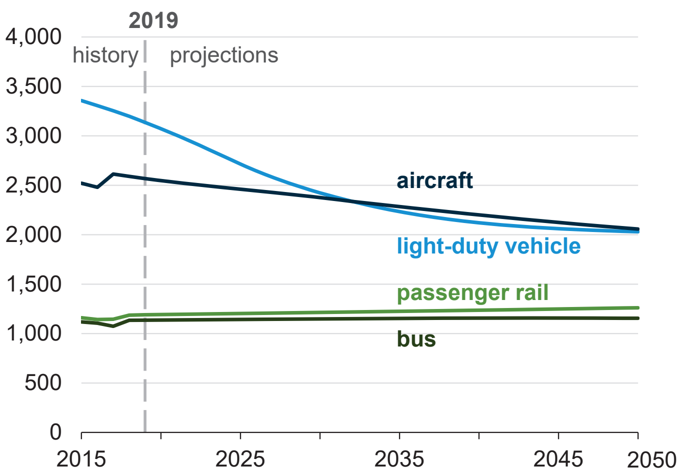
- Truck vehicle miles traveled, the dominant mode of freight movement in the United States, grow by 38%, from 300 billion miles in 2019 to 415 billion miles in 2050, as a result of increased economic activity. Freight rail ton-miles decline significantly in the early part of the projection period as a result of reduced U.S. coal shipments, but overall, freight rail ton-miles grow by 6% during the projection period, led primarily by rising industrial output.

- Air travel grows 70% from 1,020 billion revenue passenger miles to 1,729 billion revenue passenger miles through the projection period in the Reference case because of increased demand for global connectivity and rising personal incomes. Bus and passenger rail travel increase 11% and 30%, respectively.

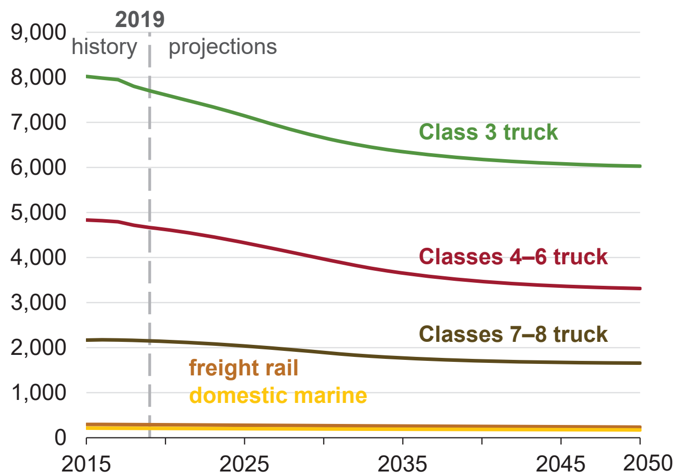
- Domestic marine shipments decline modestly during the projection period, continuing a historical trend related to logistical and economic competition with other freight modes.

Energy intensity decreases across most transportation modes in the AEO2020 Reference case—

Passenger mode energy intensity (AEO2020 Reference case)
British thermal units per passenger-mile



Freight mode energy intensity (AEO2020 Reference case)
British thermal units per ton-mile



—because of policy, economic, and technological factors

- Energy use per passenger-mile of travel in light-duty vehicles declines nearly 35% by 2050 in the AEO2020 Reference case as newer, more fuel-efficient vehicles enter the market, including both more efficient conventional gasoline vehicles and highly efficient alternatives such as battery electric vehicles. Energy efficiencies for light-duty vehicles are affected by current federal fuel economy and greenhouse gas emissions standards.

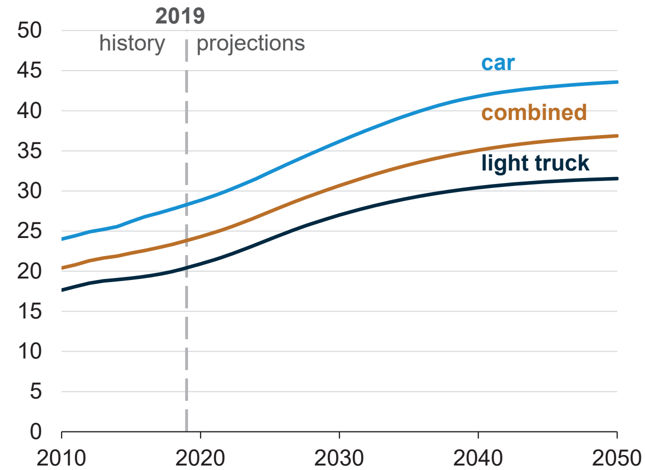
- Energy use per passenger-mile of travel in aircraft decreases because of the economically driven adoption of energy-efficient technology and practices. Energy use per passenger-mile of travel on passenger rail and buses, already relatively energy-efficient modes of travel per passenger-mile, remains relatively constant.

- Energy use per ton-mile of travel by freight modes decreases, led by increases in the fuel economy of heavy-duty trucks across all weight classes as the second phase of heavy-duty vehicle efficiency and greenhouse gas standards take full effect in 2027.

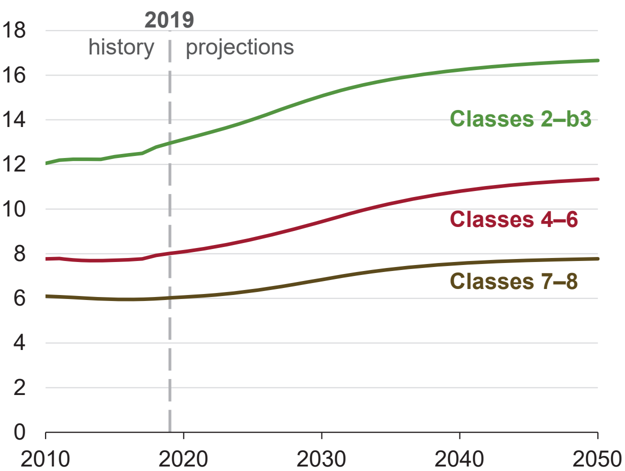
- Gains in energy efficiency offset increases in travel for passenger and freight modes. These efficiency gains decrease energy consumption by light-duty vehicles in the projection period and temper the rise in energy consumption by other transportation modes.

Fuel economy of all on-road vehicles increases in the AEO2020 Reference case—

Light–duty fuel economy (AEO2020 Reference case)
miles per gallon (all vehicles)



Heavy–duty fuel economy (AEO2020 Reference case)
miles per gallon (all vehicles)



—across all vehicle types throughout the projection period

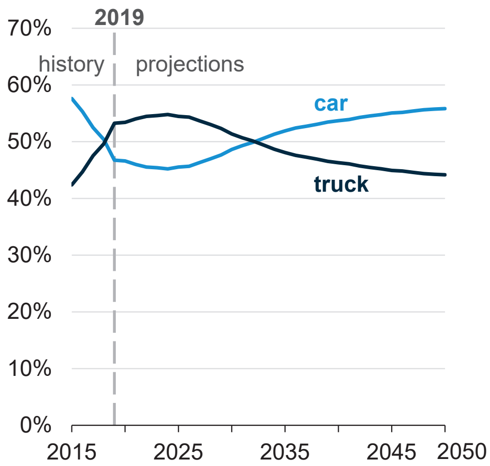
- Across all light-duty vehicles in use, fuel economy increases by 55% by 2050 in the AEO2020 Reference case as newer, more fuel-efficient vehicles enter the market and cars, which are more fuel efficient than light trucks, gain market share during the projection period. The fuel economy of cars increases from 28.3 miles per gallon (mpg) to 43.6 mpg, and the fuel economy for new light trucks increases from 20.4 mpg to 31.6 mpg.

- Fuel economy of the heavy-duty vehicles in use improves across all weight classes as the efficiency improvements required under the second phase of heavy-duty vehicle efficiency and greenhouse gas standards take full effect. Phase II of the heavy-duty vehicle efficiency and greenhouse gas standards reaches the maximum requirements in 2027. Heavy-duty vehicle fuel economy continues to improve as older vehicles are replaced with newer, more efficient vehicles.

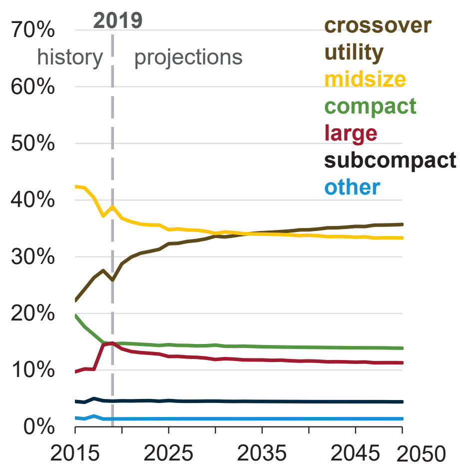
- Gains in fuel economy temper heavy-duty vehicle energy consumption growth and decrease light-duty vehicle energy consumption. For heavy-duty vehicles after 2040, increasing vehicle travel outweighs fuel economy improvements, leading to increases in fuel demand.

Sales of more fuel-efficient cars and light-truck crossover utility vehicles increase in the AEO2020 Reference case—

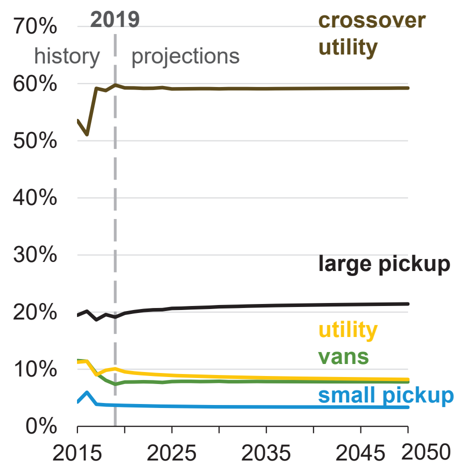
Light-duty vehicle sales shares (AEO2020 Reference case)
percent



Car sales shares by size class (AEO2020 Reference case)
percent



Light truck sales shares by size class (AEO2020 Reference case)
percent



—but other vehicle types maintain significant market share through 2050

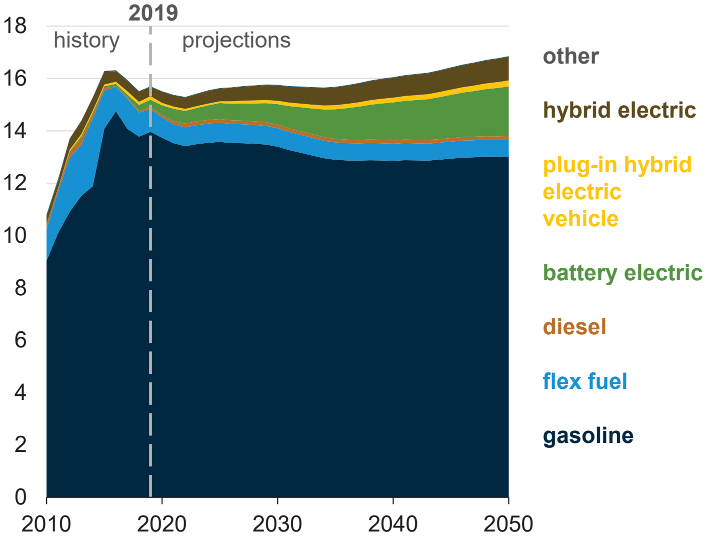
- In the AEO2020 Reference case, passenger cars gain market share in the light-duty vehicle market relative to light-duty trucks because they have higher fuel efficiency in periods when motor gasoline prices increase. They also gain market share because crossover utility vehicles, often classified as passenger cars, may replace lower fuel economy light-truck classified utility vehicles as a result of increasing availability and popularity.

- Light trucks lose some of their share in the light-duty vehicle market, and in terms of number of units sold, the classifications within light trucks shift from traditional vans and utility vehicles toward crossover utility vehicles that have higher fuel economy.

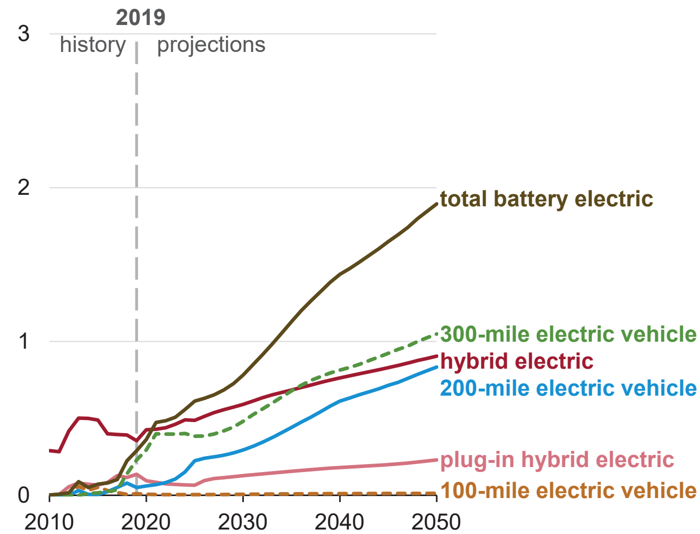
- Combined car and light-truck classified crossover utility vehicles reach 46% of new light-duty vehicle sales in 2050, largely taking away sales from traditional compact, midsize, and large cars and from truck-based sport utility vehicles.

Alternative and electric vehicles gain market share in the AEO2020 Reference case—

Light-duty vehicle sales by fuel type (AEO2020 Reference case)
millions of vehicles



New vehicle sales of battery powered vehicles (AEO2020 Reference case)
millions of vehicles



—but gasoline vehicles remain the dominant vehicle type through 2050

- The combined share of sales from gasoline and flex-fuel vehicles (which use gasoline blended with up to 85% ethanol) declines from 94% in 2019 to 81% in 2050 in the AEO2020 Reference case because of growth in sales of battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV), and hybrid electric vehicles. BEV sales increase faster than any other type of vehicle sale, growing on average by 6% per year.

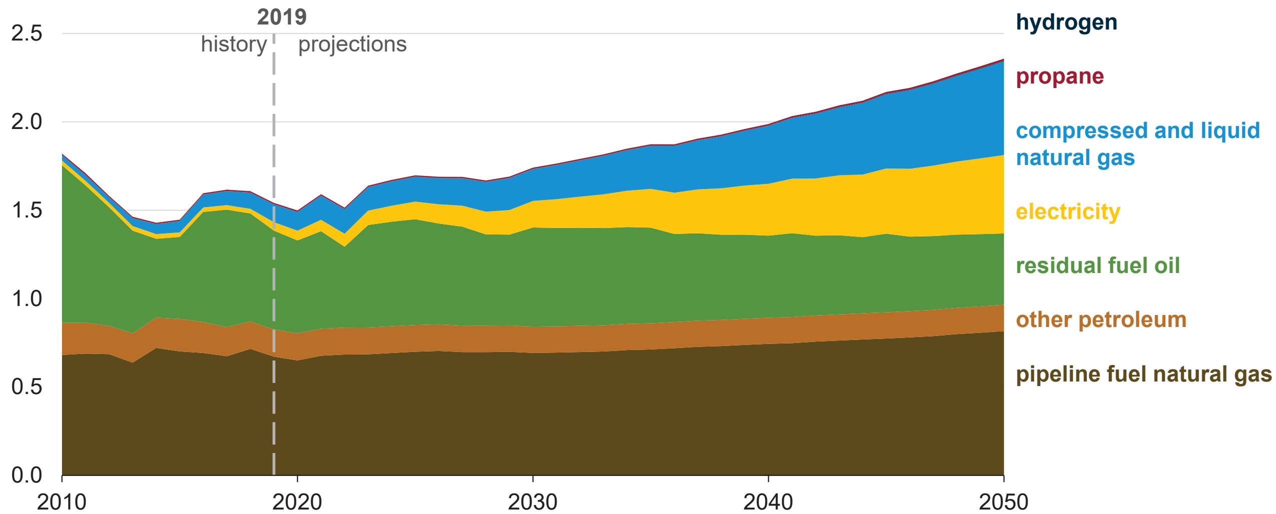
- Sales of the longer-ranged 200- and 300-mile BEVs grow during the entire projection period, tempering sales of the shorter-range 100-mile BEV and PHEV. Sales for the 200- and 300-mile BEVs increase from 280,000 in 2019 to 1.9 million in 2050, while sales of PHEVs increase from 137,000 in 2019 to 230,000 in 2050.

- Hybrid electric vehicle sales increase 3.1% per year, rising to more than 900,000 new vehicles sold by the end of the projection period.

- New light-duty vehicles of all fuel types show significant improvements in fuel economy because of compliance with increasing fuel economy standards. Light-duty vehicle fuel economy rises by 55% through the projection period.

Consumption of transportation fuels grows considerably in the AEO2020 Reference case through the projection period—

Transportation sector consumption of minor petroleum and alternative fuels (AEO2020 Reference case)
quadrillion British thermal units



—because of increased use of electricity and natural gas

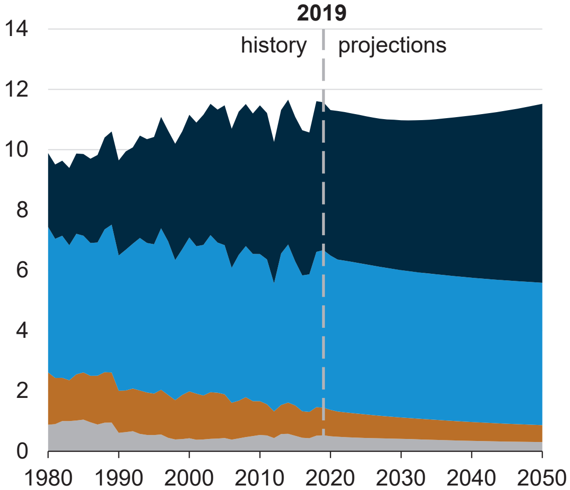
- Electricity use in the transportation sector increases sharply after 2020 in the AEO2020 Reference case because of a rise in the sale of new battery-electric and plug-in hybrid-electric light-duty vehicles.
- Natural gas consumption increases through 2050 because natural gas is increasingly used as a fuel for heavy-duty vehicles and freight rail.
- In the later years of the projection period, liquefied natural gas is used in the maritime industry as an alternative to burning high-sulfur residual fuel oil to meet the new standards set for marine fuels under the International Convention for the Prevention of Pollution from Ships (MARPOL convention).

Buildings

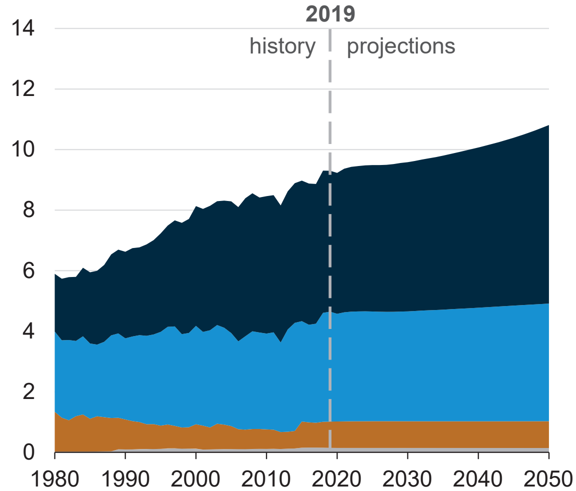
Delivered energy consumption in the U.S. buildings sector grows gradually from 2019 to 2050 in the Reference case, based, in part, on currently established efficiency standards and incentives. EIA anticipates distributed solar capacity to grow throughout the projection period based on near-term incentives, declining costs, and demographic factors.

Residential and commercial energy consumption grows slowly in the AEO2020 Reference case—

Residential sector delivered energy consumption (AEO2020 Reference case)
quadrillion British thermal units



Commercial sector delivered energy consumption (AEO2020 Reference case)
quadrillion British thermal units



electricity **natural gas** **petroleum and other liquids** **other**

—accounting for changes to energy efficiency standards and technological advances

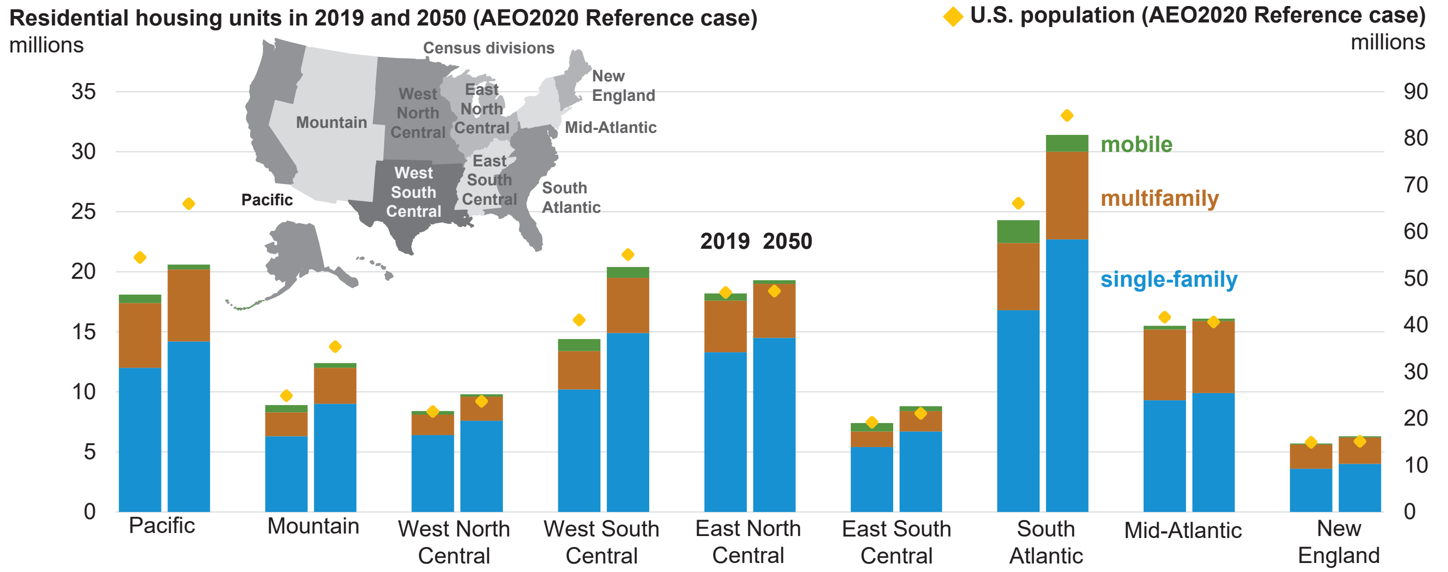
- Total delivered energy consumption in the U.S. buildings sector grows slowly through the AEO2020 Reference case projection period, 2019 to 2050, by 0.2% per year, as energy efficiency improvements, increases in distributed electricity generation, and regional shifts in the population partially offset the impacts of higher growth rates in population, number of households, and commercial floorspace.

- Purchased electricity consumption grows in both the residential and commercial sectors as a result of increased demand for appliances, devices, and equipment that use electricity. In the Reference case, purchased electricity increases by 0.6% and 0.8% per year in the residential and commercial sectors, respectively, through 2050.

- Natural gas consumption by commercial buildings grows by 0.2% per year through the projection period, led by increases in water heating and cooking. Consumption of natural gas in the residential sector falls by 0.3% per year as its use for space heating continues to decline.

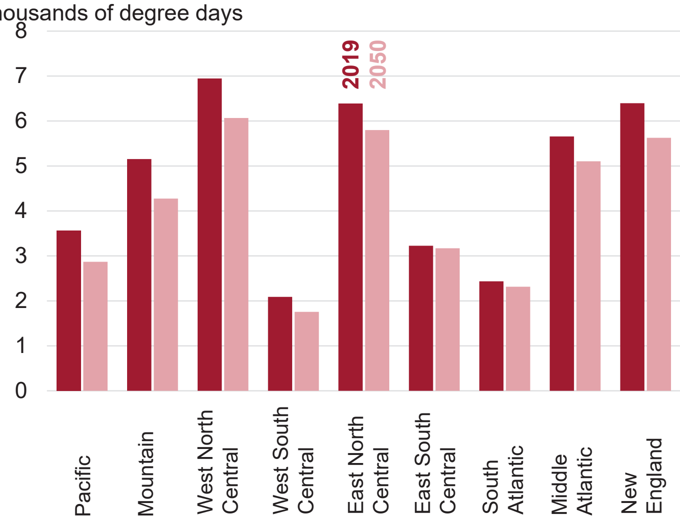
- If not for the contribution of distributed generation sources, particularly rooftop solar, purchased electricity consumption in residential and commercial buildings would be 5% and 3% higher, respectively, by the end of the projection period.

Population and residential housing stocks continue to grow mostly in the South and West between 2019 and 2050

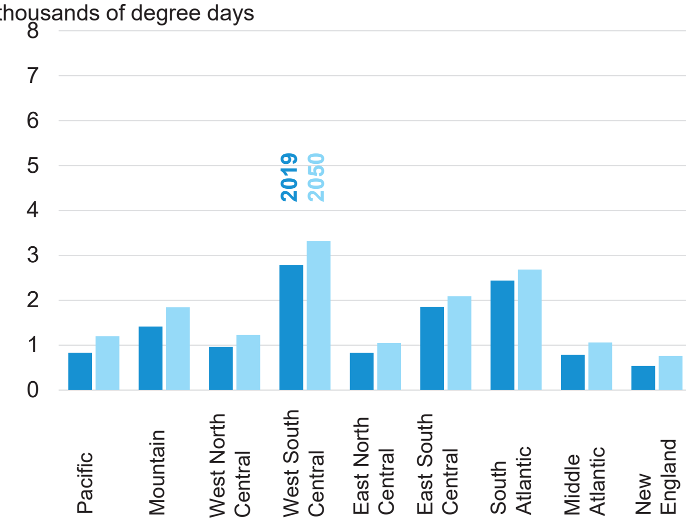


As a result of population shifts, overall U.S. heating needs decrease and cooling needs increase—

Population-weighted heating degree days by census division (AEO2020 Reference case)
thousands of degree days



Population-weighted cooling degree days by census division (AEO2020 Reference case)
thousands of degree days

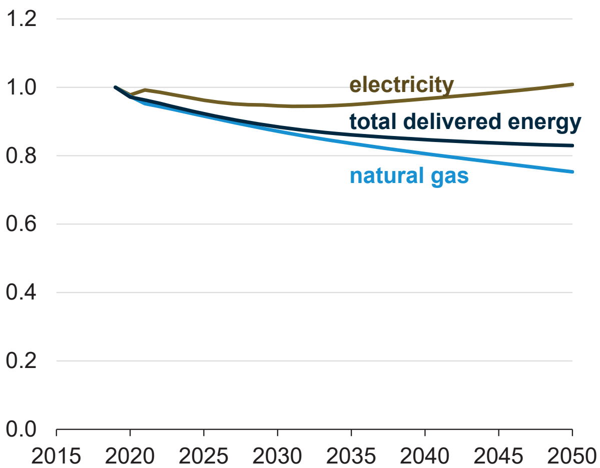


—especially in warmer regions with higher space cooling demand

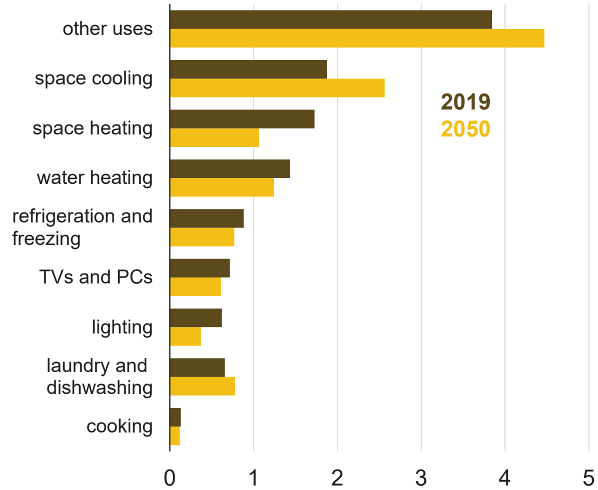
- The number of U.S. households increases by an average of 0.6% per year in the AEO2020 Reference case through 2050, and single-family homes grow the fastest, at 0.7% per year. The stock of multifamily homes grows at a rate of 0.6% per year, while mobile home stocks decrease by 1.2% per year and are the only category EIA does not expect to grow.
- Cooling-dominated West South Central and South Atlantic Census Divisions—as well as the Mountain Census Division—experience average annual housing stock growth that exceeds the national average. 12.2 million housing units are added across these areas by 2050.
- The size of housing units also continues to grow; the national average floorspace per home increases 0.3% per year from 1,786 square feet in 2019 to 1,987 square feet in 2050.
- Demand for space heating from fuels such as natural gas, distillate fuel oil, propane, and electricity decreases through 2050 as a result of fewer heating degree days (HDDs)—a measure of how cold a location is over a time period relative to a base temperature.
- Demand for space cooling from electricity increases through 2050 as a result of more cooling degree days (CDDs)—a measure of how warm a location is over a time period relative to a base temperature.
- EIA uses historical and near-term forecast HDDs and CDDs sourced from the National Oceanic and Atmospheric Administration. EIA uses this historical data and population projections to develop a 30-year linear trend for projecting population-weighted HDDs and CDDs.

U.S. residential energy intensity decreases in the AEO2020 Reference case—

Residential delivered energy intensity index (AEO2020 Reference case)
indexed annual energy use per household, 2019 = 1.0



Residential purchased electricity intensity (AEO2020 Reference case)
thousand kilowatthours per household



—although changes in electricity consumption vary by end use

- In the AEO2020 Reference case, U.S. total delivered residential energy intensity, defined as annual delivered energy use per household, decreases by 17% between 2019 and 2050 as the number of households grows faster than energy use. The main factors contributing to this decline include gains in appliance efficiency, onsite electricity generation (e.g., solar photovoltaic), utility energy efficiency rebates, rising residential natural gas prices, lower space heating demand, and a continued population shift to warmer regions.

- Lighting electricity consumption per U.S. household declines faster than other electric end uses as a result of compliance with the minimum performance requirements of the Energy Independence and Security Act of 2007. The federal standards effectively eliminate low-efficacy incandescent lamps, replacing them with more energy-efficient light-emitting diodes (LEDs) and compact fluorescent lamps (CFLs) by 2020. Energy efficiency incentives also accelerate LED and CFL penetration before 2020. In 2050, purchased electricity intensity for lighting is 40% lower than in 2019.

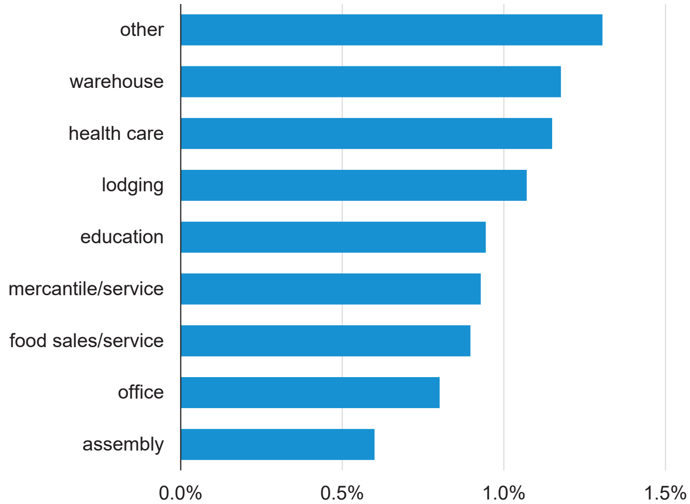
- As near-term appliance standards result in efficiency gains beyond those gains caused by market forces and technological change, electricity intensity declines before 2030 and then increases slightly as sector growth overtakes additional efficiency gains.

- Natural gas and electric equipment increasingly replace distillate fuel oil- and propane-fired equipment.

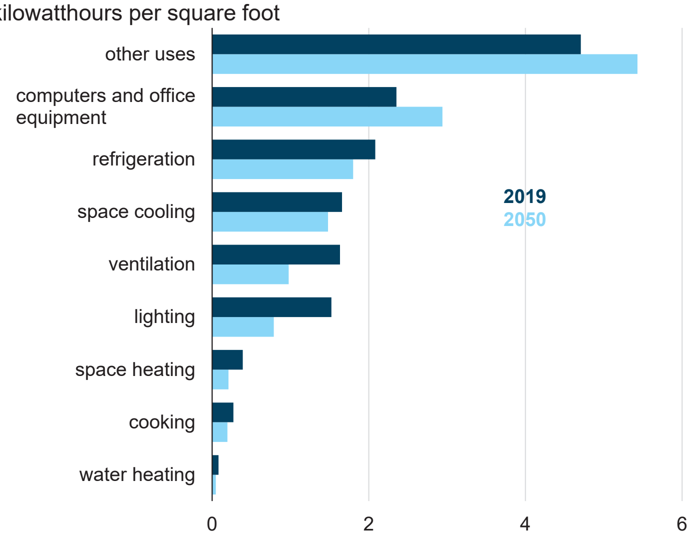
- Electricity intensity of other uses increases throughout the projection period with expected growth in the use of electronic equipment, such as security systems and rechargeable devices.

AEO2020 Reference case U.S. commercial energy consumption growth is tempered by increased equipment and lighting efficiencies—

Commercial floorspace growth (AEO2020 Reference case)
percent compound annual growth rate



Commercial purchased electricity intensity (AEO2020 Reference case)
kilowatthours per square foot

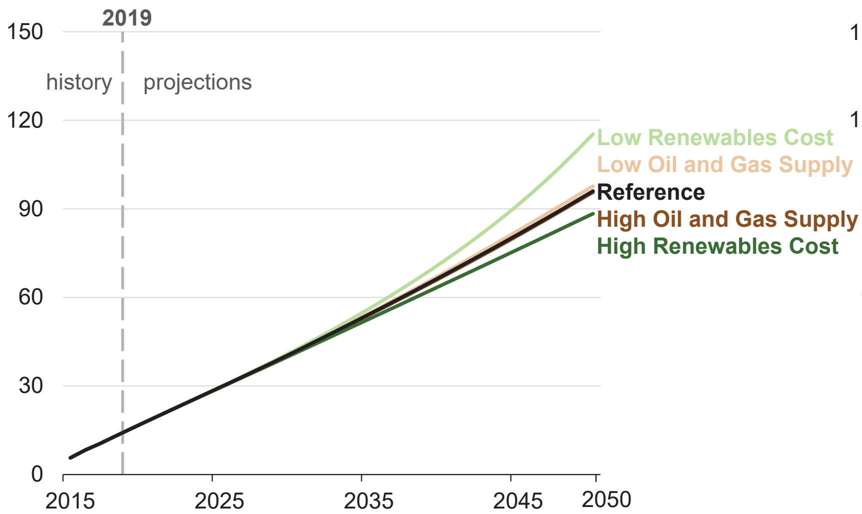


—but growing floorspace, declining electricity prices, and expanding information technology needs drive an overall increase in electricity consumption

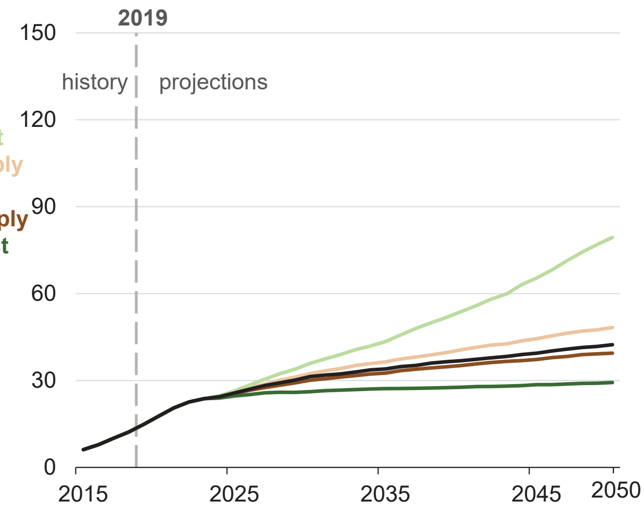
- Commercial floorspace grows by an average 1% per year in the AEO2020 Reference case through the projection period, reflecting rising economic activity. Some of the fastest-growing building types, including health care and lodging, are also among the most energy intensive.
- Commercial electricity intensity, defined as electricity consumption per square foot of commercial floorspace, declines at an average of 0.2% per year through the projection period. Combined with floorspace growth, the decline in intensity results in an overall increase in electricity consumption of 0.8% per year.
- Lighting accounts for the steepest intensity decline among the major end uses, falling by more than 2% per year throughout the projection period. Lower costs and energy efficiency incentives lead efficient LEDs to displace linear fluorescent lighting as the dominant commercial lighting technology by 2030. Similarly, intensities for major end uses such as ventilation, space heating and cooling, and refrigeration decline over time. However, other uses such as office equipment (not including computers), whose electricity intensity increases by 1.6% per year, counterbalance these declines.
- Despite increasing equipment efficiencies, declining electricity prices encourage greater use of energy-consuming appliances and devices.

Rooftop solar PV adoption grows between 2019 and 2050—

Residential solar distributed generation capacity
gigawatts direct current



Commercial solar distributed generation capacity
gigawatts direct current

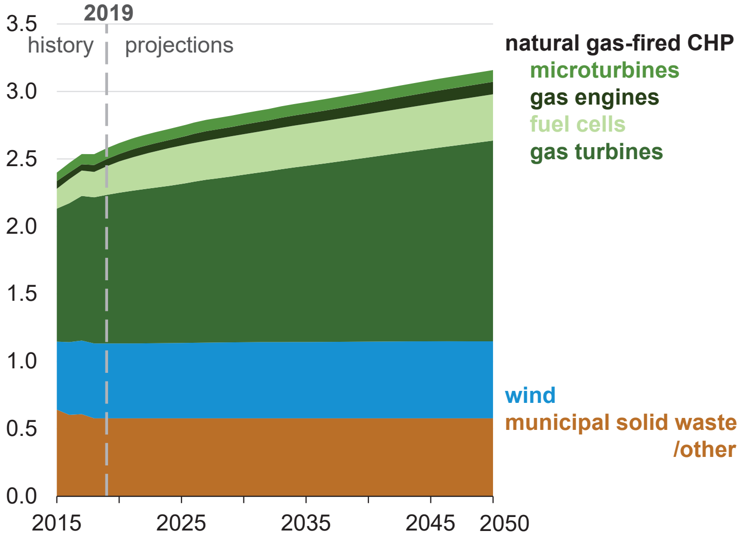


—with residential growth outpacing commercial growth in later years

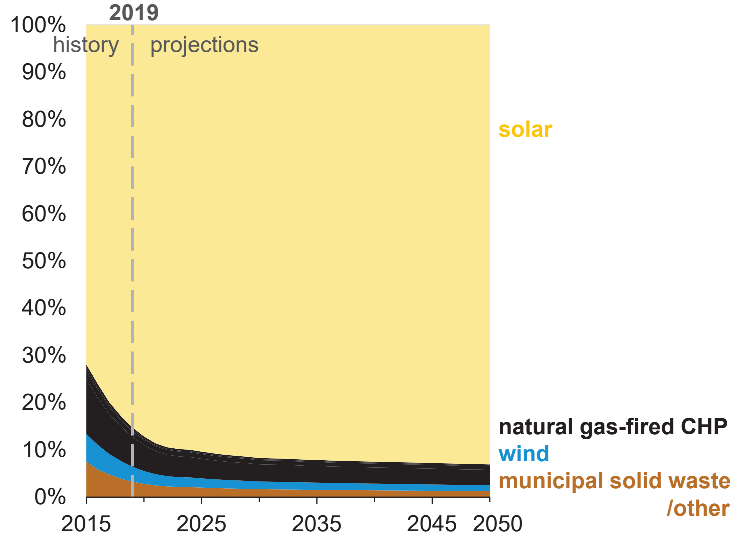
- Residential solar photovoltaic (PV) capacity increases by an average of 6.1% per year through 2050 in the AEO2020 Reference case, and commercial PV capacity increases by an average of 3.4% per year.
- PV costs decline most rapidly before 2030, despite the phasedown in the federal Energy Investment Tax Credit (ITC) from 30% in 2019 to 10% in 2022 and the four-year Section 201 tariff levied on PV cells and modules in 2018.
- Declining installation costs drive steady commercial PV adoption, although capacity growth slows after 2030. Rising incomes, declining system costs, and social influences accelerate residential PV adoption.
- For both residential and commercial sectors, the High Renewables Cost case and Low Renewables Cost case vary the most from the Reference case. Commercial PV projections are particularly responsive to variations in installed cost; a spread of 50 GW between the Low Renewables Cost case and High Renewables Cost case is projected in 2050.
- PV growth is also sensitive to electricity prices. In 2050, electricity prices vary the most from the AEO2020 Reference case in the Low Oil and Gas Supply case, by 9.7% and 9.2% for the residential and commercial sectors, respectively. In response, residential PV capacity increases by 1.7% and commercial PV capacity increase by 14% relative to the AEO2020 Reference case.

Combined heat and power (CHP) and other non-solar sources of electric generation account for 15% of commercial onsite capacity in 2019 in the AEO2020 Reference case—

Commercial non-solar distributed generation capacity (AEO2020 Reference case)
gigawatts direct current



Commercial distributed generation capacity (AEO2020 Reference case)
percent

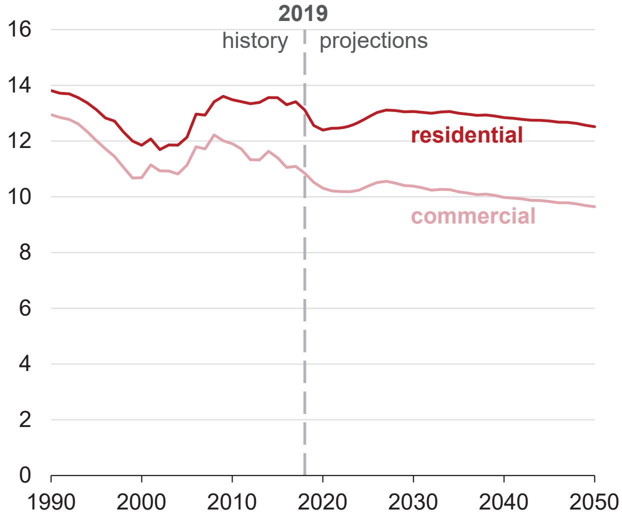


—but this share declines during the projection period as growth lags behind solar photovoltaic generation

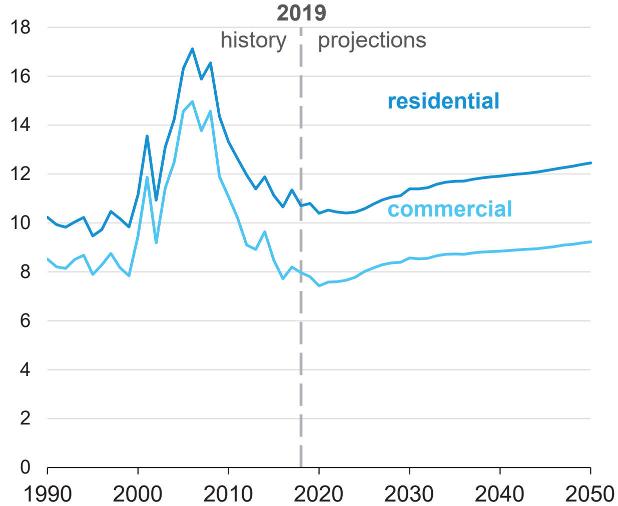
- Non-photovoltaic technologies, such as combined heat and power (CHP) and distributed wind, account for 15% of commercial distributed generation capacity in 2019 but only 7% by 2050 in the AEO2020 Reference case.
- Of the non-solar technologies, natural gas-fired CHP (namely, microturbine, reciprocating engine, fuel cell, and conventional turbine) capacity expands the fastest at an average of 1.1% per year. Incremental installed cost declines and performance improvements drive this growth, despite rising commercial natural gas prices, which increase by 0.5% per year through the projection period.
- The 2018 Bipartisan Budget Act extends the ITC provisions for qualifying CHP beginning construction before January 1, 2022. These tax credits contribute to growth in CHP in the short term.
- Wind generation capacity projections remain flat in AEO2020, in part, because of a lack of commercial mid-scale turbines (101 kilowatts to 1 megawatt) available in the U.S. market. The majority of recent commercial wind installations use large-scale turbines—the average in 2018 was 2.1 megawatts—but the commercial sector market potential for these larger turbines is limited.

Residential and commercial electricity prices decline slightly in the AEO2020 Reference case through 2050

Electricity prices (AEO2020 Reference case)
2019 cents per kilowatthour



Natural gas prices (AEO2020 Reference case)
2019 dollars per thousand cubic feet



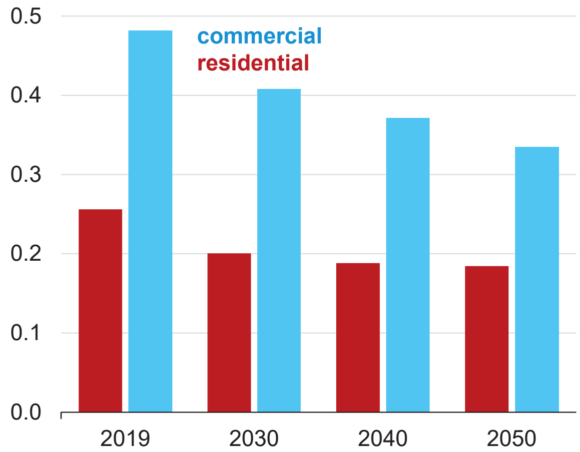
—while natural gas prices rise, moderating natural gas consumption

- AEO2020 Reference case electricity prices fall in the near term, primarily because utilities pass along savings from lower taxes under the Tax Cuts and Jobs Act of 2017. In addition, utilities are replacing more costly power plants with new plants that are less expensive to construct and operate, which also contributes to lower prices. Lower prices encourage more consumption in the near term in both sectors, although near-term efficiency standards and population shifts to warmer areas of the country moderate this trend.

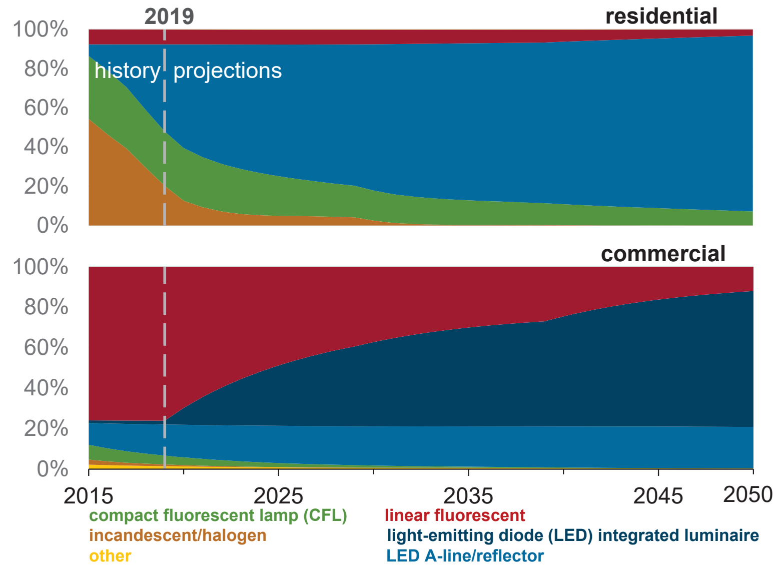
- Natural gas prices in both the residential and commercial sectors increase steadily, by an average of 0.5% per year, in the Reference case through 2050. Increasing natural gas prices decrease consumption in the residential sector and moderate consumption growth in the commercial sector.

Energy consumed to meet lighting needs decreases in the AEO2020 Reference case –

Delivered electricity consumed to meet lighting demand (AEO2020 Reference case)
quadrillion British thermal units



Lighting shares (AEO2020 Reference case)
percent



—driven by federal efficiency standards, declining upfront costs, and utility and state energy efficiency program incentives

- In 2019, 44% of residential light bulbs were LEDs, currently the most efficient light bulb technology available, and 17% of commercial lighting service demand was met by LED bulbs and fixtures. By 2050, these shares increase to 90% and 88%, respectively.

- Utility energy efficiency program incentives drive LED adoption in the AEO2020 Reference case during the short to medium term, reducing the upfront cost of purchasing LEDs by up to 40% until 2019. EIA assumes residential lighting subsidies will fall to 0% in 2020, but efficiency incentives continue to drive commercial adoption of LED lighting through 2029.

- Efficiency requirements under the Energy Independence and Security Act of 2007 eliminate inefficient incandescent bulbs from general service lighting (GSL) use after 2020, causing homes and businesses to switch to more efficient LED and CFL bulbs. Although we incorporate a U.S. Department of Energy final rule that narrows the definition of GSLs, about two-thirds of residential lighting falls under the revised definition.

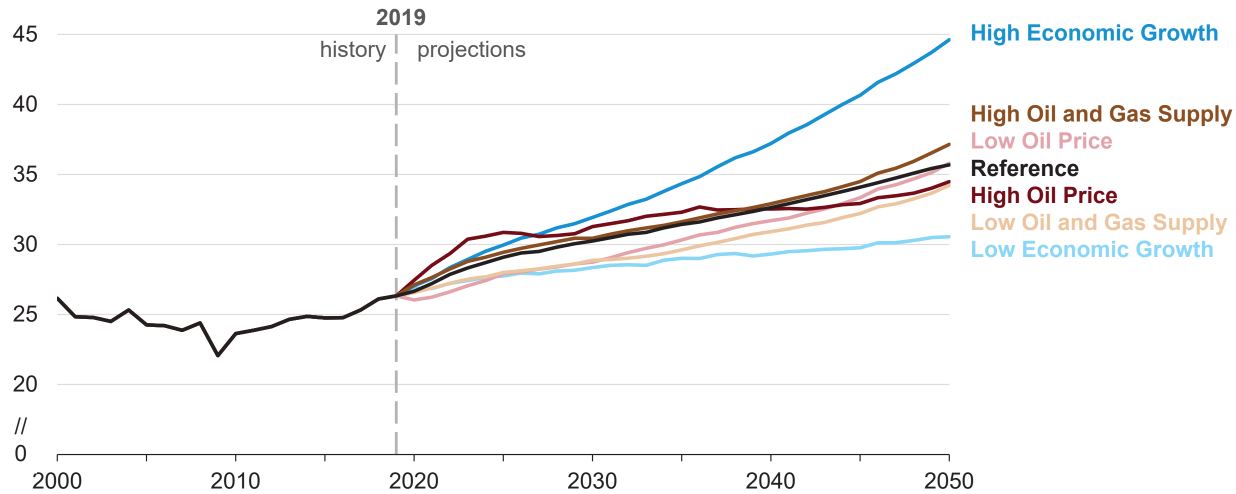
- Cost declines in LEDs drive expanded market share throughout the projection period. During the projection period, the AEO2020 shows the installed cost of residential GSL LEDs declines by 33% and the cost of commercial LED luminaires declines by up to 74%.

Industrial

As a result of projected economic growth and lower domestic energy prices relative to the world market, AEO2020 projects that energy consumption in the U.S. industrial sector will increase during the projection period across all cases. U.S. consumption of most energy sources, particularly natural gas, will increase significantly. Coal consumption, which flattens after 2020, is the only exception. Energy intensity declines across all cases as a result of technological improvements.

Consumption of delivered industrial energy grows in all AEO2020 cases—

AEO2020 industrial delivered energy consumption
quadrillion British thermal units

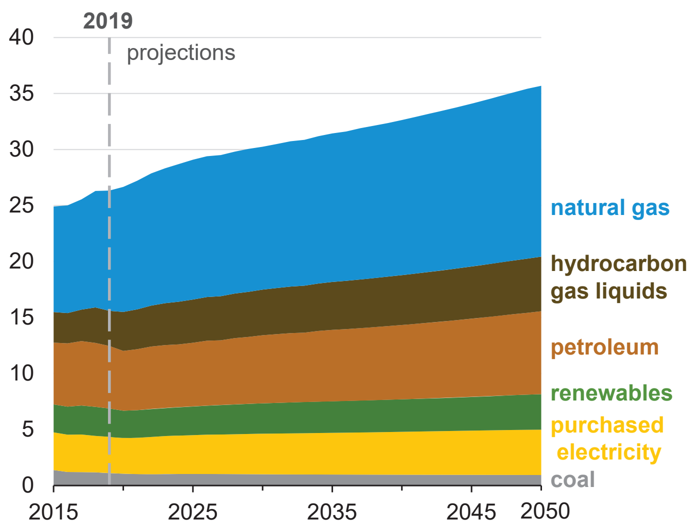


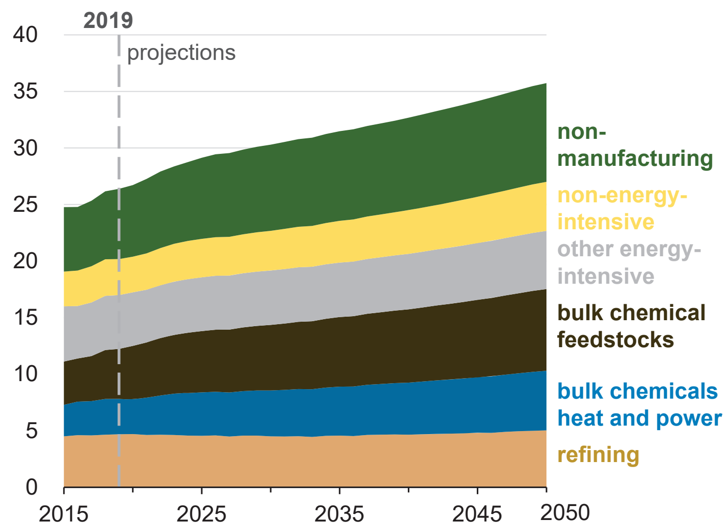
—driven by economic growth, but it is also affected by low prices and resource availability

- In the AEO2020 Reference case, U.S. delivered energy consumption in the industrial sector grows 36% from 26 quadrillion British thermal units (Btu) to 36 quadrillion Btu during the projection period.
- Industrial activity is closely correlated with economic activity. Therefore, changes in assumptions related to economic growth affect industrial sector energy consumption the most. The High Economic Growth case and the Low Economic Growth case vary the most from AEO2020 reference case projections of U.S. industrial sector energy consumption.
- Through the late 2020s, the High Oil Price case projects the fastest growth in industrial sector energy demand as a result of increased investment in the short term for more mining/oil extraction equipment and related activities (construction, cement, steel for drilling equipment, etc.). Eventually, higher oil prices dampen consumer spending in the long run, thereby lowering growth.
- Over the long term, industrial energy consumption is highest in the High Economic Growth case, reaching 45 quadrillion Btu in 2050, a 69% increase from 2019. With a faster growing economy, greater industrial activity in sectors such as food and fabricated metal products increases industrial energy use.
- Energy consumption in the High Oil and Gas Supply case is greater than in the Reference case as a result of increased crude oil and natural gas resources and improved extraction technologies that increase energy demand in the mining industry.

Industrial sector energy consumption increases fastest for natural gas and hydrocarbon gas liquids in the AEO2020 Reference case—

Industrial energy consumption by energy source and subsector (AEO2020 Reference case)
quadrillion British thermal units





—and bulk chemicals and nonmanufacturing are the fastest-growing industries in the sector

- Total U.S. industrial delivered energy consumption grows 1.0% per year on average during the projection period in the AEO2020 Reference case. Growth varies by fuel. EIA projects coal consumption to decline through the projection period, while natural gas and hydrocarbon gas liquids (HGL) consumption will grow fastest, reflecting strong supply growth and relatively low prices.

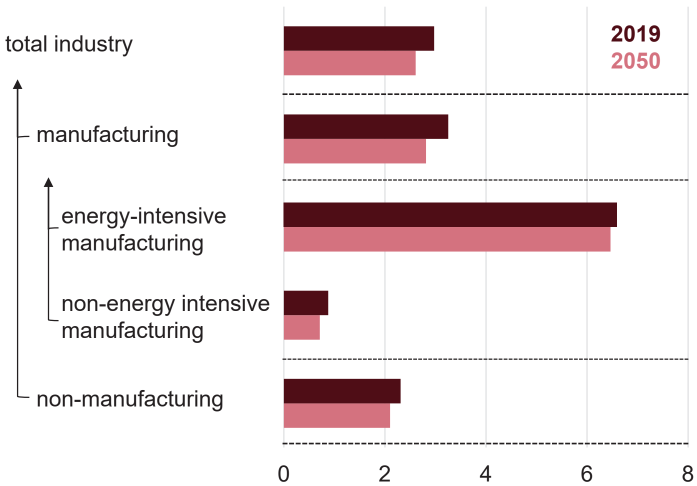
- During the projection period, industrial sector HGL consumption grows by 1.4% per year and natural gas consumption grows by 1.1% per year, as these fuels become more heavily used for heat and power and as feedstocks.

- Energy consumption in the bulk chemicals industry, including both heat and power and feedstocks, accounts for about 35% of total U.S. industrial energy consumption by the end of the projection period and grows at 1.6% per year.

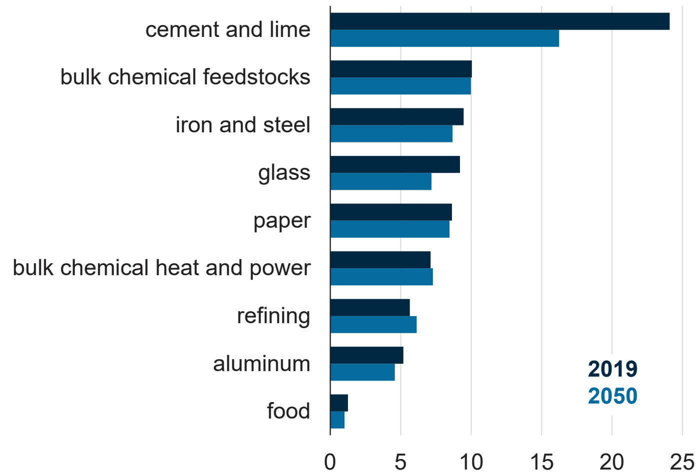
- Energy consumption in the other energy-intensive industries in the United States remains relatively flat during the projection period, growing on average 0.3% per year. Energy consumption in the iron and steel industry declines by 19% during the projection period, energy consumption in the paper industry increases by 11%, and energy consumption in the cement and lime industry consumption stays relatively flat.

In the AEO2020 Reference case, energy intensities decline in most heavy industries—

Energy intensity by subsector (AEO2020 Reference case)
trillion British thermal units per billion 2012 dollar shipments



Energy-intensive manufacturing (AEO2020 Reference case)
trillion British thermal units per billion 2012 dollar shipments



—reflecting industrial capital stock turnover and adoption of new, more energy-efficient technologies

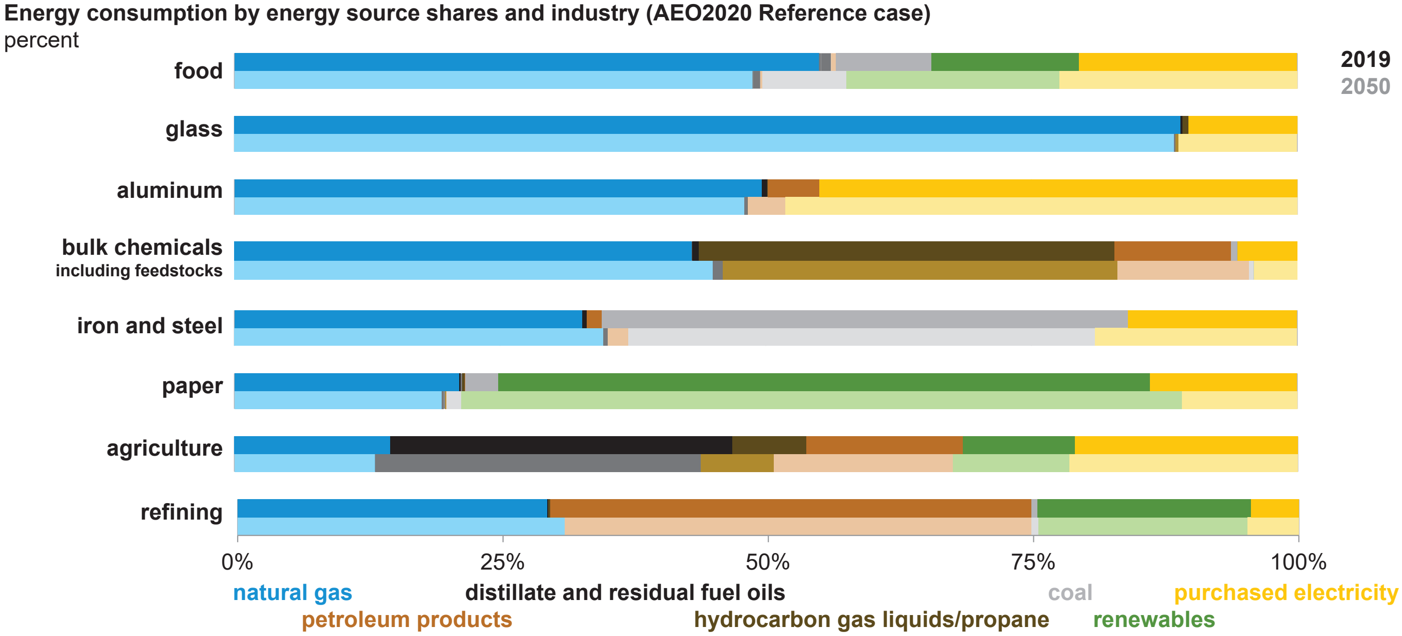
- Energy intensity in the U.S. industrial sector (energy consumption per dollar of output) declines by 0.4% per year on average through 2050 in the AEO2020 Reference case. In manufacturing, energy intensity declines 0.5% per year through the projection period as a result of the increased energy efficiency of new capital equipment and the faster growth rate in non-energy-intensive manufacturing industries relative to energy-intensive manufacturing industries.

- Energy intensities in the refining sector and in the bulk chemical heat and power sector both increase as relatively low-cost natural gas increases production of lower-value commodities.

- Higher energy intensities in the refining sector and bulk chemical sector are offset by efficiency improvements in other energy-intensive industries, such as food (0.7% per year decline in energy intensity), glass (0.8% decline per year), and cement and lime (1.3% decline per year). The net result is an overall 2% decline in energy intensity for the energy-intensive manufacturing industries sector during the projection period.

- For some industries, large amounts of combined heat and power generation (CHP) may mask some efficiency gains. EIA includes CHP generation losses in industry energy consumption. Purchased electricity generation losses are accounted for in the electricity sector.

AEO2020 Reference case energy consumption by fuel varies across energy-intensive industries—

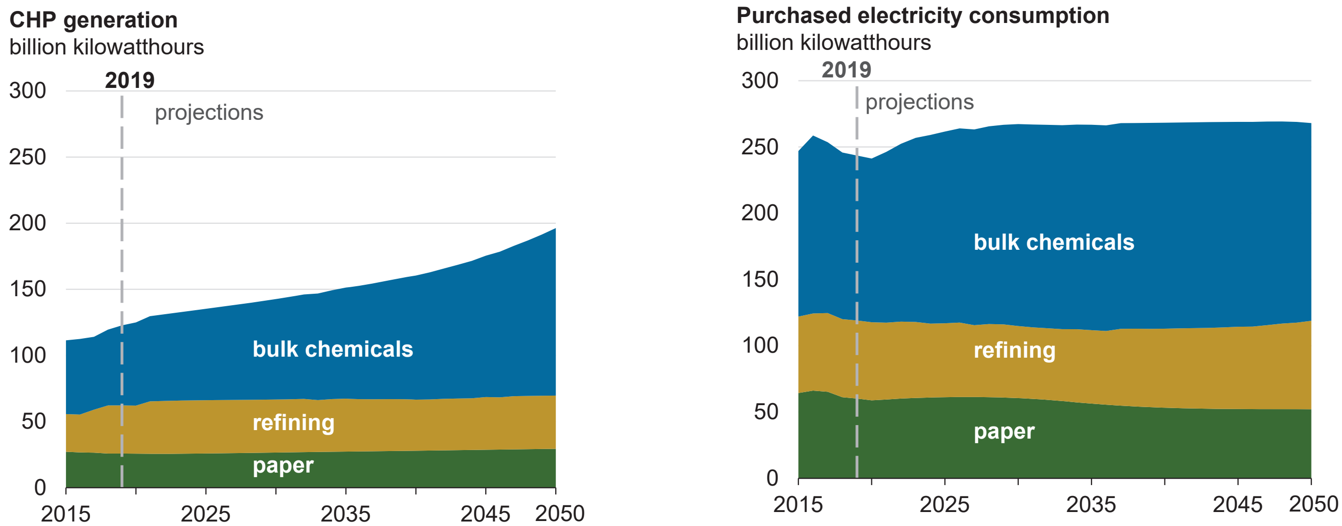


—because some industries have greater capacity for fuel switching than others

- Natural gas (used primarily for process heat) remains the primary fuel in the U.S. food and glass industries in the AEO2020 Reference case, although its share declines through 2050. In the food industry, the share of renewables grows from 14% in 2019 to 20% in 2050. In the glass industry, natural gas continues to have the largest share, retaining more than an 88% share through the projection period.
- In the U.S. iron and steel industry, coal remains the primary fuel, although its share in the total energy mix for the sector declines from 50% in 2019 to 44% in 2050 as natural gas and electricity-fueled technologies become more widely used.
- The bulk chemicals industry consumes natural gas and HGLs for both heat and power and feedstock. The relatively low projected prices for both fuels result in continued high shares of total energy consumption and reduced shares of purchased electricity as CHP adoption grows.
- In the United States, in addition to the food industry and, to some extent, refining (where bio-based feedstocks are used to produce blend-stocks for the transportation fuels sector), one of the highest shares of renewables consumption is in the paper industry, where black liquor (a byproduct of the pulping process) serves as a major fuel for boilers and on-site CHP. The renewables share of total energy consumed in the paper industry increases from 61% in 2019 to 68% in 2050.
- Petroleum remains the primary fuel for refining and for agriculture, where distillate fuels most of the on-field equipment.

Self-generation from combined heat and power (CHP), especially for bulk chemicals, accounts for most AEO2020 Reference case growth in industrial sector electricity consumption—

CHP generation and purchased electricity consumption for U.S. industries with the most installed CHP (AEO2020 Reference case)



—as quantities of purchased electricity remain fairly flat

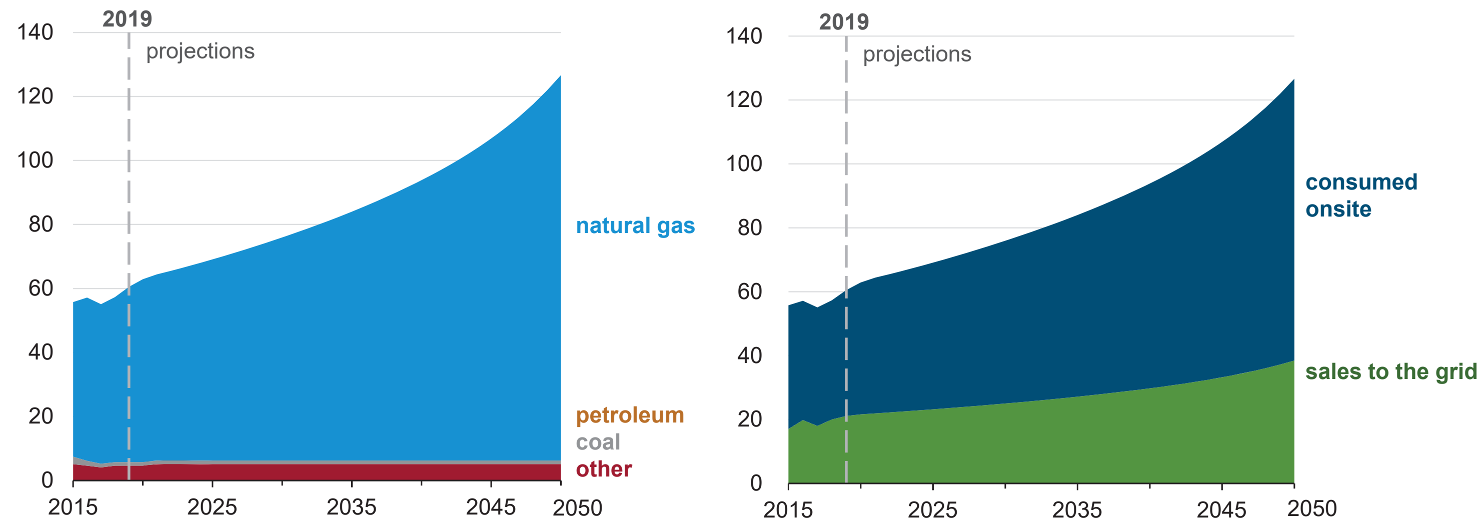
- AEO2020 Reference case electricity generation from CHP units in the U.S. bulk chemicals, refining, and paper industries (industries with the most CHP) grows 1.5% per year, from 125 billion kilowatthours (kWh) in 2019 to 196 billion kWh in 2050.

- The bulk chemical, refining, and paper industries use the most CHP in the United States because these large industries have high heating needs, and steam is readily available onsite to use for generation. The share of self-generated electricity to total electricity consumption in the sector rises from 34% in 2019 to 42% in 2050 because rapidly growing demand for industrial heat allows complementary power generation growth.

- Although natural gas accounts for more than 90% of the fuel used for CHP in the bulk chemicals industry in 2019 and 95% in 2050, petroleum products—in the form of residual oil, petroleum coke, and still gas and others—fuel some of the CHP capacity in the refining sector. In the paper industry, renewables such as black liquor fire CHP generation.

In the bulk chemicals industry, combined-heat-and-power (CHP) adoption grows in the AEO2020 Reference case; sales to the grid remain relatively flat as most generation fuels onsite consumption

Net CHP generation and disposition in the bulk chemicals sector, by fuel (AEO2020 Reference case)
billion kilowatthours

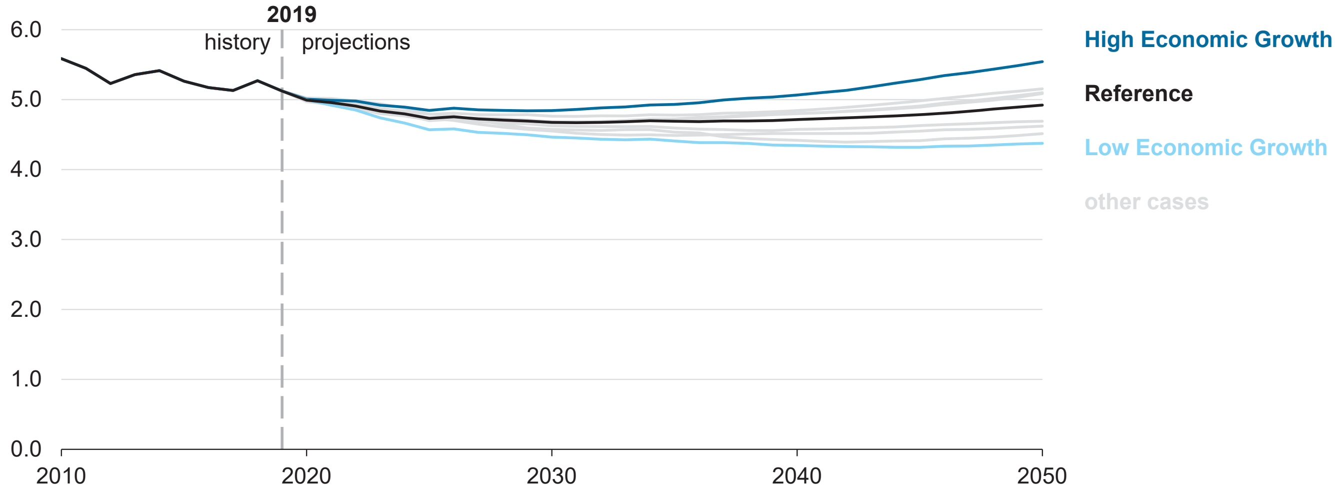


Emissions

Energy-related carbon dioxide emissions decrease until the mid-2020s in the AEO2020 Reference case as a result of changes in the fuel mix consumed by the electric power sector. After 2030, increases in energy demand in the other sectors—predominantly transportation and industrial—cause emissions to increase.

Economic growth is the biggest factor in carbon dioxide (CO_2) emissions —

AEO2020 U.S. energy-related CO2 emissions cases
billion metric tons

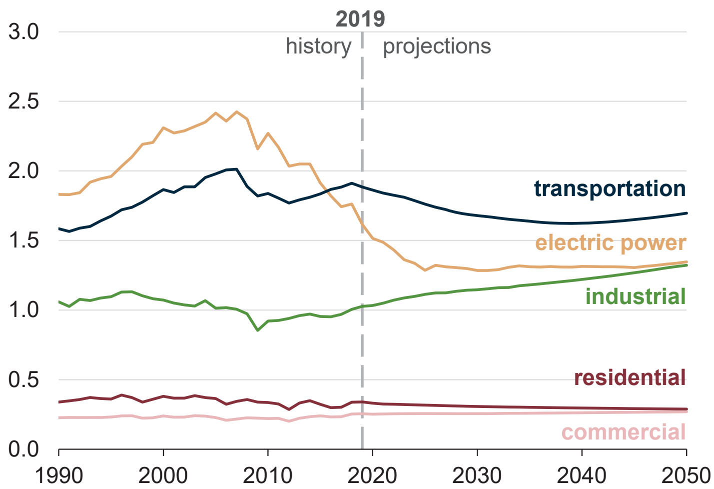


— and emissions in the High Economic Growth case rise faster than the Low Economic Growth case, as rapidly increasing energy demand outweighs improvements in efficiency

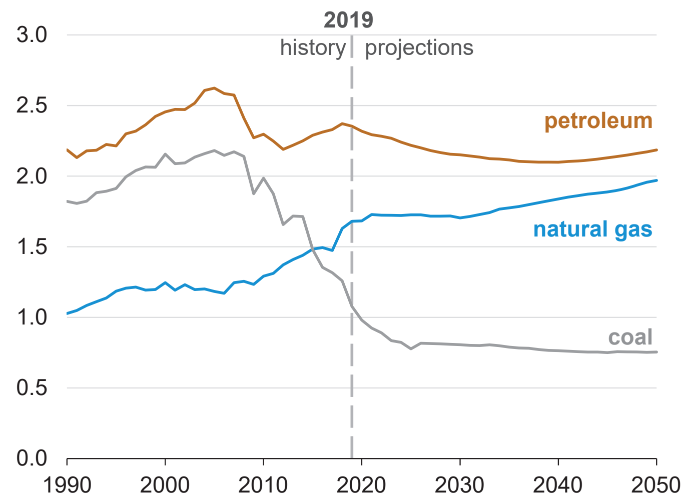
- Economic growth is the primary driver of energy demand and related CO_2 emissions.
- Energy-related CO_2 emissions in all AEO2020 cases decrease early in the projection period before increasing in the later years through 2050 as economic growth and increasing energy demand outweigh improvements in efficiency.
- In the High Economic Growth case, CO_2 emissions decrease through the late 2020s before increasing through 2050 to higher levels than in 2019.
- In the Low Economic Growth case, CO_2 emissions decline for most of the projection period and only begin to slowly increase after 2045.
- By 2050, CO_2 emissions in the High Economic Growth case are 13% higher than in the Reference case, and those in the Low Economic Growth case are 11% lower than in the Reference case.

AEO2020 energy-related CO2 emissions increase in the industrial sector, increase as a result of natural gas consumption, but remain relatively flat in other sectors and fuel types through 2050

Energy-related CO2 emissions by energy sector (AEO2020 Reference case)
billion metric tons

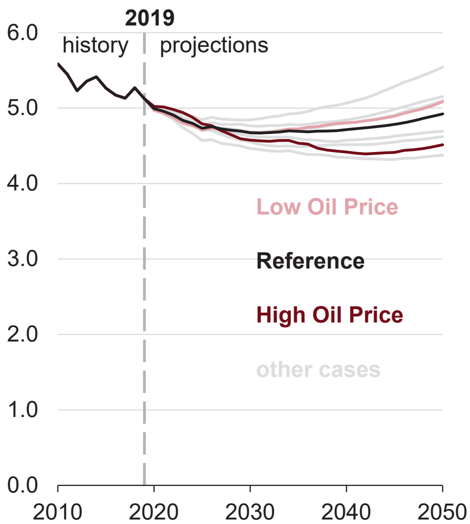


Energy-related CO2 emissions by fuel (AEO2020 Reference case)
billion metric tons

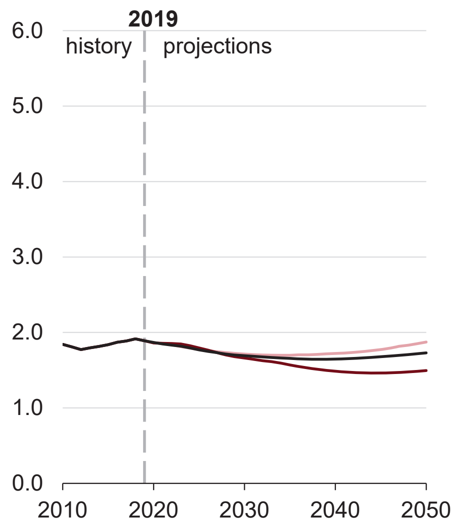


Assumptions regarding crude oil prices affect energy-related CO2 emissions in AEO2020 —

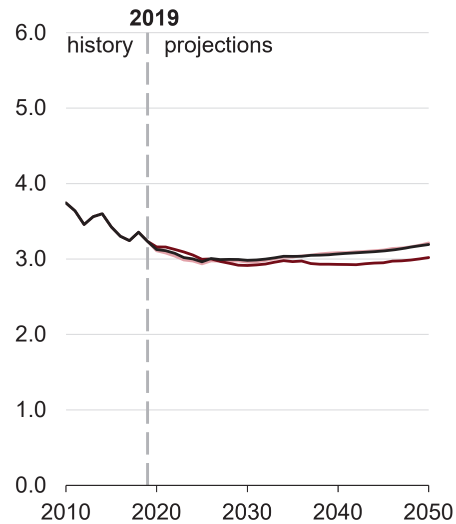
U.S. energy-related CO2 emissions
billion metric tons



Transportation sector CO2 emissions
billion metric tons



Non-transportation sectors CO2 emissions
billion metric tons

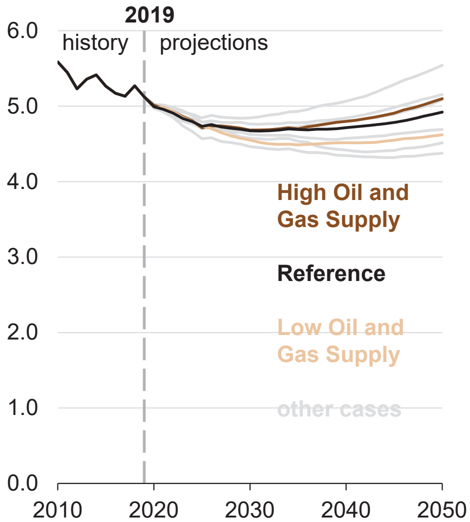


— and the oil price assumptions have the greatest effect on CO2 emissions from the transportation sector

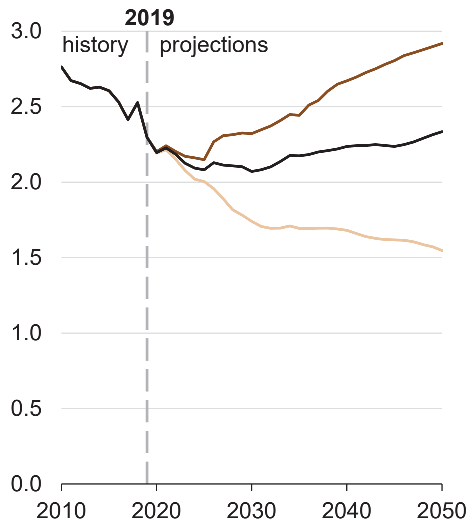
- Transportation sector emissions vary the most in the AEO2020 price cases because petroleum-related emissions dominate the transportation sector.
- In the Low Oil Price case, after an early decline, emissions increase to almost 2019 levels by 2050. Low-priced petroleum products trigger increased demand that results in greater CO2 emissions than in the Reference case.
- In the High Oil Price case, emissions decrease compared with the Reference case. Higher petroleum product prices reduce demand for petroleum products, leading to lower CO2 emissions.
- In the Low Oil Price case, transportation CO2 emissions are 1,874 million metric tons (MMmt) by 2050. In the High Oil Price case, transportation-related CO2 emissions are 1,495 MMmt.
- The industrial sector is the next most responsive sector to petroleum prices. In the Low Oil Price case, CO2 emissions from the industrial sector are 1,683 MMmt by 2050, and in the High Oil Price case, they are 1,589 MMmt.

The AEO2020 High Oil and Gas Supply and Low Oil and Gas Supply cases have different electricity generation fuel mixes than the Reference case—

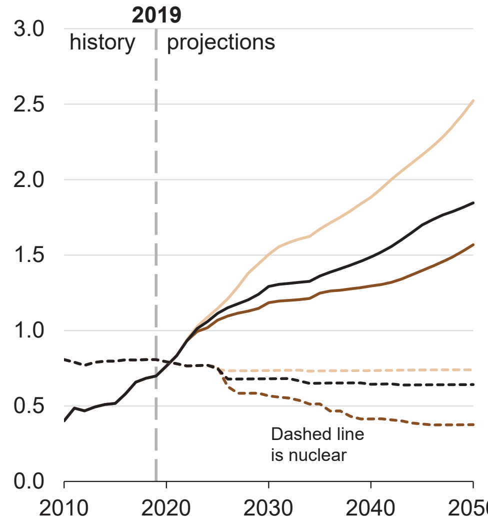
AEO2020 U.S. energy-related CO2 emissions
billion metric tons



AEO2020 fossil fuel-fired electric generation
trillion kilowatthours



AEO2020 renewables and nuclear electric generation
trillion kilowatthours



—resulting in different CO2 emissions profiles

- In the AEO2020 High Oil and Gas Supply case, energy-related CO2 emissions are higher overall compared with the Reference case, as a result of increased use of natural gas consumption, primarily in the electric power sector—and to a lesser extent, the industrial sector. The relatively low natural gas prices in this case allows natural gas to compete with renewables for new electricity generation capacity. Relatively inexpensive natural gas also accelerates nuclear retirements.

- In the Low Oil and Gas Supply case, CO2 emissions are lower overall, compared with the Reference case. Energy-related CO2 emissions decrease until about 2035 as a result of retiring coal-fired power plants, and although they increase after 2035, they remain 10% lower than 2019 levels. The relatively high natural gas prices in this case lead to greater renewables penetration and fewer nuclear retirements.

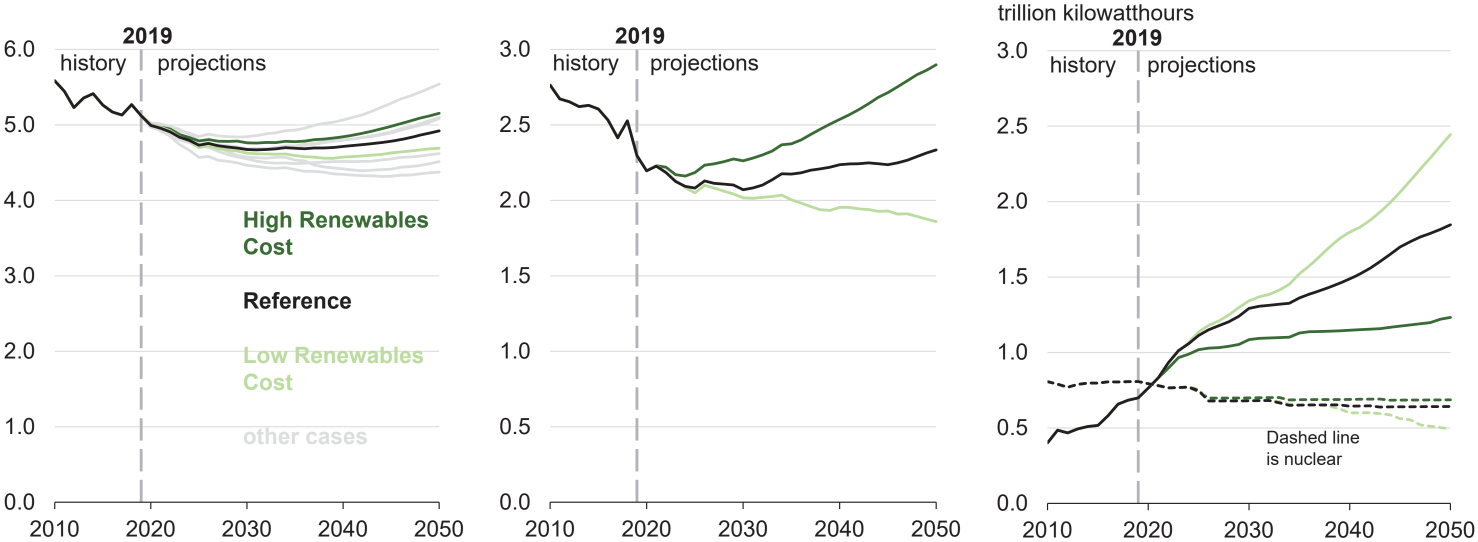
- By 2050, in the High Oil and Gas Supply case, fossil fuel-fired electric power generation is 25% higher than in the Reference case. In the Low Oil and Gas Supply case it is 34% lower than in the Reference case. The High Oil and Gas Supply case emits 5,099 MMmt CO2, and the Low Oil and Gas Supply case emits 4,620 MMmt CO2, creating a range of about 478 MMmt in CO2 emissions.

Changes in AEO2020 cost assumptions for new wind and solar projects also result in different electricity generation fuel mixes—

AEO2020 U.S. energy-related CO2 emissions
billion metric tons

AEO2020 fossil fuel-fired electric generation
trillion kilowatthours

AEO2020 renewables and nuclear electric generation
trillion kilowatthours



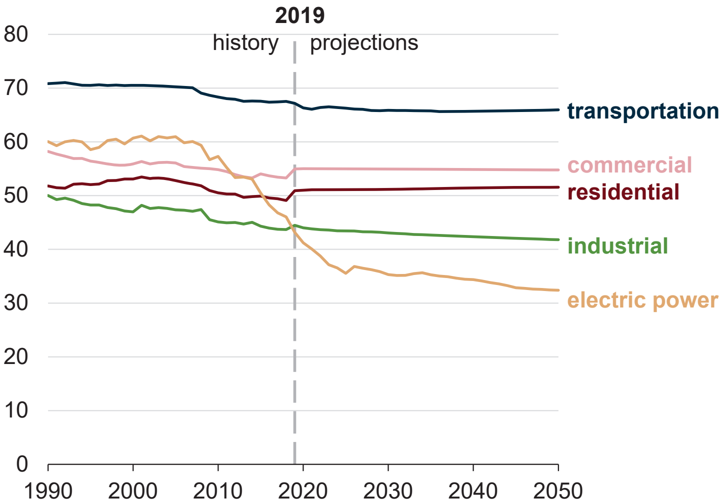
—and consequently, different energy-related carbon dioxide emission profiles

- The AEO2020 High Renewables Cost case, which assumes no further cost reductions for renewables, results in more energy-related CO2 emissions overall compared with the Reference case throughout the projection period. Until about 2030, emissions decrease as a result of retiring coal-fired generation capacity. After 2030, less penetration of renewables, increased natural gas-fired generation, and slightly fewer nuclear retirements (compared with the Reference case) lead CO2 emissions to return to nearly 2019 levels by 2050.

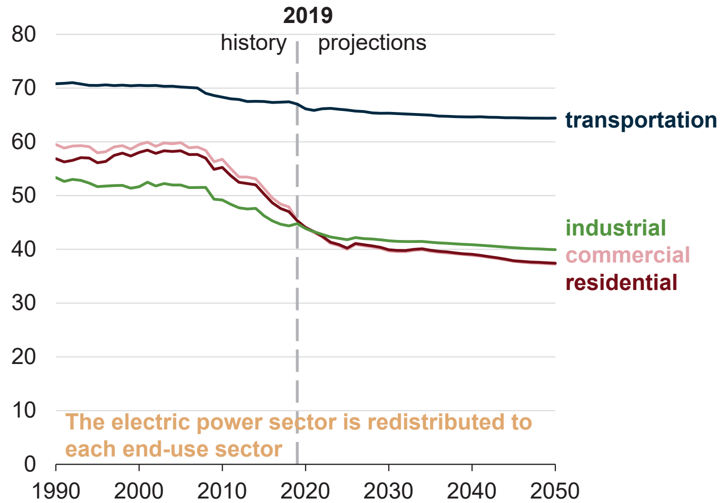
- The Low Renewables Cost case, which has sustained cost reductions for renewables through 2050, results in lower energy-related CO2 emissions overall compared with the Reference case. Increasing electricity generation from renewables leads to decreasing emissions; after 2040, total emissions increase as a result of increased energy demand in the transportation and industrial sectors that are less dependent upon electricity. However, in 2050, emissions remain 8% lower than 2019 levels.

Across end-use sectors, carbon intensity declines with changes in the fuel mix in the AEO2020 Reference case—

Carbon intensity by energy sector (AEO2020 Reference case)
metric tons of carbon dioxide per billion British thermal units



Carbon intensity by end-use sector (AEO2020 Reference case)
metric tons of carbon dioxide per billion British thermal units



—despite overall increases in energy consumption

- Carbon intensity can vary greatly depending on the mix of fuels the end-use sectors consume. Historically, the industrial sector has had the lowest carbon intensity, as measured by CO2 emissions per British thermal unit. The transportation sector historically has had the highest carbon intensity, which continues in the projection because carbon-intensive petroleum remains the dominant fuel used in vehicles throughout the projection period.

- The generation fuel mix in the electric power sector has changed since the mid-2000s; less generation is coming from high-carbon-intensive coal, and more generation is coming from natural gas and carbon-free renewables, such as wind and solar. Because of this change, the overall carbon intensity of the electric power sector declined by 30% from the mid-2000s to 2019 and is expected to continue to decline through 2050.

- If the CO2 emissions from the electricity sector in the end-use sectors that consume electricity are accounted for, carbon intensity declines to a greater degree across those sectors for all AEO2020 cases. In the Reference case, the carbon intensities of the residential and commercial sectors show no decline when their direct carbon intensities are counted from 2019 to 2050. When the electric power sector energy is distributed to the end-use sectors, the residential and commercial sectors decline by 17% and 18%, respectively, during the projection period, and the industrial sector declines by 11%. Transportation carbon intensity declines by 4%.

References

Abbreviations

AEO = Annual Energy Outlook
b = barrel(s)
BEV = battery-electric vehicle
b/d = barrels per day
bkWh = billion kilowatthours
Btu = British thermal unit(s)
CFL = compact fluorescent lamp
CHP = combined heat and power
CO2 = carbon dioxide
CPP = Clean Power Plan
EIA = U.S. Energy Information Administration
gal = gallon(s)
GDP = gross domestic product
GW = gigawatt(s)
HGL = hydrocarbon gas liquids
ITC = investment tax credit
kWh = kilowatthour(s)
LED = light-emitting diode
LNG = liquefied natural gas
MARPOL = marine pollution, the International Convention for the Prevention of Pollution from Ships
MMBtu = million British thermal units
MMst = million short tons
NEMS = National Energy Modeling System
NGPL = natural gas plant liquids
OPEC = Organization of the Petroleum Exporting Countries
PHEV = plug-in hybrid-electric vehicle
PTC = production tax credit
PV = photovoltaic
Tcf = trillion cubic feet
ZEV = zero-emission vehicle

Graph sources

Projected values are sourced from

Projections: EIA, AEO2020 National Energy Modeling System (runs: ref2020.d112119a, highprice.d112619a, lowprice.d112619a, highmacro.d112619a, lowmacro.d112619a, highogs.d112619a, lowogs.d112619a, hirencst.d1126a, lorencst.1201a)

EIA historical data are sourced from

- *Monthly Energy Review* (and supporting databases), September 2019
- Form EIA-860M, *Preliminary Monthly Electric Generator Inventory*, July 2019

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