U.S. Energy Supply and Use: Background and Policy Primer

March 14, 2024

Congressional Research Service
https://crsreports.congress.gov
R47980

CRS REPORT
Prepared for Members and
Committees of Congress

Congressional Research Service
Informing the legislative debate since 1914

U.S. Energy Supply and Use: Background and Policy Primer

SUMMARY

R47980

March 14, 2024

Brent D. Yacobucci, Coordinator
Section Research Manager

Since the start of the 21st century, the U.S. energy system has changed tremendously. Technological advances in energy production and use have driven changes in energy consumption, and the United States has moved from being a net importer of energy to a declining importer—and a net exporter on an annual basis starting in 2019. The United States remains the second-largest producer and consumer of all forms of energy in the world, behind China.

Overall energy consumption in the United States has held relatively steady since 2000, while the mix of energy sources has changed. Between 2000 and 2022, consumption of natural gas and renewable energy increased, while oil and nuclear power were relatively flat and coal decreased. For each of these sources, production moved in the same direction as consumption, except for oil, which has seen steady production increases since the mid-2000s. Overall U.S. energy production increased by 46% from 2000 to 2022.

Increases in the production of oil and natural gas are due in part to technological improvements in hydraulic fracturing and horizontal drilling that have facilitated access to resources in unconventional formations (e.g., shale). U.S. oil production (including natural gas liquids and crude oil) and natural gas production hit record highs in 2022.

Oil, natural gas, and other liquid fuels depend on a network of over three million miles of pipeline infrastructure. Increases in fuel production led to a realignment of the U.S. pipeline network, which expanded by an additional 63,000 miles of transmission pipeline between 2005 and 2022. The trajectory of future pipeline development is uncertain due to ongoing permit challenges and litigation for current pipeline expansion efforts.

Coal, used primarily for electricity generation, supplied 19% of electricity generation in 2022, while overall consumption declined by 54% since 2007 (the most recent peak) in the face of increasing competition from natural gas and renewables. A new conventional nuclear reactor began operation in June 2023, with its twin unit scheduled to start up in 2024. Because of concerns over cost and safety of conventional nuclear reactors, much congressional attention has focused on the development of advanced reactors, including small modular reactors (SMRs).

The electric power industry faces uncertainty over how to address reliability within an environment of aging infrastructure, retiring power plants, potential cybersecurity threats, and continued interest in renewable energy and other low carbon sources of electricity. Reliability and electricity prices can be affected (positively and negatively) by environmental regulations, the rising availability of natural gas for electricity generation, and increased use of renewables. As with pipelines, many efforts at transmission expansion have faced permitting challenges and litigation in recent years.

Renewable energy consumption doubled between 2000 and 2022, primarily due to increased use of wind and solar for electric power generation and biofuels for transportation. Non-hydroelectric renewable sources have comprised the majority of electric generation capacity additions each year since 2015, except for 2018.

Adoption of energy-efficiency technologies in buildings, transportation, and industry may support policy objectives toward energy security, lowering emissions, and reducing energy consumption (e.g., consumers saving money, avoiding greenhouse gas emissions). Policy options include mandatory efficiency standards and programs encouraging adoption of existing technologies, among others. Resulting changes in energy consumption may also be impacted by changes in demand for energy services.

There is also growing interest in the development of hydrogen fuel for a range of applications, including transportation, electric grid energy storage, and industrial uses.

Congress has been interested in the U.S. energy system for decades. Major legislation in the 117th Congress established and expanded research and development, grants and loans, and tax incentives for a range of energy technologies, including consumer appliances, zero-carbon electricity, nuclear power, sustainable aviation fuel, and carbon capture and storage. Current topics of concern to Congress include reliability and resilience, infrastructure, efficiency, exports, imports, prices, energy independence, security, and geopolitics, as well as environmental and climate effects.

Contents

Figures

Tables

Appendixes

Contacts

Introduction: Steady Growth

The United States has been an integral part of the global energy sector for many decades. It is a leader in energy production, consumption, and technology, and its energy market is highly sophisticated. Its energy prices, for the most part, are determined in the marketplace and rise or fall with changes in supply and demand. The United States is a major producer of all forms of energy—oil, natural gas,[1] coal, nuclear power, and renewable energy.

Since the beginning of the 21st century, the U.S. energy sector has transformed from a situation of declining production, especially of oil and natural gas, to one in which the United States is a growing producer. Exports of energy are rising while imports are falling. It has also been a situation of growing renewable energy supplies and increasing efficiency of energy use. Prices, technology, and regulations have prompted changes in the energy mix.

This report provides an overview of U.S. energy issues, and it serves as an initial resource document for related information, data, and CRS analytical contacts. The report is organized around the major fuels and energy sources used in the United States. It also highlights the role of the federal government, particularly in incentivizing new and conventional energy supplies. It does not focus on security, research and development, or environmental issues, although those subjects are also critical to the U.S. energy sector.

Issues for Congress

Policy Goals

Energy policy is a perennial concern for Members of Congress. Energy supply and consumption are key drivers of economic activity. There is ongoing debate over U.S. energy policy given the wide range of possible energy sources; their availability in terms of domestic vs. foreign resources; the economic costs and benefits of developing those resources; and the effects (e.g., economic, environmental, social) of their use. Additionally, environmental policy has a major effect on the energy sector, especially fuel use.

The United States has access to a wide range of energy sources, including fossil fuels (e.g., coal, petroleum, and natural gas), nuclear, and renewables (e.g., wind, solar, hydropower, geothermal, biomass). In addition, increases in energy efficiency have allowed the United States to produce more economic output while consuming the same amount of energy, extending existing supplies. Different U.S. sectors employ different sources. For example, nuclear energy is used exclusively in electric power generation, along with other sources, while the transportation sector is largely dependent on petroleum in the form of gasoline, diesel fuel, and jet fuel.

The energy profile has changed dramatically in recent years. Coal had been the predominant fuel for electric power generation for decades, but between 2000 and 2022, natural gas-fired power generation nearly tripled. Over the same time, non-hydroelectric renewable energy grew by

[1] Throughout this report, natural gas figures are reported for dry production. Dry production refers to natural gas production with gas liquids and nonhydrocarbon gases removed.

nearly eight times.[2] There is a growing market for electric passenger vehicles, although they do not currently represent a significant share of transportation energy use.[3]

The shift in energy use over time has led to a decrease in total U.S. energy-related carbon dioxide (CO_2) emissions. Since peaking in 2007, annual emissions have decreased roughly 12% through the end of 2022.[4] Much of this decrease has been a result of changes in the electricity sector, where coal use has decreased, replaced by lower-carbon natural gas and renewable generation. The economic downturn in 2008-2009 also played a role as energy consumption is correlated with economic activity.

COVID-19

The Coronavirus Disease 2019 (COVID-19) pandemic and subsequent response upended many of the ways that businesses, schools, and households operated day to day. Economic activity, which partly drives energy consumption, declined. These factors led to significant shifts in how Americans consumed energy. For example, U.S. consumption of petroleum products (including gasoline and diesel fuel) fell by more than 30% from the start of 2020 through mid-March 2020.[5] Annual petroleum consumption decreased by 12% from 2019 to 2020.[6] Likewise, some areas of the country saw decreases in electricity demand as businesses were shut down in response to COVID-19 mitigation.[7] Across the United States, electricity consumption decreased by 3.8% in 2020. In both cases, consumption rebounded in 2021 and 2022 nearing (petroleum) or exceeding (electricity) 2019 levels.[8]

Comprehensive Energy Legislation

Energy policy has often been legislated in large bills that deal with a wide variety of issues, with debate spanning several sessions. The Energy Policy Act of 2005 (EPAct 2005; P.L. 109-58) was a comprehensive general law, with provisions and authorizations in almost all areas of energy policy. The Energy Independence and Security Act of 2007 (EISA, P.L. 110-140) set new target fuel economy standards for cars and light trucks, and expanded the Renewable Fuel Standard (RFS). EISA also included energy efficiency standards for appliances and other equipment, and provisions on industrial and building efficiency, which have continued to be of interest to many Members.

In the 116th Congress, both the House and Senate debated large energy bills, with the House passing one bill and the Senate debating another on the floor. Neither bill was enacted by the end of the 116th Congress. Provisions from those bills (S. 2657 and H.R. 4447) were incorporated into

[2] U.S. Energy Information Administration (EIA), *Electric Power Annual 2010*, Table 2.1.A, November 2011, and EIA, *Monthly Energy Review*, March 2023.

[3] Javier Colato and Lindsey Ice, *Charging into the Future: The Transition to Electric Vehicles*, Bureau of Labor Statistics, Beyond the Numbers, vol. 12, no. 4, February 2023, https://www.bls.gov/opub/btn/volume-12/charging-into-the-future-the-transition-to-electric-vehicles.htm.

[4] EIA, *U.S. Energy-Related Carbon Dioxide Emissions, 2022,* November 29, 2023, https://www.eia.gov/environment/emissions/carbon/.

[5] Jesse Barnett, *COVID-19 Mitigation Efforts Result in the Lowest U.S. Petroleum Consumption in Decades*, EIA, April 23, 2020, https://www.eia.gov/todayinenergy/detail.php?id=43455.

[6] EIA, *Short-Term Energy Outlook*, March 9, 2021, https://www.eia.gov/outlooks/steo/.

[7] April Lee and Jonathan DeVilbiss, *Daily Electricity Demand Impacts from COVID-19 Mitigation Efforts Differ by Region*, EIA, March 7, 2020, https://www.eia.gov/todayinenergy/detail.php?id=43636.

[8] EIA, *Monthly Energy Review*, Table 7.1, "Electricity Overview," and Table 3.1, "Petroleum Overview," October 2023.

the Consolidated Appropriations Act, 2021 (P.L. 116-260). Division Z, the Energy Act of 2020, promotes increased energy efficiency in homes, schools, and federal buildings; expands research and development in nuclear energy, energy storage, electric vehicles, renewable energy, and carbon capture utilization and storage (CCUS); and promotes energy storage development.

Federal Incentives

Often, federal energy policy goals are implemented through direct and indirect incentives for preferred energy sources and/or technologies. These include direct agency research and development, as well as federal grants and loans for research, development, and demonstration by universities, state and local agencies, and private entities. Tax incentives support the deployment of a range of technologies, including electric vehicles, wind and solar power, and carbon capture and storage. Indirect incentives include federal mandates for the use of biofuels in transportation, and efficiency requirements for appliances, commercial equipment, and automobiles. Various analytical groups, including the U.S. Energy Information Administration (EIA), have quantified the effects of some of these incentives.[9]

117th Congress: Expanded Appropriations and Incentives

The 117th Congress enacted three key pieces of energy legislation. The Infrastructure Investment and Jobs Act (IIJA, P.L. 117-58) authorized and appropriated funds for a wide range of infrastructure projects, including approximately $76 billion for energy and minerals-related research, demonstration, technology deployment, and incentives.[10] IIJA appropriations provisions included funding for many of the programs authorized in the Energy Act of 2020. P.L. 117-167, commonly referred to as the CHIPS and Science Act, appropriated funds to support the domestic production of semiconductors and authorized various programs and activities of the federal science agencies, including the Department of Energy. P.L. 117-169, commonly referred to as the Inflation Reduction Act (IRA), was a wide-ranging law. Among other provisions, the IRA established new and expanded tax credits and other incentives for a range of energy technologies, including consumer appliances, zero-carbon electricity, nuclear power, sustainable aviation fuel (SAF), electric vehicles, and clean hydrogen.

118th Congress, 1st Session: IIJA/IRA Implementation, Permitting Reform, Critical Minerals/Materials, and Nuclear Energy

Fewer energy-related laws have been enacted in the 1st Session of the 118th Congress, although Congress has continued to demonstrate interest in energy policy. As noted above, legislation in the 117th Congress established or expanded tax incentives and grant/loan programs for a range of energy technologies and applications. In many cases, federal agencies distributed funds and/or issued guidance on program implementation; however, many programs (including state-run programs) had not distributed funds to recipients as of the end of 2023. Other topics of committee hearings and introduced legislation include expedited review or automatic granting of permits for new energy projects, including pipelines, electric power transmission, and liquefied natural gas exports. There have also been multiple hearings and bills aimed at addressing U.S. supplies of lithium, rare earth elements, and other minerals and materials critical for the expansion of electric

---

[9] See, for example, EIA, *Federal Financial Interventions and Subsidies in Energy in Fiscal Years 2016-2022*, https://www.eia.gov/analysis/requests/subsidy/pdf/subsidy.pdf.

[10] For a detailed discussion of energy provisions in the IIJA, see CRS Report R47034, *Energy and Minerals Provisions in the Infrastructure Investment and Jobs Act (P.L. 117-58)*, coordinated by Brent D. Yacobucci.

vehicles, wind and solar power, and other energy technologies. Legislation supporting U.S. production of nuclear fuel was enacted by Congress on December 14, 2023, in the National Defense Authorization Act for FY2024 (P.L. 118-31).

A Note on Data Availability

In most cases, this report includes data from the U.S. Energy Information Administration (EIA), which provides authoritative data on many aspects of the U.S. energy system. In many cases, full annual data may not be available for several months following the end of a calendar year. For consistency, and to allow comparisons, this report includes data through the end of calendar year 2022.

U.S. Energy Profile

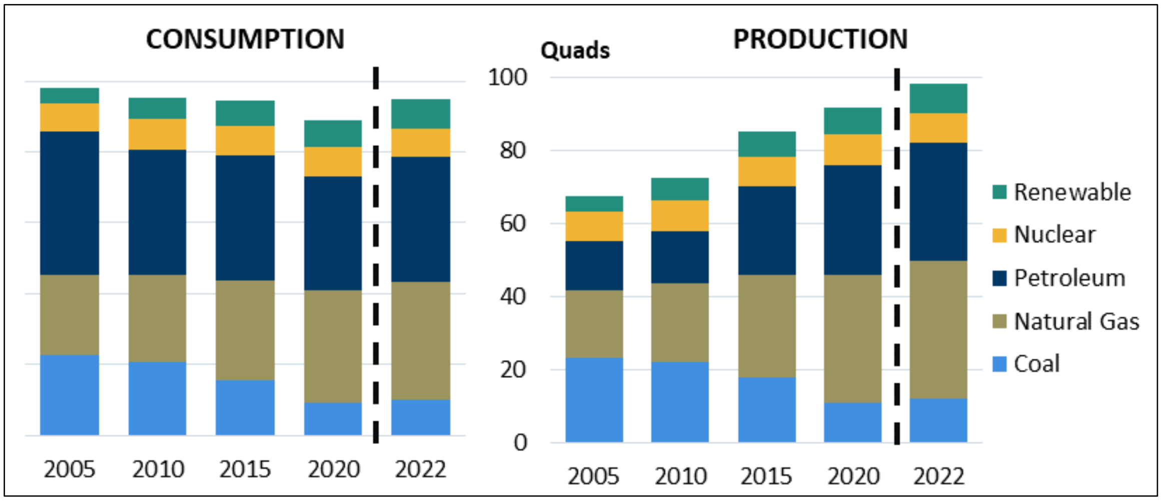
The United States is the second-largest producer and consumer of energy in the world, behind China.[11] U.S. primary energy consumption (see **Figure 1**) has held relatively steady since 2005; however, the fuel mix has changed. While oil has remained at almost 40% of the fuel mix, natural gas and renewables have increased in both percentage and absolute terms while coal consumption declined. Nuclear generation has stayed flat.

U.S. energy production between 2005 and 2022 increased 46%, altering the previous position of the United States as a growing importer of energy. (See **Figure 1**.) Crude oil production has increased by 104% during the time frame, while natural gas production increased by 90%. The increase in production of oil and natural gas resources comes from innovations in extraction from *unconventional* (or *tight*) formations, such as shale (see shaded box below, "Unconventional Shale Resources Make the Difference"). Renewable energy production (including hydropower) has grown nearly 98%, led by increases in wind and solar power. Domestic coal production, on the other hand, has declined during the same period by about 48%.

[11] EIA, *International Overview*, https://www.eia.gov/international/overview/world, accessed October 23, 2023; Energy Institute, *Statistical Review of World Energy 2023*, 2023. (Before 2023, this report was published by BP.)

Figure 1. U.S. Primary Energy Consumption and Production by Fuel, 2005-2022

Quadrillion Btu (Quads)



Sources: Data compiled by CRS from U.S. Energy Information Administration (EIA), *Monthly Energy Review*, October 26, 2023, Table 1.3, "Primary Energy Consumption by Source"; and EIA, *Monthly Energy Review*, October 26, 2023, Table 1.2, "Primary Energy Production by Source."

Note: Renewable includes hydropower, geothermal, solar, wind, and biomass (including biofuels). Petroleum includes natural gas plant liquids. For a definition of "primary energy," see EIA Glossary at https://www.eia.gov/tools/glossary/index.php?id=Primary%20energy.

Unconventional Shale Resources Make the Difference

The United States saw a rise in natural gas and oil production starting in 2006 and 2008, respectively, driven mainly by technology improvements—especially in hydraulic fracturing and directional drilling—which have enabled the extraction of oil and gas from unconventional shale formations. The United States has been the world's largest producer of natural gas since 2009 and of petroleum liquids since 2014, according to the BP Statistical Review of World Energy 2020. Production from shale and tight formations comprised 74% of U.S. natural gas production in 2022 and 66% of oil production. The contribution of unconventional shale resources to both oil and natural gas production in the United States is likely to continue to grow.

Determination of whether a formation is unconventional or conventional depends on its geology. Unconventional formations typically are fine-grained, organic-rich, sedimentary formations—usually shales and similar rocks. These unconventional formations are both the source of and the reservoir for oil and natural gas, unlike conventional petroleum reservoirs, which trap oil and gas that have migrated to the reservoir from a different source.

The Society of Petroleum Engineers describes "unconventional resources" as petroleum accumulations that are pervasive throughout a large area and are not significantly affected by pressure exerted by water (hydrodynamic influences); they are also called "continuous-type deposits" or "tight formations."[12] Although the unconventional formations may be as porous as other sedimentary reservoir rocks, their extremely small pore sizes and lack of permeability (i.e., connectivity between the pores) means that the oil and gas are not recoverable through conventional means of extraction. Instead, hydraulic fracturing technology combined with horizontal drilling creates new fractures, or extends existing fractures, enhancing permeability and enabling the oil and gas to flow to the well and up to the surface.

In contrast, conventional oil and natural gas deposits formed as hydrocarbons migrated from organic-rich source rocks into porous and permeable reservoir rocks, such as sandstones and carbonates. The hydrocarbons remained in the reservoir rocks because they were trapped beneath an impermeable *cap-rock* (such as shale). The trapped oil and gas can flow into a well drilled through the cap-rock and into the reservoir rock under natural pressure, or by using conventional enhancement techniques such as flooding the reservoir with water.

[12] Society of Petroleum Engineers, *Glossary of Terms Used in Petroleum Reserves/Resources Definition*, http://www.spe.org/industry/docs/GlossaryPetroleumReserves-ResourcesDefinitions_2005.pdf.

Conventional enhancement techniques such as water flooding are ineffective in unconventional shale formations because of their low permeability.

The change in the U.S. consumption fuel mix has occurred primarily in the electricity sector, where fuel substitutes are most readily available (see "The Electric Power Sector: In Transition"). Electric power generation in 2022 came from coal (19%), natural gas (39%), nuclear (18%), renewables (23%),[13] and petroleum (<1%), according EIA.[14] In 2005, coal accounted for approximately 50% of the electricity fuel mix, natural gas and nuclear were 19% each, and renewables were 9%.[15]

Industrial use of energy has also experienced changes in recent years, but not to the same degree as electric power generation. Energy in transportation remains dominated by petroleum, which made up 90% of the fuel used in transportation in 2022, compared with 97% in 2000 and 96% in 2005.[16]

Crude Oil and Petroleum Products: Increased Production and Exports[17]

Access to crude oil and petroleum products (e.g., gasoline, diesel fuel, heating oil, and jet fuel) at reasonable prices has been an element of U.S. energy, national security, and economic policy for decades. Geopolitical events, along with domestic price and allocation control policies, in the 1970s resulted in reduced U.S. access to world oil supplies, rapidly escalating prices, mandatory rationing, and localized shortages. Combined with an outlook at that time for increasing U.S. oil demand, decreasing domestic production, and high import dependency, these circumstances facilitated enactment of landmark legislation such as the Energy Policy and Conservation Act (EPCA, P.L. 94-163) in 1975.[18] EPCA policies that have affected the oil sector include the Strategic Petroleum Reserve (SPR),[19] which still exists, and a crude oil export prohibition that was repealed in 2015.[20]

Petroleum product consumption in the United States, which has been relatively stable since 2000, was approximately 20.0 million barrels per day (bpd) during 2022, roughly 20% of global demand and more than any other country. The transportation sector, which accounts for approximately 68% of U.S. petroleum consumption, is largely dependent on oil.

Notable changes in the U.S. oil sector since 2000 include a doubling of crude oil production, expansion of U.S. refining capacity, and nearly balanced petroleum trade (imports minus exports;

---

[13] In this report, renewables refer to hydropower, biofuels, wood biomass, wind, waste, solar, and geothermal energy.

[14] EIA, *Monthly Energy Review*, March 28, 2023, Table 7.2a, "Electricity Net Generation: Total (All Sectors)."

[15] Data for 2000-2010 from EIA, *Electric Power Annual 2010*, Table 2.1.A, November 2011; and data for 2011-2019 from EIA, *Electric Power Monthly*, Table 1.1, July 2020. For comparison, in 2000, coal accounted for approximately 52%; natural gas, 16%; nuclear, 20%, and renewables, 9%.

[16] EIA, *Monthly Energy Review*, October 26, 2023, Table 2.5, "Transportation Sector Energy Consumption."

[17] Phillip Brown, CRS Specialist in Energy Policy, is the author of this section.

[18] EPCA, as amended, is available at 42 U.S.C. §6201 et seq.

[19] For additional information, see CRS Insight IN12110, *Strategic Petroleum Reserve Crude Oil Sales: Buyers and Exports*, by Phillip Brown and Claire Mills; and DOE, "Strategic Petroleum Reserve," https://www.energy.gov/ceser/strategic-petroleum-reserve.

[20] For additional information, see CRS Report R44403, *Crude Oil Exports and Related Provisions in P.L. 114-113: In Brief*, by Phillip Brown, John Frittelli, and Molly F. Sherlock.

see **Figure 3**). Oil production in the United States for 2022 was larger than in any other country.[21] U.S.-based oil refining capacity increased by 8.7%,[22] with these assets generally recognized as some of the most sophisticated and cost-competitive in the world. Annualized petroleum exports—crude oil and products—from the United States increased by a factor of nine over the last 22 years. These developments have affected global oil supply and prices, and at times leveraged to impose economic sanctions on certain oil producing countries with the goal of achieving foreign policy objectives.[23]

Crude Oil and Natural Gas Liquids Production

During 2022, companies operating in the United States produced approximately 11.9 million bpd of crude oil. Combined with 5.9 million bpd of natural gas liquids (NGLs; see the "Natural Gas Liquids" section, below), total production during the year was roughly 17.8 million bpd for these petroleum liquids (see **Figure 2**).[24] Oil production in the United States had been in general decline for nearly 40 years (1970-2008). However, that downward trend reversed, primarily through the application of horizontal drilling and hydraulic fracturing technology to access tight oil (see shaded box on "Unconventional Shale Resources Make the Difference" above). Between 2008 and 2022, annual production of U.S. tight oil increased by nearly 8 million bpd. Tight oil represented the largest portion of domestic production volume in 2022.[25]

[21] Energy Institute, *Statistical Review of World Energy 2023*, 2023. (Before 2023, this report was published by BP.)

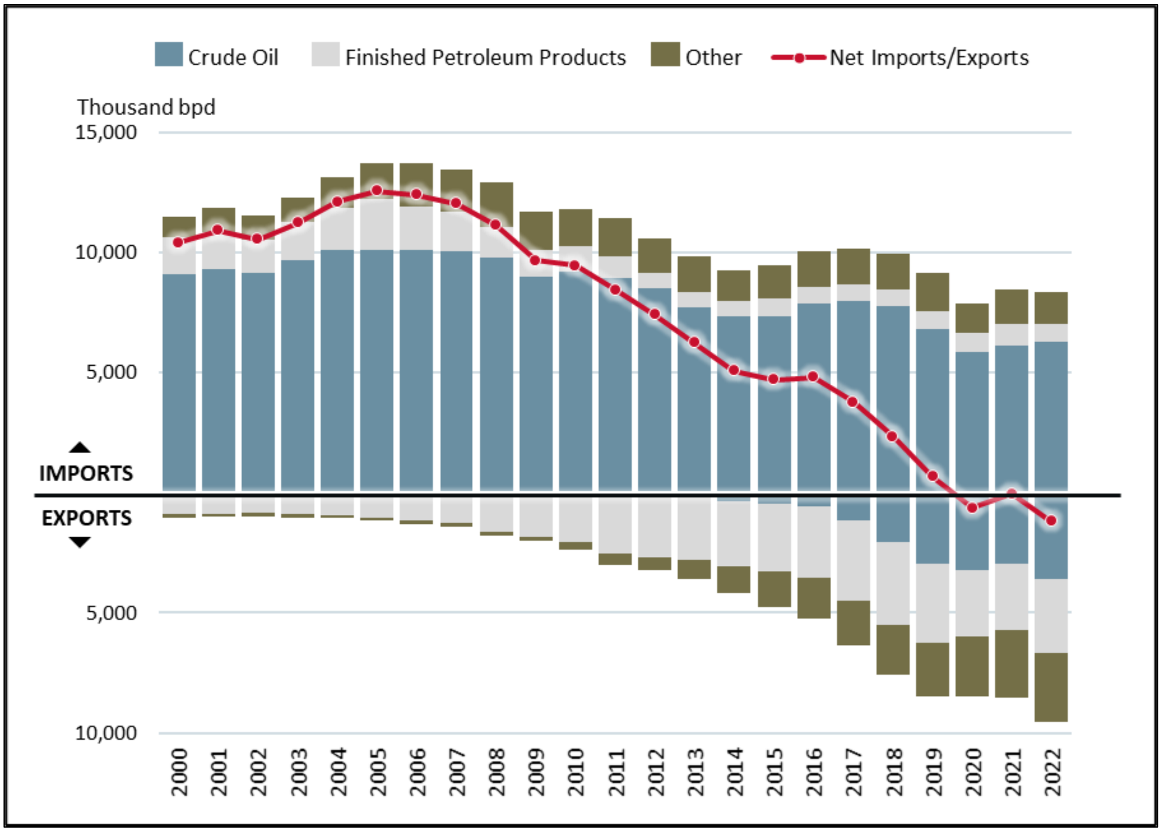
[22] EIA, *Refinery Utilization and Capacity*, September 30, 2023, https://www.eia.gov/dnav/pet/PET_PNP_UNC_A_(NA)_YRL_MBBLPD_A.htm.

[23] For additional information, see CRS Report R46213, *Oil Market Effects from U.S. Economic Sanctions: Iran, Russia, Venezuela*, by Phillip Brown.

[24] For additional information about NGLs, see CRS Report R45398, *Natural Gas Liquids: The Unknown Hydrocarbons*, by Michael Ratner.

[25] EIA, *Tight Oil Production Estimates by Play*, https://www.eia.gov/energyexplained/oil-and-petroleum-products/data/US-tight-oil-production.xlsx, accessed October 10, 2023.

Figure 2. U.S. Crude Oil Production, NGL Production, and WTI Spot Price
Calendar Years 2000-2022



Source: CRS analysis of U.S. Energy Information Administration oil production, NGL production, and price data.

Notes: Production numbers represent annual averages. Prices reflect calendar monthly averages. WTI = West Texas Intermediate. Bpd = barrels per day. NGLs = Natural Gas Liquids. RHS = Right Hand Side. Numbers may not sum due to rounding.

Oil Transportation and Storage

Produced and imported crude oil is moved using various transportation modes (e.g., pipeline, rail, barge, tanker, and truck) and is delivered to either oil refineries or commercial storage facilities located throughout the United States.[26] The majority of U.S. storage capacity is located in the Gulf Coast region and the Midwest region, which includes nearly 78 million barrels of working storage capacity in Cushing, OK.[27] Cushing is the pricing location for West Texas Intermediate (WTI) oil futures contracts frequently reported by news media. Most crude oil—both domestically produced and imported—is delivered to refineries using pipeline infrastructure. While relatively small volumes of crude oil are transported using the rail system, the rapid growth

[26] For information about crude oil transportation modes, see EIA, *Refinery Receipts of Crude Oil by Method of Transportation*, https://www.eia.gov/dnav/pet/pet_pnp_caprec_dcu_nus_a.htm, accessed March 7, 2022.

[27] EIA, *Working and Net Available Shell Storage Capacity as of March 31, 2023*, https://www.eia.gov/petroleum/storagecapacity/, accessed October 10, 2023.

of this transportation mode between 2011 and 2014 resulted in increased congressional interest and oversight of crude oil movements by rail.[28]

Oil Refining

Refineries convert crude oil into various intermediate and finished products (e.g., gasoline, diesel fuel, jet fuel, heating oil, marine fuel, and asphalt), some of which are blended with other petroleum liquids. Since 2000, the number of operable refineries in the United States declined by approximately 18%, while operable capacity increased by approximately 9%. As of January 1, 2023, 129 refineries located in 30 U.S. states have capacity to process nearly 18 million barrels of crude oil per calendar day.[29] During 2022, U.S. refineries processed approximately 16.5 million bpd.[30] Since 2019, U.S. crude oil refining capacity and processing trended lower due to refinery closures motivated by accidents and refining economics, as well as facility conversions to produce renewable fuels. Approximately 45% of U.S. refining capacity is located along the Gulf Coast areas of Texas and Louisiana. Refined petroleum products are stored, blended, transported by various modes, and ultimately delivered and sold to consumers.

Many U.S. refineries have technically sophisticated configurations and equipment that allow for upgrading low-quality crude oils with high sulfur content into high-value, low-sulfur petroleum products. U.S. refineries have also enjoyed an operational cost benefit in the form of relatively low-cost natural gas, which they use for process heat and sulfur removal. These configuration and cost advantages contribute to the global competitiveness of the U.S. refining sector.

Petroleum Trade

U.S. petroleum trade balances—imports and exports—since 2000 have changed from large net imports to a small net exports (see **Figure 3**). This trade balance shift is the result of increased petroleum product exports combined with increasing crude oil exports enabled by legislation enacted in 2015 (P.L. 114-113) that repealed crude oil export restrictions.[31] While overall petroleum trade is at a nearly balanced level, the United States continues to be one of the largest crude oil importing countries and remains integrated with the global petroleum market.[32] This import trend could continue should sophisticated U.S. refiners choose to source crude oil with quality characteristics that support optimized refining operations and petroleum product yields.

[28] For additional information, see CRS Report R43390, *U.S. Rail Transportation of Crude Oil: Background and Issues for Congress*, by John Frittelli et al.

[29] EIA, *Refinery Capacity Report*, June 21, 2023, https://www.eia.gov/petroleum/refinerycapacity/. Refining capacity is also reported in barrels per stream day, which represents maximum oil input without any downtime. Additional information is available at https://www.eia.gov/tools/glossary/index.php?id=b.

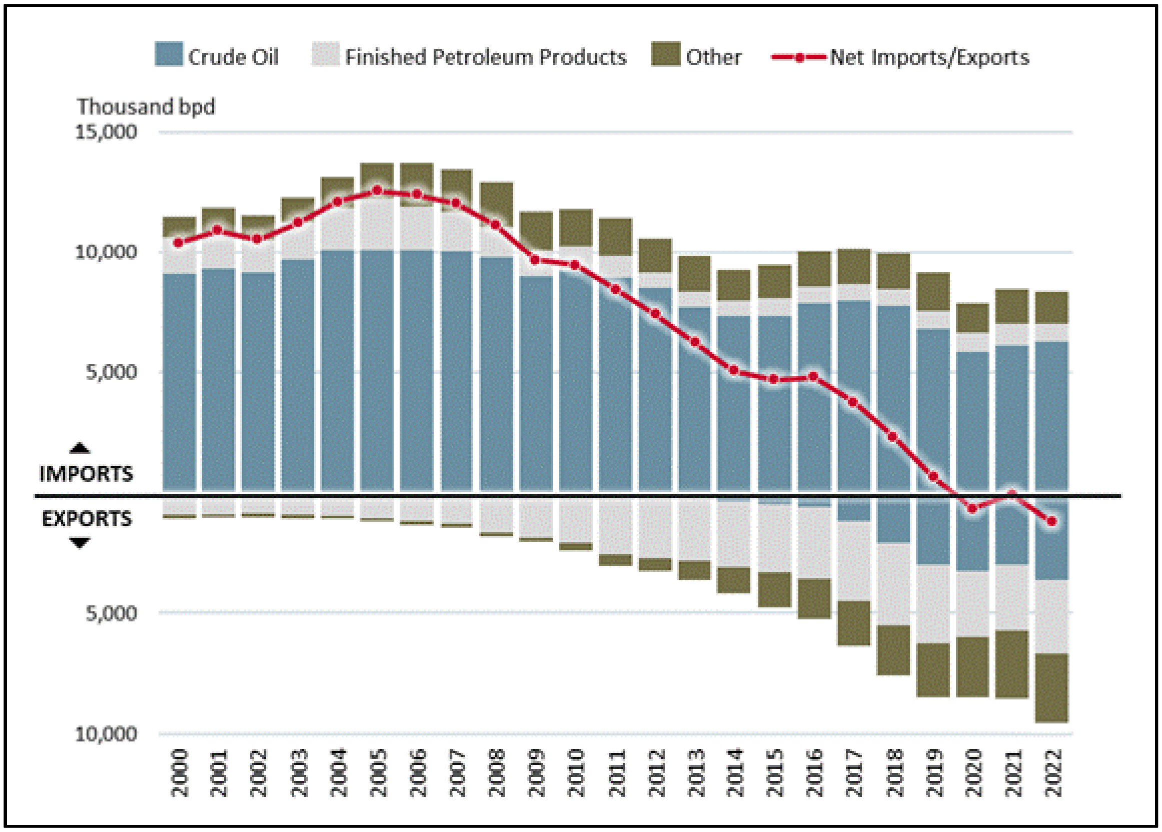
[30] EIA, *Refinery Utilization and Capacity*, https://www.eia.gov/dnav/pet/pet_pnp_unc_dcu_nus_a.htm, accessed October 10, 2023.

[31] For additional information about repeal of the U.S. crude oil export prohibition, see CRS Report R44403, *Crude Oil Exports and Related Provisions in P.L. 114-113: In Brief*, by Phillip Brown, John Frittelli, and Molly F. Sherlock. For additional information about the U.S. crude oil export debate, see CRS Report R43442, *U.S. Crude Oil Export Policy: Background and Considerations*, by Phillip Brown et al.

[32] In 2019, the United States was the second-largest crude oil importing country. China was the largest. For additional information, see EIA, *China's Crude Oil Imports Surpassed 10 Million Barrels per Day in 2019*, March 23, 2020.

Figure 3. U.S. Petroleum Imports, Exports, and Trade Balance

Calendar Years 2000-2022



Source: CRS analysis of U.S. Energy Information Administration petroleum import and export data.

Notes: "Other" includes hydrocarbon gas liquids, oxygenates, renewable fuels, blending components, and unfinished oils. Bpd = barrels per day.

Oil and Petroleum Product Prices

Crude oil (see **Figure 2**) and petroleum product prices can exhibit volatile and erratic movements. Numerous factors (e.g., global economic growth, Organization of the Petroleum Exporting Countries production policies and compliance, geopolitical events, and natural disasters) can affect petroleum market supply and demand balances, storage levels, futures prices, and ultimately the price of physical oil commodities.[33] Oil market characteristics—generally inelastic supply and demand in the short term—can contribute to market conditions that could result in volatile price movements (both up and down) when supply and demand are imbalanced by as little as 1% to 2% for a brief or sustained period. Apart from a release of SPR crude oil to address supply disruptions and associated economic dislocations, non-emergency statutory authorities that could quickly affect global oil markets and prices are limited. Congressional interest in statutory and legislative options tends to increase when crude oil and petroleum product (e.g., gasoline) prices are deemed either too low for producers or too high for consumers.[34]

[33] For additional information, see EIA, "What Drives Crude Oil Prices?," https://www.eia.gov/finance/markets/crudeoil/, accessed September 15, 2020.

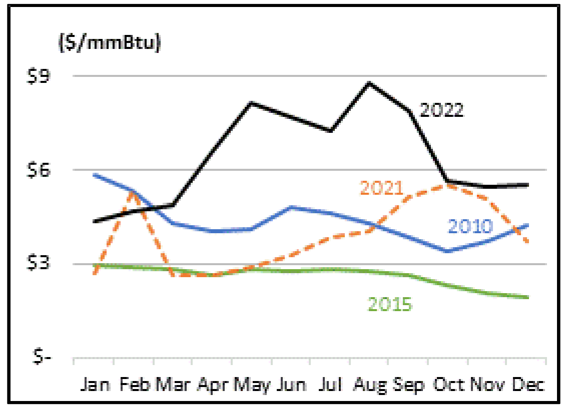
[34] During periods of low oil prices, policy options such as acquiring oil for the SPR, loans and loan guarantees, and (continued...)

Natural Gas: The United States Is a Global Player[35]

Russia's war against Ukraine has brought to the fore the strategic importance of natural gas and the rising role of the United States. In 2022, the United States was the largest producer, consumer, and exporter of natural gas.[36] This is, in part, because Russian pipeline exports to Europe were largely curtailed. The United States continues to import relatively small amounts of natural gas by pipeline from Canada and as liquefied natural gas (LNG) from Trinidad & Tobago to balance its regional demand.[37] Globally, 2022 saw natural gas prices hit highs never before reached. U.S. prices rose significantly (see **Figure 4**), but not to the same heights as in Europe and Asia.[38] TTF, one of Europe's benchmark natural gas prices, and JKM, Asia's benchmark, reached $90.77 per million British thermal unit (mmBtu) and $70.57 mmBtu in 2022, respectively, both record highs. In February 2023, U.S. prices fell below $3.00 and remained below that level for the rest of the year.

Figure 4. Monthly U.S. Natural Gas Prices

Selected Years 2010-2023



Source: CRS analysis of U.S. Energy Information Administration, *Natural Gas Spot and Futures Prices (NYMEX)*, updated December 15, 2023, http://www.eia.gov/dnav/ng/ng_pri_fut_s1_m.htm.

Note: Prices are spot prices and in nominal dollars. Units = dollars per million British thermal unit ($/mmBtu).

In response to the high prices, and in particular Europe's need to replace Russian imports because of the war, U.S. companies increased their exports of LNG. Additionally, U.S. government officials sought to encourage LNG producers domestically and internationally to export as much natural gas as possible to Europe. U.S. officials also asked LNG importers to forgo LNG cargos, so that the cargos could be sent to Europe.

Since the advent of shale gas in the mid-2000s, U.S. natural gas production increased and prices fell, while U.S. consumption of natural gas grew, rising about 38% from 2010 to 2022 (see **Figure 5**). In many years, the rise in consumption did not keep pace with production, so companies turned to exports, first by pipeline to Mexico and then as LNG to other parts of the world. (See "U.S. Exports," below.) As shown in **Figure 5**, domestic production and imports (supply) of natural gas were greater than consumption and exports (demand) in several years.

imposing trade tariffs have been explored. For additional information, see CRS Insight IN11246, *Low Oil Prices and U.S. Oil Producers: Policy Considerations*, by Phillip Brown and Michael Ratner. During periods of high oil and petroleum product prices, legislation such as the No Oil Producing and Exporting Cartels (NOPEC) Act has been introduced and debated. For additional information, see CRS In Focus IF11186, *No Oil Producing and Exporting Cartels (NOPEC) Act of 2019*, by Phillip Brown.

[35] Michael Ratner, CRS Specialist in Energy Policy, is the author of this section.

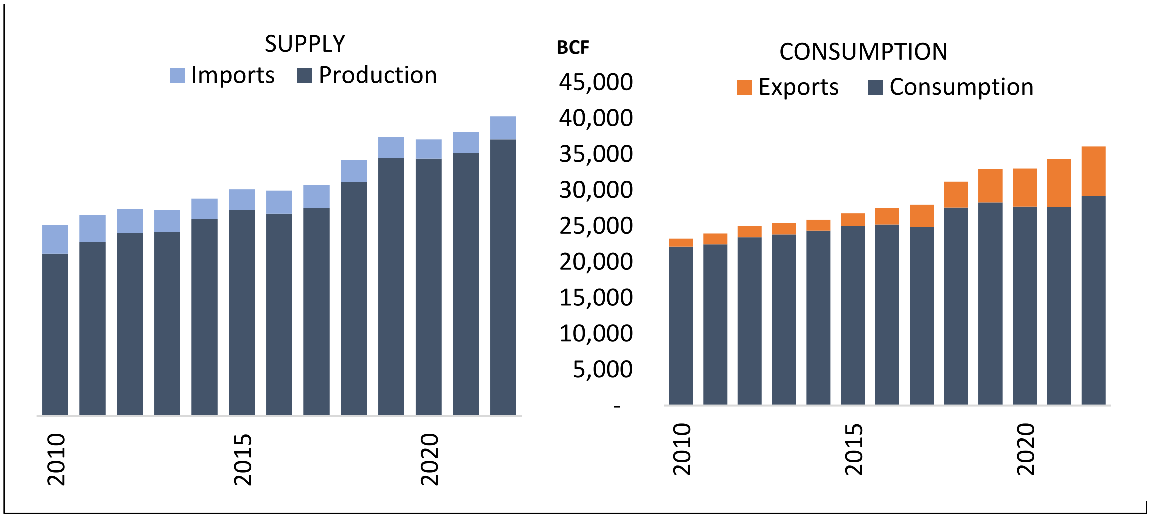
[36] Energy Institute, *Statistical Review of World Energy* 2023, 2023. (Before 2023, this report was published by BP.)

[37] Liquefied natural gas (LNG) is primarily methane that has been cooled to negative 260 degrees Fahrenheit. When natural gas is cooled to this temperature its volume contracts by 600 times, making it economical to transport on a ship.

[38] The spike in prices in February 2021 was caused by an extreme cold weather snap in the southern part of the United States. Natural gas production was temporarily halted, causing a shortage of supply and prices to skyrocket.

Figure 5. U.S. Natural Gas Supply and Demand, 2010-2022

Billion Cubic Feet



Source: CRS analysis of U.S. Energy Information Administration, http://www.eia.gov/naturalgas/data.cfm.

Note: Difference between the two columns for a given year in each chart is the volume of natural gas held in storage.

U.S. Supply

The United States is the world's largest producer of natural gas. Since 2010, U.S. natural gas production rose almost every year through 2022, even as prices declined. Production resumed growing in 2021 after a decline in demand because of the COVID-19 pandemic. It reached a new high in 2022. The increase in natural gas production between 2010 and 2022 is mostly attributed to the development of shale gas resources, specifically in the Marcellus and Utica formations in the northeastern United States (primarily Pennsylvania, New York and West Virginia). Overall, shale gas production accounted for 79% of total U.S. natural gas production in 2022;[39] the Marcellus and Utica formations in the northeast accounted for 40% of the U.S. shale gas production.

U.S. Consumption

The United States is the largest consumer of natural gas in the world, using more than 29,000 billion cubic feet (BCF) in 2022. Electric power generation made up 42% of U.S. natural gas consumption in 2022; industrial use accounted for 29%, residential use for 17%, and commercial use for 12%.[40] (See **Figure 6**.) Low natural gas prices, due to the growth of domestic gas resources, contributed to a significant rise in the use of natural gas for electric power generation. Additionally, some federal and state policies promote the use of fuels with lower greenhouse gas

[39] EIA, *Dry Shale Gas Production Estimates by Play*, https://www.eia.gov/naturalgas/weekly/img/202309_monthly_dry_shale.png, accessed October 10, 2023.

[40] EIA, *Natural Gas Consumption by End Use*, https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm, accessed September 30, 2023.

(GHG) emissions. Consumption of natural gas for power generation grew about 64% between 2010 and 2022.[41]

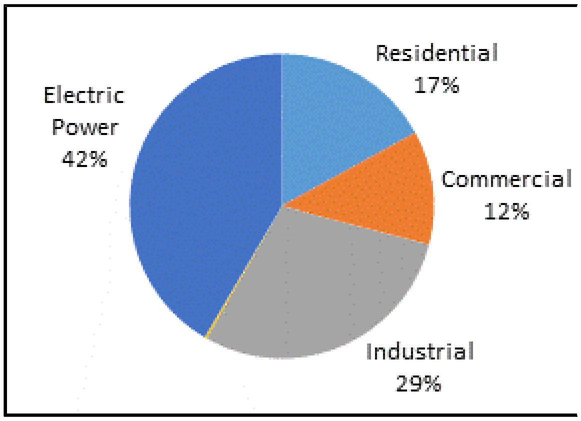
The U.S. industrial sector increased its consumption of natural gas by 25% between 2010 and 2022.[42] As the United States continues to expand its natural gas resource base, the industrial sector will see a wider array of fuel and feedstock choices, and manufacturing industries could also experience further growth.

U.S. Exports[43]

Between 2000 and 2008, the United States prepared to increase imports of LNG based on forecasts of growing consumption and flat supply, and companies began constructing LNG import terminals. However, the rise in natural gas prices gave the industry incentive to bring more domestic gas to market, reducing the need for imports. From 2010 to 2022, U.S. natural gas imports declined 19%.[44] Production surpassed consumption of natural gas in 2011, negating the need for growing imports.

The first U.S. LNG shipments from the lower 48 states occurred in February 2016 from the Sabine Pass LNG Terminal in Louisiana.[45] In 2017, the United States became a net exporter of natural gas, the first time since 1957.

Figure 6. U.S. Natural Gas Consumption by Sector, 2022



Source: CRS analysis of U.S. Energy Information Administration, *Natural Gas Consumption by End Use*, http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm, accessed December 15, 2023.

Note: Vehicle fuel represents roughly 0.2% of consumption.

Natural Gas Liquids

Most oil and gas wells produce a variety of hydrocarbons, including natural gas, oil, and natural gas liquids (NGLs),[46] as well as other gases and liquids (e.g., nitrogen, hydrogen sulfide, and water) and particulate matter. NGLs have taken on a greater prominence as the price for "dry" gas[47] dropped, primarily because of the increase in natural gas supply. In response to the price drop, the natural gas industry produced more "wet" gas[48] in order to bolster the value it receives

[41] EIA, *Natural Gas Consumption by End Use*, "U.S. Natural Gas Deliveries to Electric Power Consumers (Million Cubic Feet)," https://www.eia.gov/dnav/ng/hist/n3045us2a.htm, accessed September 30, 2023.

[42] EIA, *Natural Gas Consumption by End Use*, https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm, accessed September 30, 2023.

[43] For additional information on U.S. LNG exports, see CRS Report R42074, *U.S. Natural Gas Exports: New Opportunities, Uncertain Outcomes*, by Michael Ratner et al.; and CRS In Focus IF10878, *U.S. LNG Trade Rising, But No Domestic Shipping*, by Michael Ratner and John Frittelli.

[44] EIA, *U.S. Natural Gas Imports*, https://www.eia.gov/dnav/ng/hist/n9100us2a.htm, accessed September 30, 2023.

[45] The United States has exported LNG from Alaska since 1969.

[46] NGL is a general term for all liquid products separated from the natural gas stream at a gas processing plant and includes ethane, propane, butane, and pentanes. When NGLs are present with methane, which is the primary component of natural gas, the natural gas is referred to as either "hot" or "wet" gas. Once the NGLs are removed from the methane the natural gas is referred to as "dry" gas, which is what most consumers use.

[47] Natural gas without associated liquids.

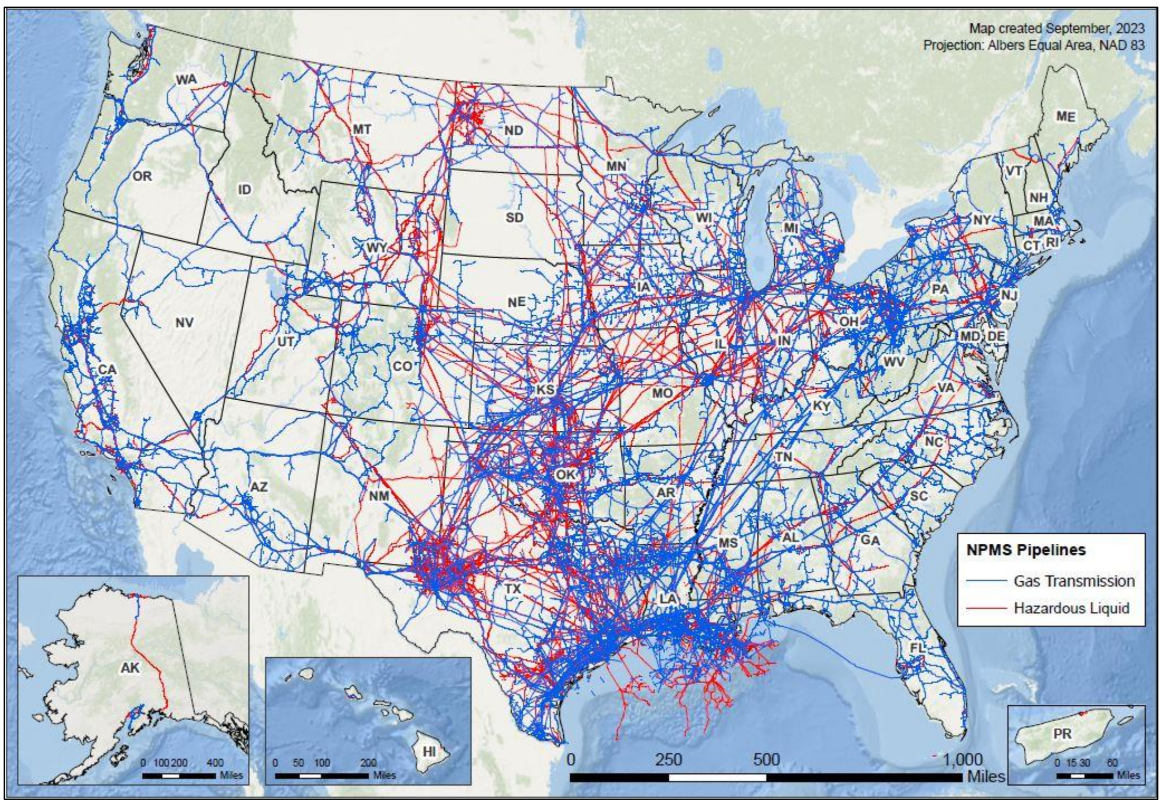
[48] Natural gas with associated liquids.

per well. Historically, individual NGL products prices, except for ethane, have been linked to oil prices. When oil prices were high relative to dry gas, it drove an increase of wet gas production, thereby maintaining production of dry gas as a "byproduct" despite its low price.

Pipelines: The Backbone of U.S. Oil and Gas Supply[49]

The U.S. pipeline network is integral to the nation's energy supply and provides vital links to other critical infrastructure, such as power plants, refineries, airports, and military bases. These pipelines are geographically widespread, running alternately through remote and densely populated regions—from Arctic Alaska to the Gulf of Mexico and nearly everywhere in between. The siting of interstate natural gas pipelines and U.S. pipeline border crossings is under federal jurisdiction. The siting of all other pipelines, including interstate crude oil and refined products pipelines, is under the jurisdiction of the states—although individual projects may still require federal approval for specific segments, such as water crossings or routes through federal lands.

Figure 7. U.S. Natural Gas Transmission and Hazardous Liquid Pipelines



Source: National Pipeline Mapping System (NPMS), "Gas Transmission and Hazardous Liquid Pipelines," September 15, 2023, https://www.npms.phmsa.dot.gov/Documents/NPMS_Pipelines_Map.pdf.

Notes: Hazardous liquids primarily include crude oil, gasoline, jet fuel, diesel fuel, home heating oil, propane, and butane. Other hazardous liquids transported by pipeline include anhydrous ammonia, carbon dioxide, kerosene, liquefied ethylene, and some petrochemical feedstocks.

[49] Paul Parfomak, CRS Specialist in Energy Policy, is the author of this section.

The onshore U.S. energy pipeline network is composed of approximately 3.3 million miles of pipeline transporting natural gas, oil, and other hazardous liquids (**Figure 7** and **Table 1**). Of the nation's approximately half-million miles of long-distance transmission pipeline, roughly 230,000 miles carry hazardous liquids—over 80% of the nation's crude oil and refined products—along with other products.[50] It also contains some 47,000 miles of crude oil gathering pipeline, which connects extraction wells to processing facilities prior to long-distance shipment. The U.S. natural gas pipeline network consists of around 301,000 miles of transmission and 434,000 miles of gathering lines. The natural gas transmission pipelines feed around 2.3 million miles of regional pipeline mains in some 1,500 local distribution networks serving over 70 million customers.[51]

Table 1. U.S. Hazardous Liquid and Natural Gas Pipeline Mileage, 2022

Category	Miles
Hazardous Liquids Transmission	229,374
Hazardous Liquids Gathering (2021)	47,126
Natural Gas Transmission	300,796
Natural Gas Gathering (2021)	434,076
Natural Gas Distribution Mains and Service Lines	2,321,509
TOTAL	**3,332,881**

Source: Hazardous liquids transmission, natural gas transmission, and natural gas distribution mains and service lines mileage is from PHMSA, "Annual Report Mileage Summary Statistics," web tables, October 2, 2023, http://www.phmsa.dot.gov/portal/site/PHMSA/menuitem.7c371785a639f2e55cf2031050248a0c/?vgnextoid=3b6c03347e4d8210VgnVCM1000001ecb7898RCRD&vgnextchannel=3b6c03347e4d8210VgnVCM1000001ecb7898RCRD&vgnextfmt=print. Hazardous liquids and natural gas gathering lines mileage is from Environmental Protection Agency, "Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2020: Updates Under Consideration for Activity Data," memorandum, September 2021, p. 3, https://www.epa.gov/system/files/documents/2021-09/2022-ghgi-update-activity-data_sept-2021.pdf. PHMSA also estimates "that there are over 400,000 miles of onshore gas gathering lines throughout the U.S." See 86 *Federal Register* 2017, November 15, 2021.

Notes: Hazardous liquids gathering mileage is for crude oil pipelines. The most recent comprehensive data for gathering pipelines comes from 2021; these data have not been updated. See note on hazardous liquids in **Figure 7**.

Natural gas pipelines also connect to 173 active liquefied natural gas storage sites, as well as underground storage facilities, both of which can augment pipeline gas supplies during peak demand periods.[52]

The oil pipeline infrastructure of the United States is fully integrated with that of Canada. Six major pipeline systems link oil-producing regions, refineries, and intermediate storage and transportation hubs in both countries. Although Canada-U.S. cross-border oil pipelines have been in place since the 1950s, pipeline capacity from Canada to the United States experienced a period of rapid growth between 2010 and 2015. During this time several cross-border pipelines were constructed and others were rebuilt or significantly expanded to provide increased takeaway

[50] Bureau of Transportation Statistics, "Crude Oil and Petroleum Products Transported in the United States by Mode," https://www.bts.gov/content/crude-oil-and-petroleum-products-transported-united-states-mode, accessed January 10, 2022.

[51] PHMSA, "Annual Report Mileage for Gas Distribution Systems," October 2, 2023, https://www.phmsa.dot.gov/data-and-statistics/pipeline/annual-report-mileage-gas-distribution-systems.

[52] PHMSA, "Liquefied Natural Gas (LNG) Facilities and Total Storage Capacities," October 2, 2023, https://www.phmsa.dot.gov/data-and-statistics/pipeline/liquefied-natural-gas-lng-facilities-and-total-storage-capacities.

capacity from the growing crude oil production in the Canadian oil sands. By comparison, U.S. liquid fuel pipeline connections to Mexico are limited, with several small-diameter pipelines between the two countries used primarily for U.S. refined product exports. Unlike oil, which is readily moved by vessels, railcars, and trucks, natural gas is transported among the United States, Canada, and Mexico almost entirely by pipeline. There are over 50 individual gas pipelines linking the United States and its neighbors at 24 border crossings to Canada and 19 border crossings to Mexico.

Pipeline Network Expansion from the Shale Boom

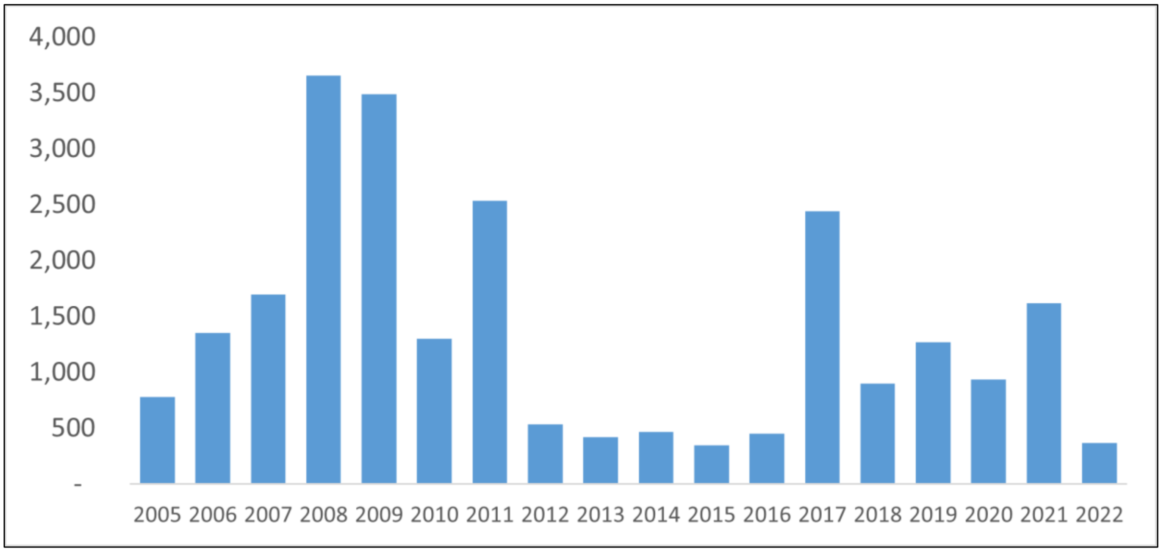
The rapid growth of U.S. natural gas and crude oil production from shale in the mid-2000s has led to a corresponding realignment and expansion of the nation's pipeline system. Developers and operators have invested billions of dollars to connect major new production regions, such as the Marcellus (Pennsylvania) and Bakken (North Dakota) shale basins, to traditional oil and gas markets. They have converted, reversed, and expanded existing pipelines; added relatively short laterals to supply new wholesale customers; and developed entirely new long-haul pipelines to fundamentally reconfigure oil and natural gas flows throughout North America.

Between 2005 and 2021, developers added nearly 63,000 miles of hazardous liquids transmission pipeline in the United States, an increase of approximately 38% in total reported mileage, not counting the expansion of capacity on existing pipelines.[53] During roughly the same period, total mileage for U.S. natural gas transmission grew 1%, in part due to retirements and conversions (i.e., to transport crude oil), but there were major investments to expand the capacity of existing lines and to construct major new connections to key markets. Altogether, developers expanded or constructed over 38,000 miles of interstate natural gas transmission between 2005 and 2022, most of it in the years immediately after the initial commercialization of shale gas resources (**Figure 8**).

[53] PHMSA, "Annual Report Mileage for Hazardous Liquid or Carbon Dioxide Systems," web table, October 2, 2023, https://www.phmsa.dot.gov/data-and-statistics/pipeline/annual-report-mileage-hazardous-liquid-or-carbon-dioxide-systems.

Figure 8. Annual U.S. Natural Gas Transmission Capacity Expansion and New Construction

Pipeline Mileage



Source: CRS analysis of U.S. Energy Information Administration (EIA), "U.S. Natural Gas Pipeline Projects," online spreadsheet, accessed February 24, 2023, https://www.eia.gov/naturalgas/pipelines/EIA-NaturalGasPipelineProjects.xlsx. EIA's figures are based on its analysis of regulatory filings and industry reports.

Notes: Capacity expansion may include adding a parallel line, increasing pipeline diameter, or adding additional compressor stations along a pipeline route to increase carrying capacity.

Although changes in the U.S. economy due to the COVID-19 pandemic and the war in Ukraine have temporarily disrupted global and domestic demand for gas, if long-term trends continue, some industry analysts expect continued expansion of U.S. gas pipeline infrastructure. A 2018 analysis by the INGAA Foundation, a pipeline industry research organization, projected the need for approximately 26,000 miles (1,400 miles annually) of new natural gas transmission pipeline between 2018 and 2035; in 2018, INGAA reported that total capital expenditure for these projects could range from $154 billion to $190 billion.[54]

Challenges to Pipeline Network Expansion

Over the last decade, proposals for new oil and natural gas transmission pipelines at both the federal and state levels have been subjected to greater public scrutiny and have become increasingly controversial. Many pipeline permit applications have faced significant challenges in permit application review and are the subject of protracted litigation. Pipeline proponents have based their support primarily on increasing the diversity of the U.S. energy supply and on expected economic benefits, including oil and gas production jobs and near-term job creation associated with pipeline construction and operation. Opponents, primarily environmental groups and affected communities along pipeline routes, have objected to these projects principally on the grounds that pipeline development has negative environmental impacts, disproportionately impacts disadvantaged communities, and promotes continued U.S. dependency on fossil fuels. As a result, major pipeline projects, especially natural gas projects in the Northeast and Mid-Atlantic,

[54] INGAA Foundation, "North American Midstream Infrastructure Through 2035: Significant Development Continues," June 18, 2018, p. 48. The INGAA Foundation is affiliated with the Interstate Natural Gas Association of America (INGAA), the interstate gas pipeline industry trade association.

have been denied permits or have been cancelled by their developers due to regulatory uncertainty, cost overruns, and unfavorable economics. Others, such as the Dakota Access Pipeline and the Spire STL Pipeline, have been constructed but have been subject to permit challenges and litigation. These complexities, and the potential for changing environmental policies to address the climate impacts of fossils fuels, make the trajectory for future pipeline development uncertain.

Coal: An Industry in Decline[55]

The U.S. coal industry has been declining for decades in part because of other fuels' technological improvements and more competitive prices. The Trump Administration rolled back or initiated reversing several coal-related regulations that were finalized under the Obama Administration. This effort coincided with the emergence of three of the largest coal producers from Chapter 11 bankruptcy, higher coal prices, lower inventories, and higher natural gas prices (which have reverted in 2023)—factors that could improve coal's competitiveness as a fuel for electricity generation. However, in May 2023 the Biden Administration proposed new carbon dioxide emission standards from fossil fuel power plants that could require coal plants to install carbon capture technology, or to employ other emissions-reduction strategies such as co-firing with natural gas or hydrogen.[56] Coal will likely remain an essential component in the U.S. energy picture, but how big a role it will play remains an open question.

Coal Reserves and Production

The United States has the largest coal reserves and resources in the world.[57] EIA estimated in 2022 that there were about 12 billion short tons of recoverable domestic coal reserves, down from 15 billion short tons in 2018 and 17 billion short tons in 2001.[58] The total demonstrated U.S. reserve base (DRB) in 2022 was estimated at about 470 billion short tons, down from 499 billion short tons in 2000.[59] The majority of coal from Western states[60] is produced from surface mines (91%), while the majority of coal from Appalachian and Interior states is produced from underground mines (82% and 67%, respectively).[61]

---

55 Lexie Ryan, Analyst in Energy Policy, and Brent Yacobucci, Section Research Manager, are the authors of this section.

56 Environmental Protection Agency, *Greenhouse Gas Standards and Guidelines for Fossil Fuel-Fired Power Plants*, updated November 15, 2023, https://www.epa.gov/stationary-sources-air-pollution/greenhouse-gas-standards-and-guidelines-fossil-fuel-fired-power.

57 BP, *Statistical Review of World Energy*, London, July 2021, p. 44. For something to be categorized a reserve, it must be reasonably certain that it can be recovered in the future from known resources under existing economic and operating conditions. It must also be able to reach a market. Reserves are a subset of resources, which is a broader estimation.

58 A short ton, a measurement of weight often used in the United States, is 2,000 pounds. A metric ton, commonly used internationally, is about 2,200 pounds (1,000 kilograms).

59 EIA, *Annual Coal Report 2022*, Washington, DC, October 2023, p. 25, https://www.eia.gov/coal/annual/pdf/acr.pdf, and EIA, *Coal Data Browser*, Washington, DC, October 2023, https://www.eia.gov/coal/data/browser/#/topic/31?agg=0,1&mntp=g&geo=vvvvvvvvvvvvo&linechart=COAL.RECOVER_RESERVE.TOT-US.A&columnchart=COAL.RECOVER_RESERVE.TOT-US.A&map=COAL.RECOVER_RESERVE.TOT-US.A&freq=A&start=2001&end=2022&ctype=linechart&ltype=pin&rtype=s&maptype=0&rse=0&pin=.

60 Ibid. "The Western coal region includes Alaska, Arizona, Colorado, Montana, New Mexico, North Dakota, Utah, Washington, and Wyoming."

61 Ibid. "The Appalachian coal region includes Alabama, Eastern Kentucky, Maryland, Ohio, Pennsylvania, Tennessee, (continued...)

U.S. coal production and reserves are highly concentrated. EIA statistics show that more than half of U.S. coal reserves are located in the West, with Montana and Wyoming together accounting for 42%. According to EIA, 41% of U.S. coal in 2021 was produced in Wyoming, while 14% came from West Virginia.[62] The top five producing states—Wyoming, West Virginia, Pennsylvania, Illinois, and Kentucky—accounted for 73% of U.S. coal production in 2021.[63]

Even though U.S. coal production reached its highest level of production in 2008 (1.17 billion short tons) and remained strong until 2014 (at or near 1 billion short tons per year), coal is losing its share of overall U.S. energy production and consumption, primarily to natural gas in electricity generation. Coal production declined 41% between 2014 and 2022 (see **Table 2**). EIA projections show coal production continuing a steady decline through the 2020s, and remaining around 300 million short tons through the 2030s.[64] The softening of demand for coal has been attributed to utilities opting for low-cost natural gas, declining costs for renewable energy options, increasing regulatory costs associated with coal-fired power plants, and lower demand for U.S. coal exports (see **Table 2**). EIA projects long-term demand growth in the Asian coal market, but long-term penetration of U.S. coal exports into this market remains uncertain.[65]

Coal mining employment declined from roughly 174,000 in 1985 to roughly 72,000 in 2000 (a 58% decline), then rose to a recent high of about 87,000 in 2011 before falling to roughly 40,000 in 2022 (see **Figure 9**).[66] A similar pattern was true for the number of coal mines, as the majority of the decline occurred between 1985 and 2000, when the number of coal mines fell by 55% (from 3,355 to 1,513) before declining further by 64% from 2000 to 2022 (from 1,513 to 548).[67] The number of coal mining firms has decreased in the United States, while the size of the average mine and output per mine and per worker have increased.

Virginia, and West Virginia.... The Interior coal region includes Arkansas, Illinois, Indiana, Kansas, Louisiana, Mississippi, Missouri, Oklahoma, Texas, and Western Kentucky."

[62] EIA, *Coal Explained*, October 19, 2022, https://www.eia.gov/energyexplained/coal/where-our-coal-comes-from.php.

[63] Ibid.

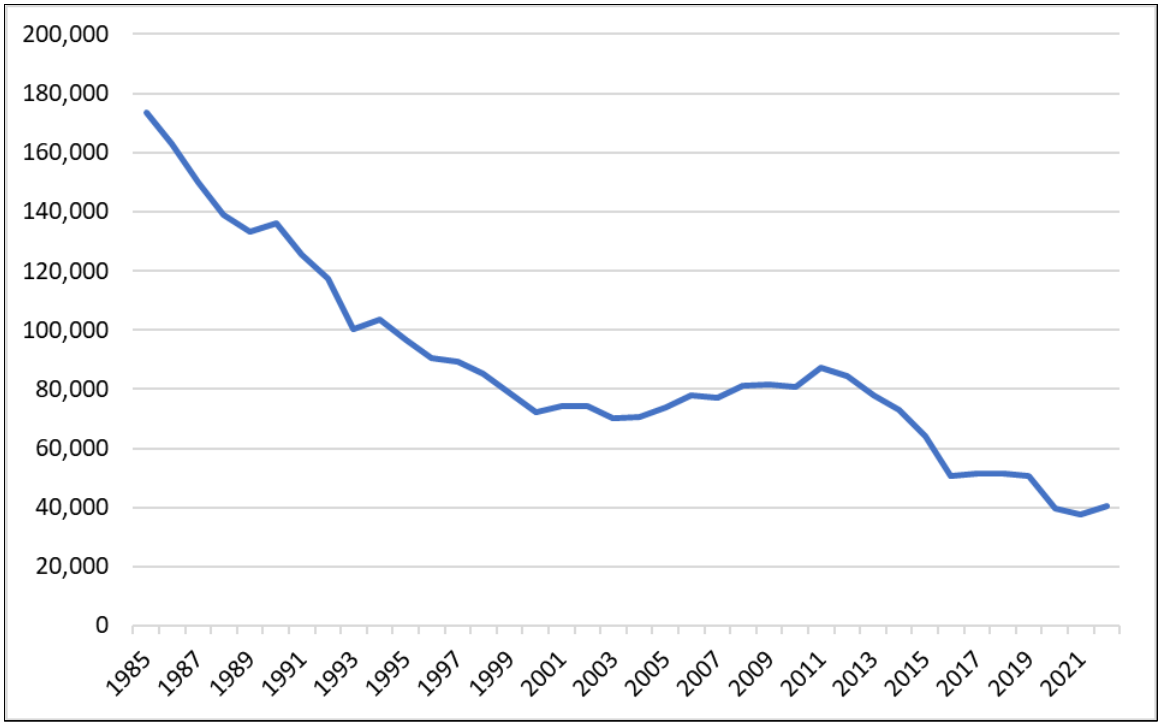
[64] EIA, *Annual Energy Outlook 2023*, Washington, DC, March 16, 2023, https://www.eia.gov/outlooks/aeo/. Based on EIA's reference case scenario.

[65] EIA, Quarterly Coal Report, October-December 2017, April 2018, p. 11.

[66] Bureau of Labor Statistics, *Employment, Hours, and Earnings from the Current Employment Statistics Survey (National)*, https://data.bls.gov/pdq/SurveyOutputServlet, accessed October 3, 2023.

[67] EIA, *Annual Coal Report 2022*, Washington, DC, October 2023, p. 27, https://www.eia.gov/coal/annual/pdf/acr.pdf.

Figure 9. Coal Mining Employment, 1985-2022



Source: Bureau of Labor Statistics, *Employment, Hours, and Earnings from the Current Employment Statistics survey (National)*, accessed October 3, 2023, https://data.bls.gov/pdq/SurveyOutputServlet.

Notes: Series title: all employees, thousands, coal mining, seasonally adjusted. Monthly data averaged over each year.

Coal Consumption

Coal consumption in the United States was consistently near or over 1 billion short tons per year from 2000 (peaking in 2007 at 1.128 billion short tons) until 2012, when demand fell below 900 million short tons (pre-1990 levels). As shown in **Table 2**, consumption has declined further since 2012, reaching 513 million short tons in 2022. EIA projects annual coal consumption to fall below 200 million short tons by 2050. Power generation is the primary market for coal, accounting for over 90% of total consumption. Other end uses for coal include production of iron and steel.[68] With the retirement of many coal-fired power plants and the building of new gas-fired plants, there has been a structural shift in demand for U.S. coal. A structural shift would mean long-term reduced capacity for coal-fired electric generation.[69] Thus, coal could likely be a smaller portion of total U.S. energy consumption for years to come. As noted earlier, in 2016, natural gas overtook coal as the number-one energy source for power generation.

[68] EIA, *Monthly Energy Review*, October 26, 2023, Section 6, https://www.eia.gov/totalenergy/data/monthly/pdf/sec6.pdf.

[69] The costs of modernizing older power plants to meet new regulatory requirements can be relatively high. When the cost of upgrades to meet new environmental requirements is considered along with (perhaps increasing) operation and maintenance expenses, many older coal power plants are likely to face retirement. EIA projects many more U.S. coal-fired plants to be retired and replaced with natural gas and renewable energy facilities as coal plants become too expensive to maintain or upgrade. Another consideration is the capacity factor (utilization) of coal plants. As they are used less regularly (because renewables and natural gas outcompete them on cost), their revenue and profits decrease. Operators may choose to retire an underutilized plant rather than maintain it.

Table 2. U.S. Coal Production, Consumption, and Exports, 2000-2022

Million short tons

Year	Total Production	Total Consumption	Total Exports
2000	1,073.6	1,084.1	58.5
2001	1,127.7	1,060.1	48.7
2002	1,094.3	1,066.4	39.6
2003	1,071.8	1,094.9	43.0
2004	1,112.1	1,107.3	48.0
2005	1,131.5	1,126.0	49.9
2006	1,162.8	1,112.3	49.6
2007	1,146.6	1,128.0	59.2
2008	1,171.8	1,120.5	81.5
2009	1,075.0	997.5	59.1
2010	1,084.4	1,048.5	81.7
2011	1,095.6	1,002.9	107.3
2012	1,016.5	889.2	125.7
2013	984.8	924.4	117.7
2014	1,000.0	917.7	97.3
2015	896.9	798.1	74.0
2016	728.4	731.1	60.3
2017	774.1	716.9	96.9
2018	756.2	688.1	116.2
2019	706.3	586.5	93.8
2020	535.4	476.7	69.1
2021	577.4	545.7	85.1
2022	594.2	512.6	86.0

Source: EIA, *Monthly Energy Review*, July 2023, Table 6.1, https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf.

Notes: U.S. Coal production peaked in 2008 at 1,171.8 million short tons.

Coal Exports

One of the big questions for the industry is how to penetrate the overseas coal market, particularly for steam coal,[70] to compensate for declining domestic demand. EIA forecasts coal exports to decline to 74 million short tons in 2021, before rising to about 100 million short tons per year out to 2050.[71] Exports to the Asian market are expected to increase, but there are potential bottlenecks such as infrastructure (e.g., port development and transportation) that could slow export growth.

[70] Steam coal is used to generate steam for electrical power plants, while metallurgical coal is used for steel production.

[71] EIA, *Annual Energy Outlook 2023*, February 3, 2021, p. 13, https://www.eia.gov/outlooks/aeo/pdf/AEO2023_Narrative.pdf.

Several key factors are likely to influence how much coal will be exported from the United States in the future, one of which is whether new export terminals are built, particularly for coal from the Powder River Basin (PRB) in Wyoming and Montana. Another major factor is the level of global demand for metallurgical (met) coal, which is used to make steel. Historically, met coal has represented the majority of coal exported by the United States, accounting for as much as two-thirds of exports in some years.[72] Some PRB coal is exported from Canadian terminals at Roberts Bank (near Vancouver, British Columbia) and Ridley Terminal at Prince Rupert, British Columbia. PRB coal is transported to both facilities for export via railway.

PRB coal producers have sought to export via the Pacific Northwest to supply growing Asian market, without success. For example, three port terminal projects for exporting coal in Washington and Oregon had permit applications before state regulators and the U.S. Army Corps of Engineers (the Corps), although none were successful.[73]

U.S. Coal-Producing Industry

The U.S. coal industry is highly concentrated, with a handful of major producers operating primarily in five states—Wyoming, West Virginia, Pennsylvania, Illinois, and Kentucky, in order of volume. In 2022, the top five coal mining companies were responsible for 51% of U.S. coal production, led by Peabody Energy Corp., with 17.2%, and Arch Resources, Inc., with 13.2% (see **Table 3**). Other major producers include the Navajo Transitional Energy Co., ACNR Holdings, Inc., and Alliance Resource Partners.

Three of the top five coal producers filed for Chapter 11 bankruptcy protection between 2015 and 2016: Alpha Natural Resources, LCC (August 2015), Arch Coal (February 2016), and Peabody Energy Corp. (April 2016). Other major producers, such as Patriot Coal, Walter Energy, James River Coal, Armstrong Energy, and FirstEnergy Solutions have filed as well. All told, over 50 coal producers have filed for bankruptcy since 2015, with more than $19.3 billion in debt being reorganized. The top-two largest producers, both of which filed for bankruptcy, accounted for nearly 33% of U.S. coal production in 2016.

Arch Coal, ANR Inc.,[74] and Peabody Energy emerged from Chapter 11 bankruptcy with plans to move forward, all three shedding substantial debt. Opponents are critical of the plans and of the long-term viability and reliability of the U.S. coal industry.[75] Major challenges for the U.S. coal industry will be to obtain the level of financing needed for new or expanded projects and to become profitable in a market with declining domestic demand.

---

[72] EIA, *Coal Data Browser*, https://www.eia.gov/coal/data/browser/.

[73] A permit from the Corps is needed for any project that discharges dredge or fill material in waters of the United States or wetlands, pursuant to provisions in Section 404 of the Clean Water Act; and for the construction of any structure in, over, or under navigable waterways of the United States, including excavation, dredging, or deposition of these materials in these waters, pursuant to Section 10 of the Rivers and Harbors Act of 1899. The proposed projects in Washington and Oregon would involve such activities and must obtain either or both a Section 404 and Section 10 permit from the Corps before the projects can proceed. Discussion of the Corps permit requirements is beyond the scope of this report.

[74] Alpha Natural Resources, LLC, emerged from bankruptcy as two distinct entities: ANR, Inc., and Contura Energy Inc.

[75] Heather Richards, "Does the Sale of Contura Coal Mines Herald a Change in the Northeast Wyoming? Depends on Who You Ask," *Casper Star Tribune*, December 16, 2017, https://trib.com/business/energy/does-the-sale-of-contura-coal-mines-herald-a-change/article_2322fa81-d1b7-5c0b-8de9-d048156fa255.html.

Table 3. Leading U.S. Coal Producers and Percentage of U.S. Coal Production

2022		2010		2000	
Producer	Percentage of Total	Producer	Percentage of Total	Producer	Percentage of Total
Peabody Energy Corp.	17.2	Peabody Coal Co.	17.7	Peabody Coal Co.	13.1
Arch Resources, Inc.	13.2	Arch Coal, Inc.	16.0	Arch Coal, Inc.	10.1
Navajo Transitional Energy Co.	8.6	Cloud Peak Energy	8.6	Kennecott Energy	9.9
ACNR Holdings, Inc.	6.1	Alpha Natural Resources	7.4	CONSOL Energy, Inc.	6.9
Alliance Resource Partners	6.0	CONSOL Energy, Inc.	5.7	RAG	5.9

Source: U.S. Energy Information Administration (EIA), *Annual Coal Report 2022*, released October 5, 2023, https://www.eia.gov/coal/annual/. EIA, *Annual Coal Report 2010*. EIA, *Coal Industry Annual 2000*.

Notes: In 2020, Arch Coal, Inc., changed its name to Arch Resources, Inc. In 2021, Peabody Coal Company changed its name to Peabody Energy Corporation.

The Electric Power Sector: In Transition[76]

The electric power industry is in the process of transition, with a shift in energy sources used to generate electricity and a growing presence of customer-sited generation sources. At the same time, the electricity infrastructure of the United States is aging, and uncertainty exists around how best to modernize the grid to reliably accommodate the changes in generation. Unresolved questions about electricity reliability also are arising due to the changing energy mix, as well as cybersecurity threats and recent high profile physical attacks. Electricity supply chains, including the source of some critical minerals used in electricity system equipment, are growing areas of congressional interest. Congress has played a role already in this transition (e.g., with tax credits for renewable energy), and may continue to be faced with policy issues regarding this industry. States have also played major roles in this area through renewable portfolio standards (RPS),[77] and regional carbon pricing programs, such as the Regional Greenhouse Gas Initiative (RGGI), among other programs.[78]

Supply and Demand

The U.S. electric power sector consists of all the power plants generating electricity, together with the transmission and distribution lines, and their associated transformers and substations which bring power to end-use customers. Electricity must be available upon demand, is rarely stored in bulk, and is generally consumed as soon as it is produced. Approximately two-thirds of U.S. electricity consumers are in regions of the country served by competitive wholesale electricity markets, where companies compete to supply electricity to consumers generally at the lowest cost (considering reliability and environmental requirements). The remaining third of consumers are

[76] Ashley Lawson, Specialist in Energy Policy, is the author of this section.

[77] CRS Report R45913, *Electricity Portfolio Standards: Background, Design Elements, and Policy Considerations*, by Ashley J. Lawson.

[78] CRS Report R41836, *The Regional Greenhouse Gas Initiative: Background, Impacts, and Selected Issues*, by Jonathan L. Ramseur.

served by electric utilities that operate under what is sometimes called a "cost-of-service model," where rates for electricity are established by a state regulatory body based on the utility's cost of providing electric power to customers (i.e., its cost-of-service).[79]

Electric power generation in the United States is currently dominated by the use of combustible fossil fuels, mostly natural gas and coal. These fuels are burned to produce steam in boilers that turn steam turbine-generators or, in the case of natural gas, burned directly in a combustion turbine to produce electricity.[80] Another major source of electricity is nuclear power (see "Nuclear Power: Federal Support for Advanced Reactors"), which uses heat from the fission of radioactive elements such as uranium and plutonium to produce steam to turn a generator. Electricity can also be generated mechanically by wind turbines and hydropower, or by solar photovoltaic panels (PV), which convert light directly into electricity. Geothermal energy power plants use natural underground steam to run turbine generators or may use the heat from hot underground rock formations to make steam for that purpose.

The choice of power generation technology in the United States is heavily influenced by the cost of fuel. Historically, the use of fossil fuels has provided some of the lowest prices for generating electricity. As a result, fossil fuels (coal and natural gas) have accounted for about two-thirds of electricity generation since 2000.[81] However, while some renewable sources of electricity (notably wind and solar PV power) do not require a fuel, the electricity they produce varies with the wind and available sunlight. Prices for wind turbines and solar panels have fallen in the last decade, resulting in increased use of these sources (see "Renewable Electricity").

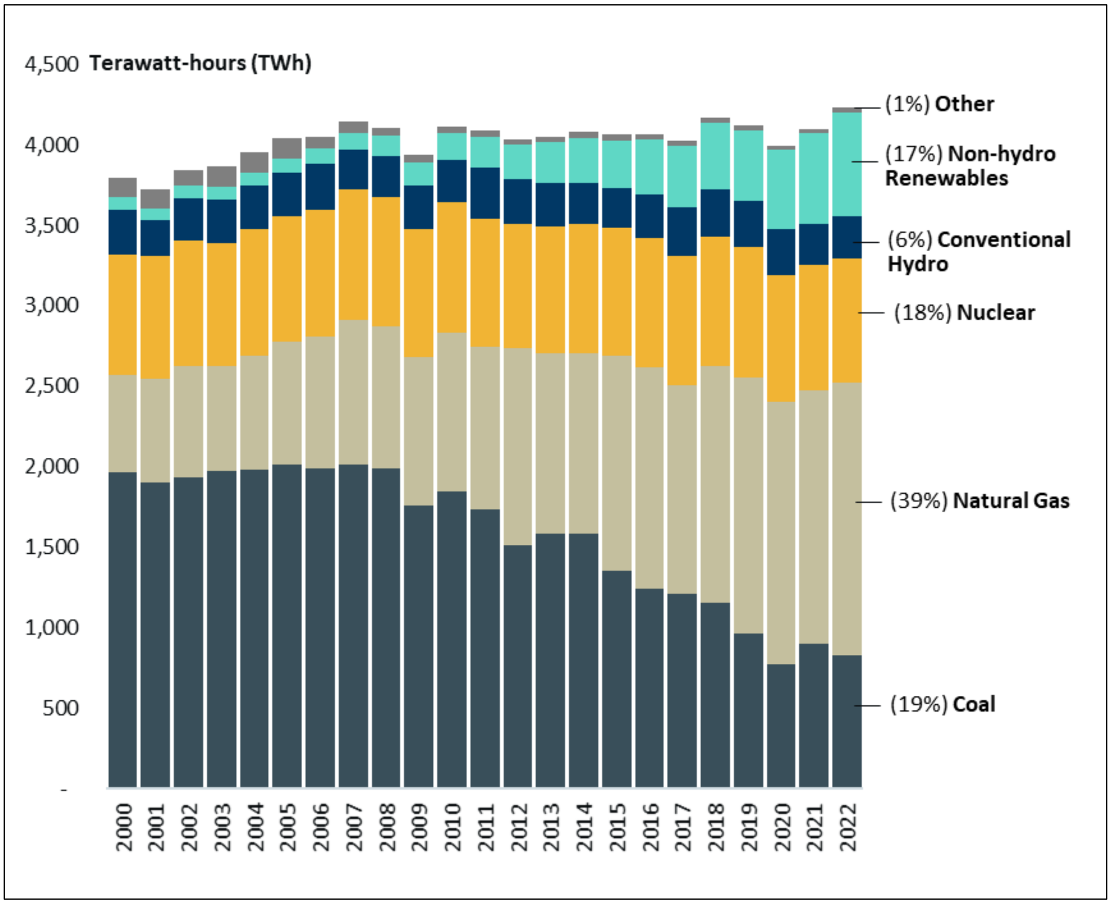
Figure 10 illustrates the changing mix of fuels used for U.S. electric power generation from 2000 to 2022. Beginning in 2016, natural gas overtook coal as the largest percentage of net electricity generation. In 2020, renewable energy sources (including hydropower) surpassed nuclear as the third largest contributor to total generation.

[79] "Cost-of-service" is a ratemaking concept used for the design and development of rate schedules to ensure that the filed rate schedules recover only the cost of providing the electric service, including a reasonable rate of return to the provider, at issue. This concept attempts to correlate the utility's costs and revenue with the service provided to each of the various customer classes.

[80] The exhaust heat from gas combustion turbines is typically used to make steam for additional electricity generation (in natural gas combined-cycle power plants).

[81] In most years since 2000, the share of U.S. net electricity generation from coal and natural gas ranged from 60% to 70%. The exception was 2020, when the combined share was 59%. The U.S. generation profile that year was affected by overall reductions in electricity demand caused in large part by responses to the COVID-19 pandemic.

Figure 10. U.S. Net Electricity Generation by Fuel, 2000-2022



Sources: Data for 2000-2010 from U.S. Energy Information Administration (EIA), *Electric Power Annual 2010*, Table 2.1.A, November 2011, and data for 2011-2021 from EIA, *Electric Power Annual 2021*, Table 3.1.A, November 2022. Data for 2022 from EIA, *Monthly Energy Review*, March 2023.

Notes: "Other" includes petroleum liquids, petroleum coke, pumped storage (which tends to be a negative value), blast furnace gas and other manufactured and waste gases derived from fossil fuels, non-biogenic municipal solid waste, batteries, hydrogen, purchased steam, sulfur, tire-derived fuel, and other miscellaneous energy sources. "Non-hydro Renewables" includes wood, black liquor, other wood waste, biogenic municipal solid waste, landfill gas, sludge waste, agricultural byproducts, other biomass, geothermal, solar thermal, solar photovoltaic, and wind. Beginning in 2014, EIA reported net generation from small-scale solar photovoltaic facilities which are also included in Non-hydro Renewables.

The shift in the share of coal and natural gas reflects a range of factors, predominantly the changing economics of power generation. Historically, since coal was readily available across a large part of the United States, coal power plants were able to dominate electricity production for many decades. However, increased natural gas supply and lower prices, improvements in natural gas combined-cycle generation technology, and the costs of compliance with environmental regulations for coal plants have led to older, less-efficient coal plants being used less or retired from service.

U.S. Consumption

For many years, the growth in sales of electricity was closely related to growth in the economy. However, a decoupling of growth in electricity demand from growth in gross domestic product (GDP) has occurred, mostly because of efficiency improvements across the economy. According to EIA, the linkage has been declining over the last 60 years, as U.S. economic growth is outpacing electricity use.[82] U.S. electricity generation (an approximate measure of consumption) has been relatively flat since the mid-2000s, as shown in **Figure 10**.

Action by the 117th Congress to promote greater electrification across the economy could potentially change electricity consumption patterns. For example, the Infrastructure Investment and Jobs Act (IIJA; P.L. 117-58) provided $2.5 billion for alternative fuel infrastructure, such as electric vehicle charging equipment. P.L. 117-169, commonly known as the Inflation Reduction Act of 2022, includes additional incentives for electric vehicles, such as a tax credit of up to $7,500 for the purchase of qualifying vehicles. The IRA also funds a rebate program for purchase of qualifying electric products, such as heat pumps and electric stoves.[83] These laws also include provisions aimed at promoting energy efficiency (see "Energy Efficiency: An Untapped Resource"), which generally counteracts increased electricity demand from greater electrification of energy end uses. On net, most analysts expect electricity consumption to increase moving forward, in part because of electrification incentives in these laws. Of note: It may take a decade or more for electrification to affect national trends in energy consumption, because of the turnover time in certain sectors. For example, vehicle stocks turn over relatively slowly.[84]

Nuclear Power: Federal Support for Advanced Reactors[85]

Nuclear power has supplied about one-fifth of annual U.S. electricity generation during the past three decades. In 2022, nuclear reactors generated 18% of U.S. electricity supply, behind natural gas, coal, and renewable energy (including conventional hydropower).[86] Ninety-three reactors are currently operating at 54 plant sites in 28 states.[87] They generated electricity at 92.7% of their total capacity in 2022, the highest rate of any generation source.[88] Total net generation of nuclear power in 2022 was 772 billion kilowatt-hours.[89]

One new reactor, at the Vogtle nuclear power plant in Georgia, began operation in June 2023, and a twin unit was connected to the grid on March 1, 2024, with commercial operation scheduled for

[82] "Total annual U.S. electricity consumption increased in all but 11 years between 1950 and 2021, and 8 of the years with year-over-year decreases occurred after 2007." EIA, *Electricity Explained: Use of Electricity*, updated May 3, 2022, https://www.eia.gov/energyexplained/electricity/use-of-electricity.php.

[83] CRS In Focus IF12258, *The Inflation Reduction Act: Financial Incentives for Residential Energy Efficiency and Electrification Projects*, by Martin C. Offutt.

[84] "The transportation-related provisions [of the IRA] are likely to take longer to yield [greenhouse gas] emissions reductions than the provisions affecting the electric power sector due to the duration of vehicle stock turnover cycles. For instance, the Princeton study indicates that the emissions reductions in 2035 in the transportation sector are almost double the reductions in 2030." CRS Report R47385, *U.S. Greenhouse Gas Emissions Trends and Projections from the Inflation Reduction Act*, by Jonathan L. Ramseur. Transportation sector greenhouse gas emissions reductions are closely associated with the pace of transportation electrification.

[85] Mark Holt, CRS Specialist in Energy Policy, is the lead author of this section.

[86] EIA, "Net Generation for All Sectors, Annual," Electricity Data Browser, online database, http://www.eia.gov/electricity/data/browser/, accessed October 27, 2023.

[87] EIA, *Nuclear Explained: U.S. Nuclear Energy Industry*, accessed October 27, 2023.

[88] EIA, *Electric Power Monthly with Data for August 2023*, Tables 6.7.A and 6.7.B, https://www.eia.gov/electricity/monthly. Other 2022 capacity factors for major generation sources were coal, 48.4%; natural gas combined-cycle, 56.6%; geothermal, 69.0%; hydropower, 36.3%; solar photovoltaic, 24.4%; and wind power, 35.9%.

[89] Ibid., Table 1.1. Net generation excludes electricity used to operate the power plant.

the second quarter of 2024.[90] Six additional new reactors have received licenses from the Nuclear Regulatory Commission (NRC), but construction of those projects is uncertain; other projects that were issued licenses have subsequently been terminated.[91] Aside from the Vogtle units, two other reactors, at the Watts Bar plant in Tennessee, have begun operation during the past three decades, while several nuclear plants have permanently closed.

Although existing U.S. reactors have operated well, economic factors have been the main source of stress for the U.S. nuclear power industry. Thirteen reactors have permanently closed since the beginning of 2013.[92] Construction of two new reactors at the Summer plant site in South Carolina was cancelled following a bankruptcy filing in 2017 by the project's lead contractor, Westinghouse Electric Company.[93] Most of the closed nuclear power plants sold their electricity at competitive market prices, in contrast to plants that recover their costs (including a reasonable rate of return) through regulated rates. Nuclear plants that rely on power markets have seen low average wholesale power prices and stagnant demand (see "U.S. Consumption" above), combined with relatively high operating and capital costs in some cases, particularly at plants with a single reactor.[94]

Congress has recently enacted sharply higher funding and tax credits to support new reactor construction, largely because of nuclear power's low carbon emissions. Much of this interest in new nuclear power plants is focused on "advanced" reactors, which would use different technology from that of existing plants. Proponents contend that advanced reactors would be smaller and cheaper than existing commercial reactors, although the economics of these proposed designs have yet to be demonstrated. There is also considerable interest in "small modular reactors," which would be smaller than today's commercial reactors and could use a variety of technologies.

Some contend that electricity markets are undervaluing the reliability of nuclear generation, its role in diversifying the nation's power supply, and its importance in reducing greenhouse gas emissions.[95] Nuclear power accounted for 48% of U.S. sources considered to be zero-carbon electricity generation in 2021.[96] Several states have established programs to preserve nuclear power as a non-direct carbon emitting electricity source.[97]

At the federal level, as part of the IIJA (P.L. 117-58), Congress enacted a new Civil Nuclear Credit Program. Under this program, existing nuclear reactors that face closure because of economic factors may be eligible for credits from DOE. DOE announced a final Civil Nuclear Credit award totaling up to $1.1 billion to the two-unit Diablo Canyon plant in California on

[90] Georgia Power, *Vogtle Unit 4 Connects to Electric Grid for the First Time*, March 1, 2024, https://www.georgiapower.com/company/news-center/2024-articles/vogtle-unit-4-connects-to-electric-grid-for-the-first-time.html.

[91] Nuclear Regulatory Commission (NRC), "Combined License Applications for New Reactors," updated July 3, 2023, https://www.nrc.gov/reactors/new-reactors/col.html.

[92] NRC, *Information Digest 2022-2023*, Appendix C, https://www.nrc.gov/docs/ML2304/ML23047A378.pdf.

[93] Brad Plumer, "U.S. Nuclear Comeback Stalls as Two Reactors Are Abandoned," *New York Times*, January 20, 2018, sec. Climate, https://www.nytimes.com/2017/07/31/climate/nuclear-power-project-canceled-in-south-carolina.html.

[94] For more information, see CRS Report R44715, *Financial Challenges of Operating Nuclear Power Plants in the United States*, by Phillip Brown and Mark Holt.

[95] For example, see "Electricity Markets: Markets Must Value Clean, Reliable, Sustainable Energy," Nuclear Energy Institute, https://www.nei.org/advocacy/preserve-nuclear-plants/electricity-markets.

[96] EIA, "U.S. Energy-Related Carbon Dioxide Emissions, 2019," Figure 6, December 14, 2022, https://www.eia.gov/environment/emissions/carbon/.

[97] CRS Report R46820, *U.S. Nuclear Plant Shutdowns, State Interventions, and Policy Concerns*, by Mark Holt and Phillip Brown.

January 2, 2024.[98] P.L. 117-169, the IRA, established two new tax credits that would support new and existing nuclear power plants. The zero-emission nuclear power production credit applies to existing power plants, while the clean electricity production tax credit would apply to any new zero-emission power plant, including new nuclear. (See text box below.)

Recently Enacted Support for Nuclear Power

Section 40323 of the IIJA (P.L. 117-58) established a new Civil Nuclear Credit Program. Under this program, existing nuclear reactors that sell their electricity in competitive wholesale markets are eligible for credits if the Secretary of Energy certifies that the reactors are likely to close because of economic factors, that such closure would result in increased pollution, and that the Nuclear Regulatory Commission (NRC) has reasonable assurance that the reactor will operate safely. Owners or operators of reactors certified by the Secretary can submit bids to receive credits for four years. The IIJA appropriated $6 billion for the program. In November 2022, DOE announced a conditional award of $1.1 billion for the Diablo Canyon Power Plant in California and finalized the award in January 2024. A second award cycle closed May 31, 2023.

Section 41002 of the IIJA appropriated $2.5 billion over four years for the Advanced Reactor Demonstration Program established in the Energy Act of 2020 (P.L. 116-260).

Section 13105 of the IRA (P.L. 117-169) established a tax credit (I.R.C. §45U) per kilowatt-hour of electricity produced at nuclear plants in operation before August 4, 2022. The credit is reduced based on the amount of electricity produced and wholesale electricity rates in a given year. Producers may qualify for a bonus credit five times the base amount if certain wage requirements are met.

Section 13701 of the IRA established a new clean electricity production tax credit (I.R.C. §45Y) that replaces the existing renewable electricity production tax credit for facilities placed in service after December 31, 2024. The new credit applies to facilities with greenhouse gas emissions rates no greater than zero, including new nuclear facilities. Like the nuclear tax credit, the credit is increased if certain prevailing wage requirements are met. There is a further bonus credit if the facility is placed in an "energy community," generally defined as a brownfield site or an area with a history of fossil fuel industries in decline.

Reactors funded by DOE's Advanced Reactor Demonstration Program are intended to be safer, more efficient, and less expensive to build and operate than today's conventional light water reactors (LWRs), which use ordinary water as a coolant and for moderating (slowing) the neutrons in the nuclear chain reaction. Some of the designs are also intended to produce less long-lived radioactive waste than existing reactors. Nearly all advanced designs currently under development would be far smaller than conventional reactors, which typically have around 1,000 megawatts (MW) of electric generating capacity. Most proposed advanced reactors would have less than 300 MW of electrical capacity, typically classified as small modular reactors (SMRs). Some have less than 20 MW of electrical capacity, which DOE classifies as microreactors.[99]

Some express doubts that new nuclear plants, even with advanced technology, can overcome such drawbacks as accident risk, high costs, and disposal of radioactive waste. Focusing on renewable energy and energy efficiency would be far more effective in reducing carbon emissions, they argue.[100] Remaining in question is whether these alternatives can provide sufficient baseload power supplies to replace nuclear, at least in the near term.

---

[98] DOE, "Record of Decision for the Final Environmental Impact Statement for the Civil Nuclear Credit Program Proposed Award of Credits to Pacific Gas and Electric Company for Diablo Canyon Power Plant," *Federal Register*, January 2, 2024, https://www.federalregister.gov/documents/2024/01/02/2023-28808/record-of-decision-for-the-final-environmental-impact-statement-for-the-civil-nuclear-credit-program; DOE, "Biden-Harris Administration Announces Major Investment to Preserve America's Clean Nuclear Energy Infrastructure," November 21, 2022, https://www.energy.gov/articles/biden-harris-administration-announces-major-investment-preserve-americas-clean-nuclear.

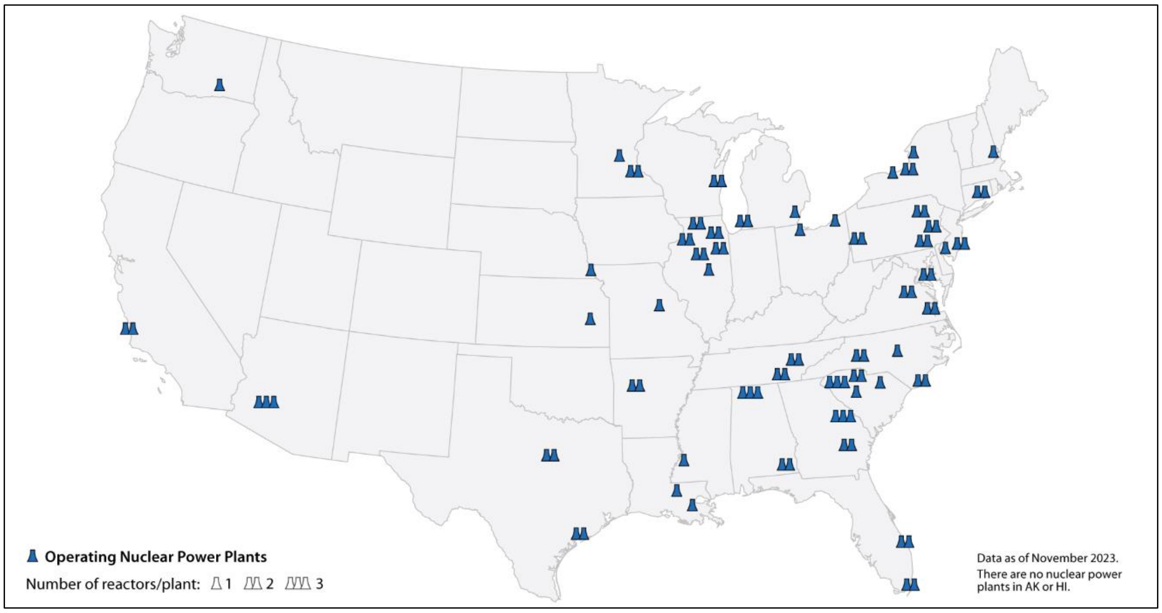
[99] Department of Energy (DOE), Office of Nuclear Energy, "What Is a Nuclear Microreactor?," October 23, 2018, https://www.energy.gov/ne/articles/what-nuclear-microreactor.

[100] Nuclear Information and Resource Service, "Nukes and Climate Change," https://www.nirs.org/climate/, accessed August 13, 2020.

All but 6 of today's 93 nuclear power reactors (**Figure 11**) began operating before 1990, and most started commercial operation before 1980. They were initially licensed by NRC to operate for 40 years, a period that for more than half of U.S. reactors expired before 2020. However, most reactors have been issued 20-year license renewals, pushing back the license expiration of almost all nuclear plants at least to the 2030s. Subsequent 20-year renewals, for a total operating life of 80 years, are also allowed. NRC has issued six such subsequent license renewals for up to 80 years of operation. Another 11 subsequent license renewal applications are currently under review, and at least 8 more have been announced.[101]

Figure 11. U.S. Operating Commercial Nuclear Power Reactors

As of November 2023



Source: CRS analysis of U.S. Energy Information Administration, U.S. Total Nuclear and Uranium Data and Map, updated November 2023, https://www.eia.gov/beta/states/data/dashboard/nuclear-uranium.

Renewable Energy: Continued Growth[102]

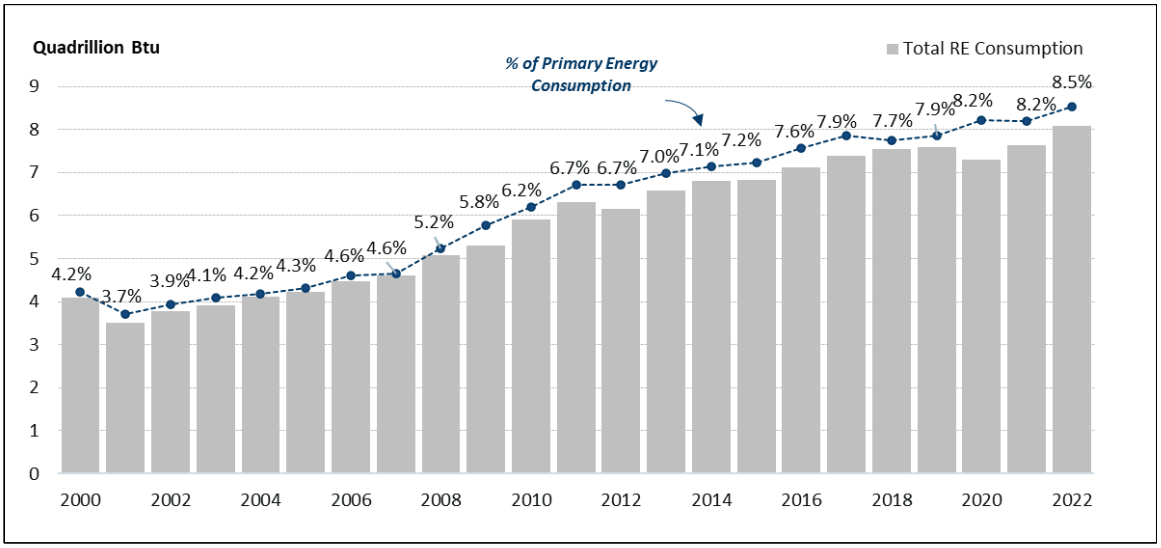
Federal policies that support the use of renewable energy date mainly back to the mid-1970s—the years following the 1973 oil embargo and the ensuing gasoline price volatility. At that time, support for renewable energy was generally oriented towards achieving energy security goals (e.g., steady, independent access to domestic energy sources). While energy security remains a policy objective, much of the current debate regarding renewable energy relates to the environment (e.g., GHG emission reduction) and the economy (e.g., affordability).

[101] NRC, "Status of Subsequent License Renewal Applications," updated October 25, 2023, https://www.nrc.gov/reactors/operating/licensing/renewal/subsequent-license-renewal.html.

[102] Kelsi Bracmort, Specialist in Natural Resources and Energy Policy, and Ashley Lawson, Analyst in Energy Policy, are the lead authors of this section.

Renewable energy is a relatively small portion of the total U.S. energy portfolio, constituting around 9% of total U.S. energy consumption in 2022.[103] Renewable energy consumption has increased since 2000, approximately doubling between 2000 and 2022, as illustrated in **Figure 12**.[104] Most of this growth was due to increased use of wind and solar for electric power generation and biofuels for transportation.

Figure 12. Renewable Energy Consumption in the United States, 2000-2022



Source: CRS analysis of U.S. Energy Information Administration, *Monthly Energy Review*, October 2023, https://www.eia.gov/totalenergy/data/monthly/.

Renewable energy is available in a variety of distinct forms that use different conversion technologies to produce usable energy products (e.g., heat, electricity, and liquid fuels). Each energy product derived from a renewable source has unique market and policy considerations. For example, renewable electricity generation is supported by state-level renewable portfolio standards—where enacted—in addition to federal-level tax incentives for certain renewable energy sources. Biofuels, on the other hand, are supported by the federal-level Renewable Fuel Standard (RFS) that requires a specified volume of renewable fuels to be included in the national fuel supply each year.

Renewable energy is consumed within the electric power, industrial, transportation, residential, and commercial sectors. As indicated in **Table 4**, the contribution of the different renewable energy sources to each sector varies. For example, nearly all hydropower is consumed in the electric power sector and most of the industrial sector renewable energy use is in the form of biomass energy generation.

[103] EIA, *Monthly Energy Review*, Table 1.1, "Primary Energy Overview," October 2023. Renewable energy sources include hydropower, geothermal, solar, wind, and biomass (including biofuels).

[104] Ibid.

Table 4. U.S. Renewable Energy Consumption by Sector and Source, 2022

Trillion Btu

	Residential	Commercial	Industrial	Transportation	Electric Power	Total
Hydropower	0	1	3	0	890	**894**
Geothermal	40	22	4	0	56	**122**
Solar	192	61	15	0	493	**761**
Wind	0	1	0	0	1,483	**1,484**
Biomass	423	147	2,266	1,579	413	**4,827**
Total	**654**	**231**	**2,288**	**1,579**	**3,335**	**8,088**

Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 10.2a, "Consumption: Residential and Commercial Sectors," Table 10.2b, "Consumption: Industrial Sector," and Table 10.2c, "Consumption: Transportation and Electric Power Sectors," October 2023.

Notes: Values may not sum due to independent rounding. Biomass includes wood, waste, fuel ethanol, and biodiesel.

Renewable energy consumption has grown over the last couple of decades. The electric power sector was the largest renewable energy consumer in 2022, accounting for 41% of total renewable energy consumption that year (see **Table 4**). Following the trend for renewable energy overall, electric power renewable energy consumption approximately doubled between 2000 and 2022.[105] The industrial sector was the second-largest renewable energy consumer in 2022, with consumption levels increasing approximately 20% between 2000 and 2022.[106]

The following sections discuss renewable transportation fuels and renewable electricity generation trends from 2000 to the present, and provide some context about the policy and market dynamics that have contributed to the growth of these separate and distinct markets, as well as a brief discussion about recent legislative action. It is beyond the scope of this report to include either detailed descriptions or analysis of each renewable energy source or a comprehensive assessment of each consumption sector.

Renewable Transportation Fuels

Renewable energy production and consumption in the transportation sector comes in the form of two primary types of renewable fuels: ethanol and biodiesel. The primary use of ethanol is as a blending component of motor gasoline. Although it can vary by vehicle type and access to high-level ethanol-gasoline blends, ethanol content generally represents approximately 10% of gasoline by volume (i.e., E10). Biodiesel is a direct substitute for diesel fuel, and can be blended at various volume amounts, including 5% (i.e., B5) and 20% (i.e., B20).

U.S. ethanol and biodiesel production and consumption in the United States have experienced growth over the last two decades. Significant growth occurred following the establishment and expansion of the Renewable Fuel Standard—a mandate that U.S. transportation fuel contain a minimum volume of biofuel.[107] U.S. ethanol production has steadily increased from

[105] EIA, *Monthly Energy Review*, Table 10.2c, "Renewable Energy Consumption: Transportation and Electric Power Sectors," October 2023.

[106] EIA, *Monthly Energy Review*, Table 10.2b, "Renewable Energy Consumption: Industrial Sector," October 2023.

[107] For more information, see CRS Report R43325, *The Renewable Fuel Standard (RFS): An Overview*, by Kelsi Bracmort.

approximately 1.6 billion gallons in 2000 to approximately 15 billion gallons in 2022.[108] Ethanol consumption increased from 1.7 billion gallons to 14 billion gallons over the same time period.[109] From 2001 to 2022, biodiesel production increased from 9 million gallons to approximately 1.6 billion gallons.[110] Including imported fuel, biodiesel consumption increased from 10 million gallons in 2001 to approximately 1.7 billion gallons in 2022.[111]

Legislative Action in the 117th Congress

The 117th Congress supported renewable transportation fuels with laws such as the Inflation Reduction Act of 2022 (IRA; P.L. 117-169) and the CHIPS and Science Act (P.L. 117-167). The IRA provides the U. S. Department of Agriculture with $500 million for grants to increase the sale and use of agricultural commodity-based fuels through infrastructure improvements for blending, storing, supplying, or distributing biofuels, and it provides the U.S. Environmental Protection Agency with $10 million for new grants to support investment in advanced biofuels. The IRA also establishes a sustainable aviation fuel tax credit and extends the biodiesel and renewable diesel tax credit. The CHIPS and Science Act authorizes the U.S. Department of Energy to carry out a research and development program in the areas of biological systems science and climate and environmental science "relevant to the development of new energy technologies and to support the energy, environmental, and national security missions of the Department" including the cost-effective and sustainable production of advanced biofuels, and authorizes up to six bioenergy research centers "to accelerate advanced research and development of advanced biofuels," among other things. Advanced biofuel is generally defined as a renewable fuel, other than corn starch ethanol, with lifecycle greenhouse gas emissions of at least 50% less than lifecycle greenhouse gas emissions of its gasoline or diesel counterpart. Lastly, the 117th Congress started deliberations for the next farm bill—an omnibus, multiyear law. Since 2002, the farm bill has contained an energy title which incentivizes research, development, and adoption of renewable energy, including renewable fuels, among other things.

CRS Written Products:

- CRS Insight IN11978, *Inflation Reduction Act: Agricultural Conservation and Credit, Renewable Energy, and Forestry*, by Jim Monke et al.
- CRS Report R47171, *Sustainable Aviation Fuel (SAF): In Brief*, by Kelsi Bracmort and Molly F. Sherlock
- CRS In Focus IF10639, *Farm Bill Primer: Energy Title*, by Kelsi Bracmort

Renewable Electricity

U.S. electricity generation from renewable sources more than doubled between 2000 and 2022.[112] The contribution of renewable energy to the U.S. power sector increased from 9% in 2000 to 23% in 2022.[113] While hydropower generation has represented 6% to 8% of total U.S. electric power generation since 2000, essentially all of the growth in renewable electricity generation during this period was from non-hydro renewables, particularly wind and solar. Due to the established nature of hydropower, and a lack of significant change in the amount of hydroelectric generation over the last 20 years, this section limits the remaining discussion of renewable electricity to non-hydro renewables.

[108] EIA, *Monthly Energy Review*, Table 10.3, October 2023.

[109] Ibid.

[110] EIA, *Monthly Energy Review*, Table 10.4, October 2023. The *Monthly Energy Review* reports biodiesel data starting in 2001.

[111] Ibid.

[112] Data for 2000-2010 from EIA, *Electric Power Annual 2010*, Table 2.1.A, November 2011. Data for 2012-2021 from EIA, *Electric Power Annual 2021*, Table 3.1.A, November 2022. Data for 2022 from EIA, *Monthly Energy Review*, March 2023.

[113] Ibid.

Non-Hydro Renewables

Non-hydro renewable energy sources (i.e., wind, solar, geothermal, and biomass) for electricity generation have been supported by policies at both the state and federal level. Renewable portfolio standard policies instituted in many states have been a demand catalyst for these renewables, especially wind and solar.[114] Federal tax incentives—in the form of investment and production tax credits,[115] as well as accelerated depreciation—have provided a federal-level financial incentive that has resulted in renewable electricity being financially attractive to both project investors and power purchasers. These policies, along with declining technology costs for wind and solar, have contributed to growth in the use of non-hydro renewable energy sources to generate electric power in the United States.[116] In 2022, non-hydro renewable energy sources provided 17% of total U.S. electric power generation, up from 2% in 2000 (see **Figure 13**).

Wind and solar have dominated growth in non-hydro renewables for electricity generation, while generation from biomass and geothermal has remained essentially flat. Electricity generation from wind energy increased from less than 5 terawatt-hours (TWh) in 2000 to 434 TWh in 2022. Electricity generation from solar energy increased from 0.5 TWh in 2000 to 205 TWh in 2022 (see **Figure 13**).

U.S. electricity demand has been relatively flat since 2000, as discussed in the section "The Electric Power Sector: In Transition." As a result, electricity from non-hydro renewables has grown in both absolute terms and as a share of the total.

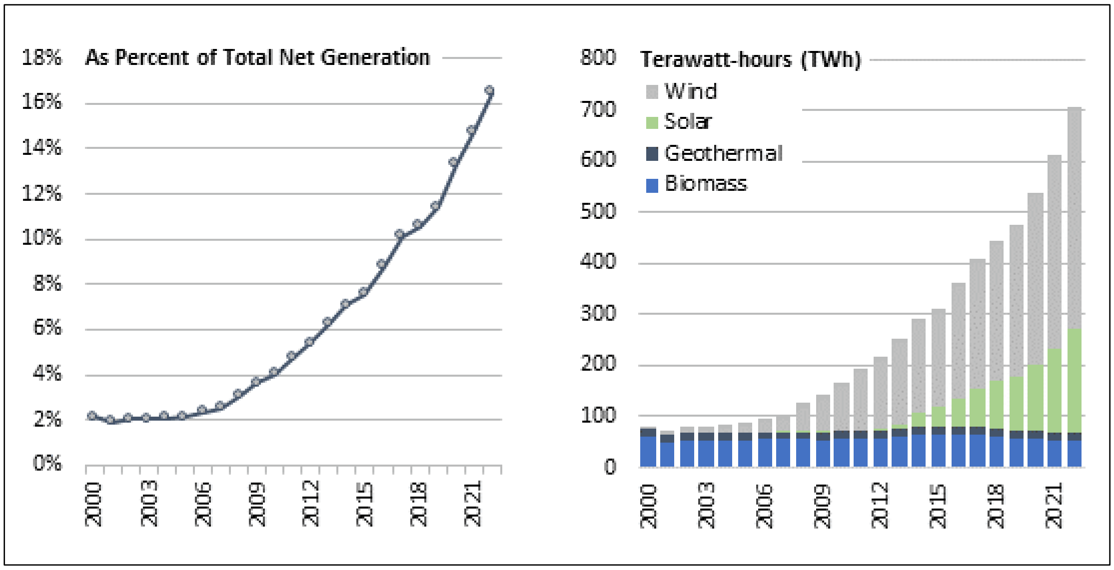
---

[114] For additional information about Renewable Portfolio Standard policies, see CRS Report R45913, *Electricity Portfolio Standards: Background, Design Elements, and Policy Considerations*, by Ashley J. Lawson; and the Database of State Incentives for Renewables and Efficiency (DSIRE) summary map of state renewable policies available at https://ncsolarcen-prod.s3.amazonaws.com/wp-content/uploads/2023/11/RPS-CES-Nov2023-1.pdf.

[115] For additional information about investment tax credits for renewable electricity generation technologies, see CRS In Focus IF10479, *The Energy Credit or Energy Investment Tax Credit (ITC)*, by Molly F. Sherlock. For additional information about production tax credits for renewable electricity production, see CRS Report R43453, *The Renewable Electricity Production Tax Credit: In Brief*, by Molly F. Sherlock. Congressional offices interested in follow-up may contact Donald J. Marples, Specialist in Public Finance, or Nicholas E. Buffie, Analyst in Public Finance.

[116] For a discussion of factors contributing to the increase use of solar energy, see CRS Report R46196, *Solar Energy: Frequently Asked Questions*, coordinated by Ashley J. Lawson.

Figure 13. Non-Hydro Renewable Electricity Generation, 2000-2022

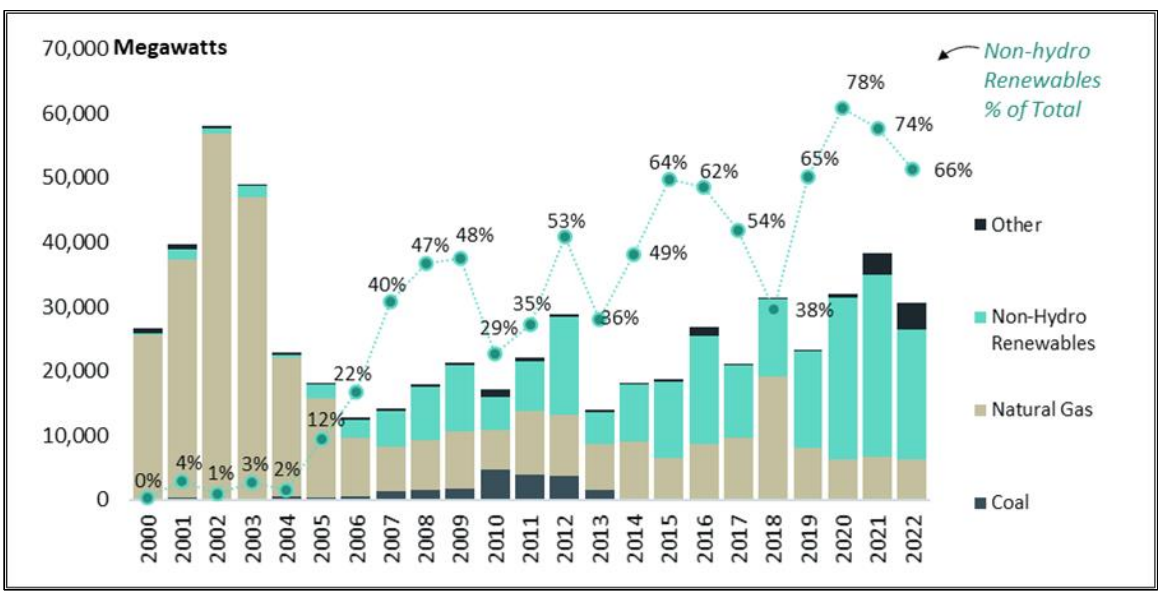


Sources: U.S. Energy Information Administration (EIA), *Electric Power Annual 2010*, Table 2.1.A, November 2011, EIA, *Electric Power Annual 2021*, Table 3.1.A and Table 3.1.B, November 2022, and EIA, *Electric Power Annual 2022*, Table 3.1.A and Table 3.1.B, October 2023.

Notes: Solar includes utility-scale and small-scale solar. Biomass includes biomass, wood and wood-derived fuels, landfill gas, biogenic solid municipal waste, and other waste biomass. Additional information about renewable energy categories is in the EIA sources.

In terms of new electric power capacity additions, non-hydro renewables comprised more than half of all additions every year since 2015 (except 2018; see **Figure 14**). The large majority of non-hydro renewable capacity additions came from wind and solar. Battery additions, shown as part of the Other category in **Figure 14**, have grown in recent years and are frequently associated with solar facilities.

Figure 14. Electric Power Capacity Additions, 2000-2022



Source: CRS analysis of U.S. Energy Information Administration, *Form EIA-860*.

Notes: Figure shows summer capacity for all capacity additions. Dataset covers new generators with capacity greater than 1 megawatt. Non-hydro renewables includes biomass, geothermal, solar photovoltaic, solar thermal, and wind.

Small-Scale Solar

Generation from small-scale solar has grown in recent years, albeit at a slightly slower pace than larger projects.[117] Some of the factors discussed above have also contributed to growth in small-scale solar. Other state policies, such as net metering, affect small-scale solar uniquely.[118]

Costs and benefits for small-scale solar differ from larger solar projects. Electricity generated from small solar projects is several times more expensive on a per megawatt basis than electricity generated from large ones.[119] The cost difference arises in part from the fact that large solar projects benefit from economies of scale. Another factor is that small projects may not be ideally situated for electricity generation. For example, PV panels on rooftops may be partially shaded or north-facing, thus receiving less sunlight throughout the year than more ideally situated panels (e.g., a "solar farm," which may be installed on an unshaded area).

Proponents of small-scale solar may value some characteristics that large projects do not have: they can be installed on developed land in urban areas, minimizing impacts to the environment and minimizing disruptions to other land uses; they rarely require new electricity transmission infrastructure; and, under certain circumstances, they can lower electricity bills for individuals and communities.[120]

Small-scale solar—typically rooftop installations at a residential, commercial, or industrial location—represented 35% of all installed solar capacity in 2022.[121] Generation from small-scale solar (new and existing installations) made up 30% of generation from all solar in that same year.[122]

Energy Efficiency: An Untapped Resource[123]

Similar to renewable energy policies, federal supports for energy conservation and efficiency date mainly back to the mid-1970s, and were similarly oriented towards promoting energy security goals, providing relief from high energy prices to low-income households, and encouraging energy conservation. Energy conservation and energy efficiency are not synonymous. *Energy conservation* is any action or behavior that results in consuming less energy (e.g., turning off a lamp when leaving a room). *Energy efficiency* is providing the same or an improved level of

[117] Solar photovoltaic (PV) panels—the most commonly used solar electricity technology today—can be assembled in configurations of different sizes, ranging from large "solar farms" to small-scale installations such as those on rooftops. Different organization use different definitions for "small-scale" solar. For more information, see CRS Report R46196, *Solar Energy: Frequently Asked Questions*, coordinated by Ashley J. Lawson.

[118] CRS Report R46010, *Net Metering: In Brief*, by Ashley J. Lawson.

[119] Vignesh Ramasamy et al., *U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, with Minimum Sustainable Price Analysis: Q1 2022*, National Renewable Energy Laboratory, September 2022, https://www.nrel.gov/docs/fy22osti/83586.pdf.

[120] One financial benefit comes through the policy of net metering, which is implemented in many states. For more information, see CRS Report R46010, *Net Metering: In Brief*, by Ashley J. Lawson.

[121] EIA, *Electric Power Annual*, Table 4.2.B, "Existing Net Summer Capacity of Other Renewable Sources by Producer Type."

[122] EIA, *Electric Power Annual*, Table 3.1.B, "Net Generation from Renewable Sources: Total (All Sectors)."

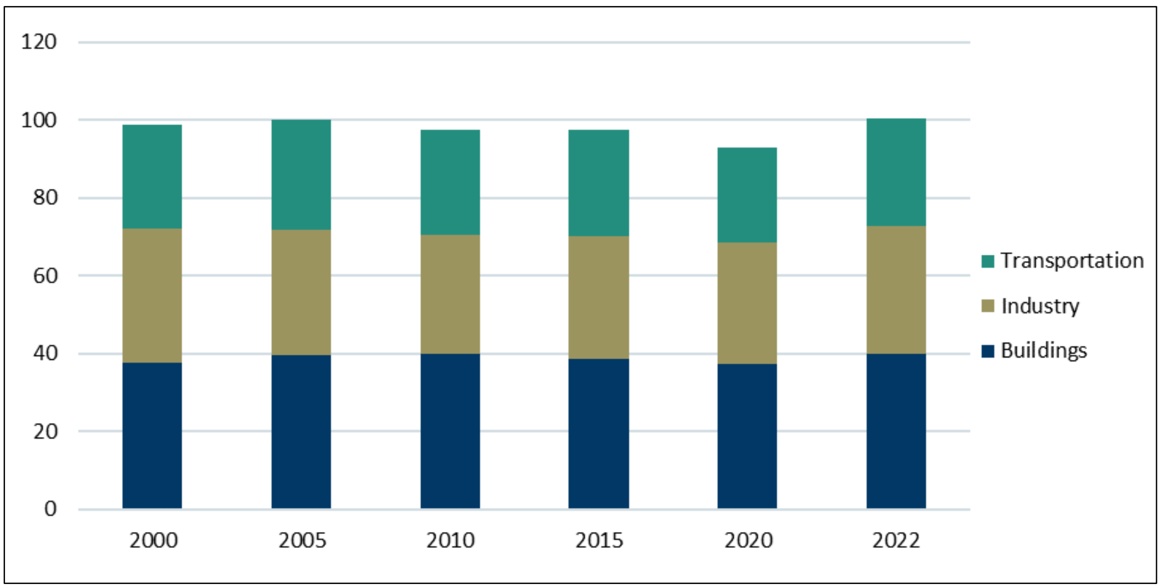
[123] Corrie Clark, CRS Specialist in Energy Policy, is the lead author of this section.

service with less energy (e.g., replacing an incandescent light bulb with a light-emitting diode [LED] light bulb).

Although energy security remains a policy objective, much of the current debate about supporting energy efficiency is related to the benefits of reduced energy consumption (e.g., consumers saving money, energy sector avoiding GHG emissions) and the costs to builders and manufacturers (e.g., investments in equipment or processes to meet mandatory or voluntary performance metrics). Proponents of increased energy efficiency see an untapped "resource" that can mitigate the demand for additional energy supplies. Perceived benefits of energy efficiency include lowered energy bills, reduced demand for energy, improved energy security and independence, and reduced air pollution and GHG emissions. Challenges to energy efficiency include market barriers that do not incentivize builders or developers to invest in energy efficiency, customers' lack of information or awareness of energy saving opportunities and investment returns, and policy barriers that focus on energy supply rather than investment in energy use and efficiency.

Figure 15. U.S. Total Energy Consumption by Sector 2000-2022

Quadrillion Btu (Quads)



Source: Data compiled by CRS from U.S. Energy Information Administration, *Monthly Energy Review*, Tables 2.1a and 2.1b, April 2023, https://www.eia.gov/totalenergy/data/monthly/.

Notes: Total energy consumption by end-use sectors in this chart includes electrical system energy losses, which are allocated proportionally to the amount of electricity retail sales to each end-use sector.

According to the EIA, U.S. total energy consumption is about 100 quadrillion Btu (Quads).[124] Of that total, the buildings and industrial sectors collectively consume approximately 73% of U.S. total energy, and the transportation sector consumes approximately 27% (see **Figure 15**).[125]

[124] For 2022, EIA reported that energy consumption was approximately 100 Quads. In light of the COVID-19 pandemic, EIA reported that energy consumption declined to approximately 93 Quads in 2020. EIA, *Monthly Energy Review*, Tables 2.1a and 2.1b, April 2023, https://www.eia.gov/totalenergy/data/monthly.

[125] The building sector is an end-use energy consumption segment of the nation's energy system that comprises residential and commercial buildings. The industrial sector is an end-use energy consumption segment of the nation's energy system that comprises energy-intensive manufacturing, non-energy-intensive manufacturing, and nonmanufacturing activities.

Increased adoption of energy-efficiency technologies by these sectors could potentially realize significant energy savings and reduce emissions to the environment.

Improvements in energy efficiency may not translate into overall energy consumption reductions. If demand for energy services remained constant, then improving energy efficiency would reduce energy consumption. However, demand for energy services can change. For example, consumers could offset gains in appliance efficiency standards by buying larger appliances or multiple appliances.[126] This type of outcome is commonly referred to as the "rebound effect."[127]

Efficiency in Buildings

The residential and commercial buildings sector accounts for 39% of U.S. total energy consumption, with space heating being the largest single source of consumption within the sector (**Figure 16**).[128] DOE estimates that building energy use could be reduced by more than 20% through implementation of technologies that are known to be cost-effective.[129] Policy options to increase energy efficiency in the building sector include building energy codes, mandatory appliance and equipment energy conservation standards, and voluntary programs such as the ENERGY STAR program.[130]

[126] According to EIA, from 1978 to 1997, the percentage of households that reported a second refrigerator remained consistently between 12% and 15% for every residential energy consumption survey cycle; however, between 1997 and 2015, the percentage of households increased to 30% of all housing units. EIA also found that households with multiple refrigerators tended to have more rooms than those households with only one refrigerator. EIA, "What's New in How We Use Energy at Home," May 2018, https://www.eia.gov/consumption/residential/reports/2015/overview/index.php.

[127] S. Sorrell, J. Dimitropoulos, and M. Sommerville, "Empirical Estimates of the Direct Rebound Effect: A Review," *Energy Policy*, 2009, vol. 37, no. 4, pp. 1356-1371.

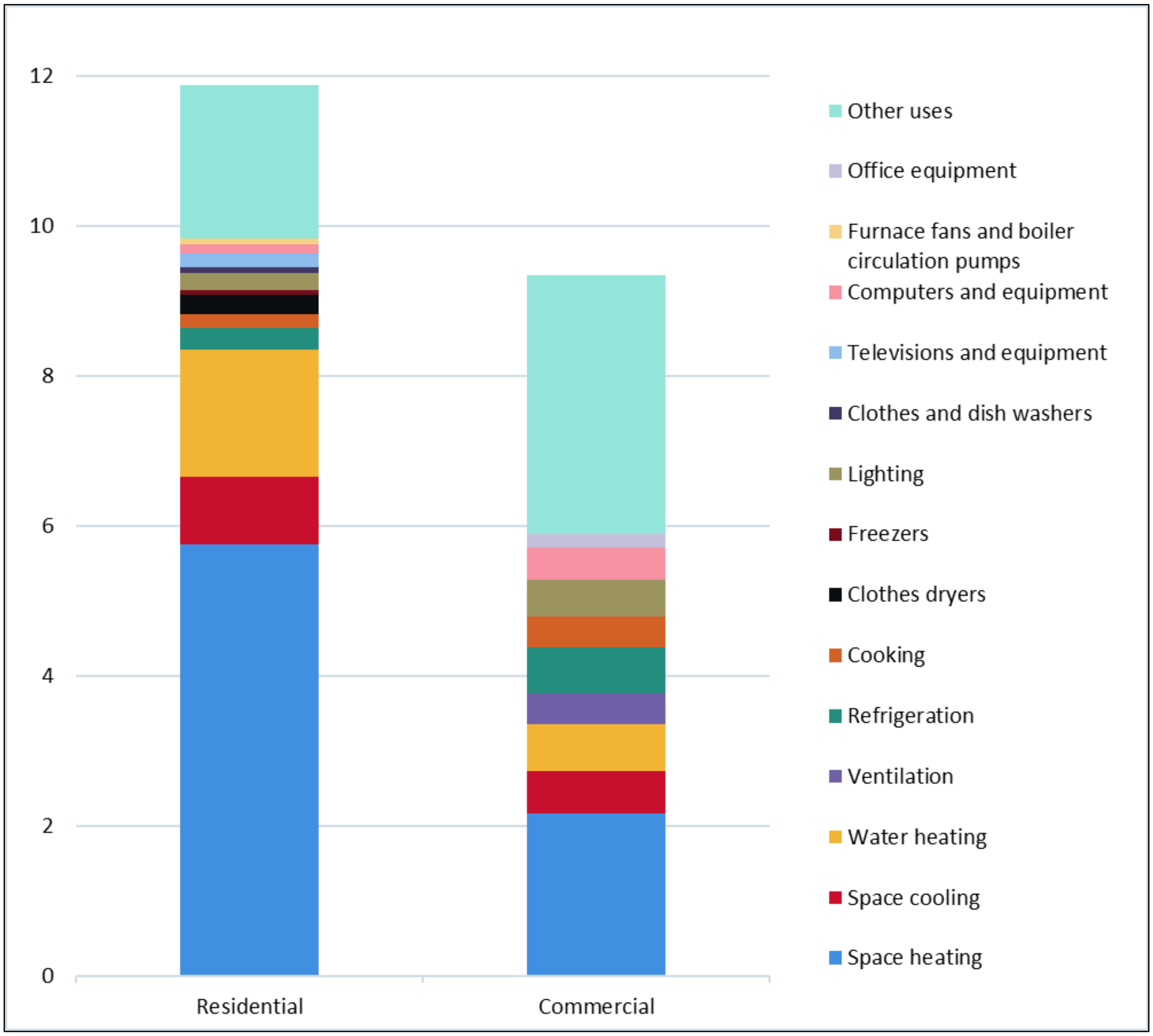
[128] See EIA, *Annual Energy Outlook*, Reference Case Projection Table 2, "Energy Consumption by Sector and Source," 2023, https://www.eia.gov/outlooks/aeo/excel/aeotab_2.xlsx.

[129] DOE, "Chapter 5: Increasing Efficiency of Building Systems and Technologies," *Quadrennial Technology Review*, September 2015, p. 2, https://energy.gov/sites/prod/files/2017/03/f34/qtr-2015-chapter5.pdf.

[130] For more information on building practices and building energy codes, see CRS Report R46719, *Green Building Overview and Issues*, by Corrie E. Clark. For more information on appliance and equipment standards, see CRS Report R47038, *The Department of Energy's Appliance and Equipment Standards Program*, by Martin C. Offutt. For more information on ENERGY STAR®, an internationally recognized voluntary labeling program for energy-efficient products, homes, buildings, and manufacturing plants that is jointly administered by EPA and DOE, see CRS In Focus IF10753, *ENERGY STAR Program*, by Corrie E. Clark.

Figure 16. Estimated U.S. Delivered Building Energy Consumption by End Use, 2022

Quadrillion Btu (Quads)



Source: CRS using EIA, *Annual Energy Outlook*, Reference Case Projection Tables 4-A5, March 2023.

Notes: "Other uses" for residential buildings include (but are not limited to) dehumidifiers, ceiling fans, non-PC rechargeables, smart speakers, smartphones, tables, microwaves, coffee makers, miscellaneous refrigeration products, other small kitchen appliances, pool heaters, pool pumps, portable electric spas, outdoor grills, natural gas- and propane-fueled lights, security systems, and backup electricity generators, as well as electric and electronic devices, heating elements, and motors not listed above. Electric vehicles are included in the transportation sector. "Other uses" for commercial buildings include (but are not limited to) miscellaneous uses such as transformers, medical imaging and other medical equipment, elevators, escalators, off-road electric vehicles, laboratory fume hoods, laundry equipment, coffee brewers, water services, emergency generators, combined heat and power in commercial buildings, and manufacturing performed in commercial buildings, and cooking (distillate). Also includes residual fuel oil, propane, coal motor gasoline, kerosene, and marketed renewable fuels (biomass).

Residential Building Energy Efficiency and Electrification Rebates[131]

P.L. 117-169, commonly known as the Inflation Reduction Act of 2022 (IRA), appropriated $9 billion for rebates and training related to residential energy efficiency and electrification. The energy efficiency or HOMES (Home Owner Managing Energy Savings) rebates are awarded according to the energy savings of the whole house. The electrification rebates support a menu of projects, including replacing appliances, adding insulation, and upgrading the in-home electrical delivery system itself. The two rebate programs have unique means-testing provisions and cost recovery rates and caps.

For the HOMES rebates, applicants can demonstrate savings by comparing energy consumption before and after the retrofits, either through use of building energy models that estimate the energy performance of the whole house, or by measured performance. The energy savings requirements and the rebate calculation differ for the two methods, but generally reimburse project costs at 50% or, for low and moderate income (LMI), 80%, up to applicable caps.

For electrification, the IRA establishes point-of-sale rebates to eligible entities—generally households earning 150% or less of area median income (AMI) for purchase and installation of specific appliances, including heat pumps for water heating, up to $1,750; heat pumps for space heating/cooling, up to $8,000; and electric stoves or electric heat pump clothes dryers, up to $840. Complementing these provisions are rebates for enabling electrification—for example, up to $4,000 for an electric load service center upgrade. The total of all rebates is generally limited to $14,000 per household, and new equipment generally must be ENERGY STAR certified (42 U.S.C. §6294a). The IRA appropriated $4.5 billion for electrification rebates, and also appropriated $200 million for training and education to contractors and organizations involved in the rebate programs.

The Infrastructure Investment and Jobs Act (IIJA, P.L. 117-58) establishes within the DOE Building Technologies Office (BTO) a competitive grant program to implement updated building energy codes. IIJA also directs the Secretary of Energy to provide grants to post-secondary institutions to establish building training and assessment centers. The IIJA further provides grants to eligible entities to pay the federal share of career skills training programs (50%) to train and certify students to install energy efficient building technologies. Lastly, Congress in the IIJA directs the EIA and Environmental Protection Agency to enter into an information-sharing agreement on their respective datasets on commercial building energy consumption.

Efficiency in Transportation

In 2022, the transportation sector consumed approximately 28 Quads of total U.S. energy, accounting for 72% of all U.S. petroleum use.[132] Of the total energy consumed, approximately 55% is attributable to light duty vehicles and commercial light trucks, 21% is attributable to freight trucks, and 10% is attributable to aircraft (see **Figure 17**). Two agencies establish fuel standards for passenger vehicles: the Corporate Average Fuel Economy (CAFE) standards are promulgated by the National Highway Traffic Safety Administration (NHTSA), and the Light-Duty Vehicle GHG Emission Standards are promulgated by the U.S. Environmental Protection Agency (EPA; see shaded box below on "Fuel Efficiency Standards for Vehicles").[133] In addition to policy options such as mandatory standards, other energy efficiency considerations for the transportation sector include procurement goals for federal fleets and potential expansion of alternative fuel and electric vehicle recharging infrastructure.[134]

---

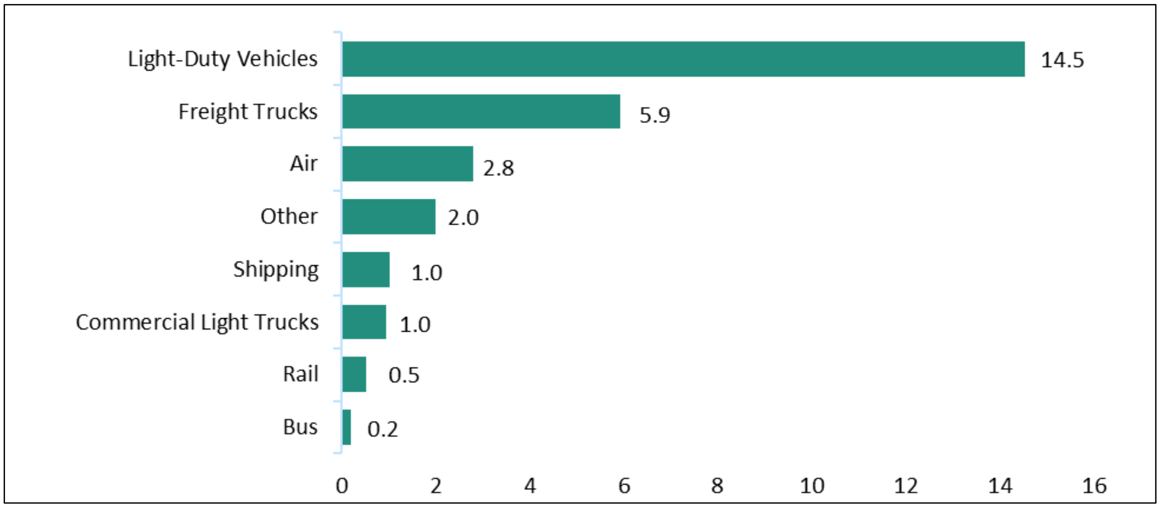
[131] For more information, see CRS In Focus IF12258, *The Inflation Reduction Act: Financial Incentives for Residential Energy Efficiency and Electrification Projects*, by Martin C. Offutt.

[132] EIA, *Annual Energy Outlook*, Reference Case Projection Table A2, "Energy Consumption by Sector and Source," 2023, https://www.eia.gov/outlooks/aeo/excel/aeotab_2.xlsx.

[133] For more information on fuel economy standards and greenhouse gas standards, see CRS In Focus IF10871, *Vehicle Fuel Economy and Greenhouse Gas Standards*, by Richard K. Lattanzio, Linda Tsang, and Bill Canis.

[134] For more information on electrification issues, see CRS Report R47675, *Federal Policies to Expand Electric Vehicle Charging Infrastructure*, by Melissa N. Diaz and Corrie E. Clark; CRS Report R46231, *Electric Vehicles: A Primer on Technology and Selected Policy Issues*, by Melissa N. Diaz; and CRS Report R46420, *Environmental Effects of Battery Electric and Internal Combustion Engine Vehicles*, by Richard K. Lattanzio and Corrie E. Clark.

Figure 17. U.S. Transportation Sector Energy Use by Mode in 2022
Quadrillion Btu



Source: CRS using EIA, *Annual Energy Outlook*, Reference Case Projection Table A7, March 2023.

Notes: Shipping includes domestic and international shipping. Rail includes passenger and freight. Other includes recreational boats, military uses, lubricants, pipeline fuel, and natural gas liquefaction for export.

Fuel Efficiency Standards for Motor Vehicles[135]

Light-duty vehicles, commercial light trucks, and freight trucks comprise approximately 78% of delivered energy used by the transportation sector.[136] Two key federal statutes regulate the fuel efficiency of these vehicles. First, the Energy Policy and Conservation Act (EPCA, P.L. 94-163, see specifically 49 U.S.C. §§32901-32919) requires the U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA), to administer Corporate Average Fuel Economy (CAFE) standards for passenger cars starting in model year (MY) 1978 and light trucks in MY1979. Over time, Congress has amended the statute to modify the structure of the program, require tighter standards, and include heavy-duty trucks. Second, the Clean Air Act (CAA, 42 U.S.C. §7521 et seq.) provides authority to EPA to regulate greenhouse gas (GHG) emissions—which are closely linked to fuel consumption. In addition to the federal requirements, the State of California, which has authority to set its own vehicle emissions standards under CAA,[137] has established a set of low-emission and zero-emission vehicle programs, which some other states have adopted. (EPCA preempts states from setting their own fuel economy standards; and CAA generally preempts states from setting their own emissions standards, except that they may adopt the California emission standards under certain conditions.[138])

EPA promulgated the most recent set of light-duty vehicle GHG emission standards for MY2023-2026 in December 2021 (86 *Federal Register* 74434); NHTSA promulgated the most recent set of light-duty fuel economy standards for MY2024-2026 in May 2022 (87 *Federal Register* 25710). The agencies estimate that the final CAFE standards would produce a fleet-wide, sales-weighted, fuel economy of roughly 49 miles per gallon (mpg) in MY2026 and avoid the consumption of about 234 billion gallons of petroleum between MY2030 and MY2050. Further, in August 2021, President Biden signed Executive Order 14037, "Strengthening American Leadership in Clean Cars and Trucks," which (1) sets a nonbinding electrification goal that "50 percent of all new passenger cars and light trucks sold in 2030 be zero-emission vehicles, including battery electric, plug-in hybrid electric, or fuel cell electric vehicles," and (2) requires EPA and NHTSA to begin work on rulemakings for multipollutant and fuel efficiency standards for both light-duty vehicles and heavy-duty vehicles and engines that would take effect beginning in MY2027. In April 2023, EPA proposed new standards that would cut per-mile emissions roughly in half from the MY2021 standards by MY2032. In July 2023, NHTSA proposed new CAFE standards estimated to reach 58 miles per gallon in MY2032. On January 23, 2024, 120 Senators and Representatives sent a letter to the Deputy Administrator of NHTSA expressing their concern over the proposal and challenging its legality.[139]

---

135 For more information, see CRS In Focus IF12433, *Light-Duty Vehicles, Air Pollution, and Climate Change*, by Richard K. Lattanzio; CRS Report R40506, *Cars, Trucks, Aircraft, and EPA Climate Regulations*, by James E. McCarthy and Richard K. Lattanzio; and CRS In Focus IF10871, *Vehicle Fuel Economy and Greenhouse Gas Standards*, by Richard K. Lattanzio.

136 Data for 2022 in terms of million barrels per day oil equivalent from EIA, *Annual Energy Outlook 2023*, Reference Case Projection Table 7, https://www.eia.gov/outlooks/aeo/tables_ref.php.

137 42 U.S.C. §7543.

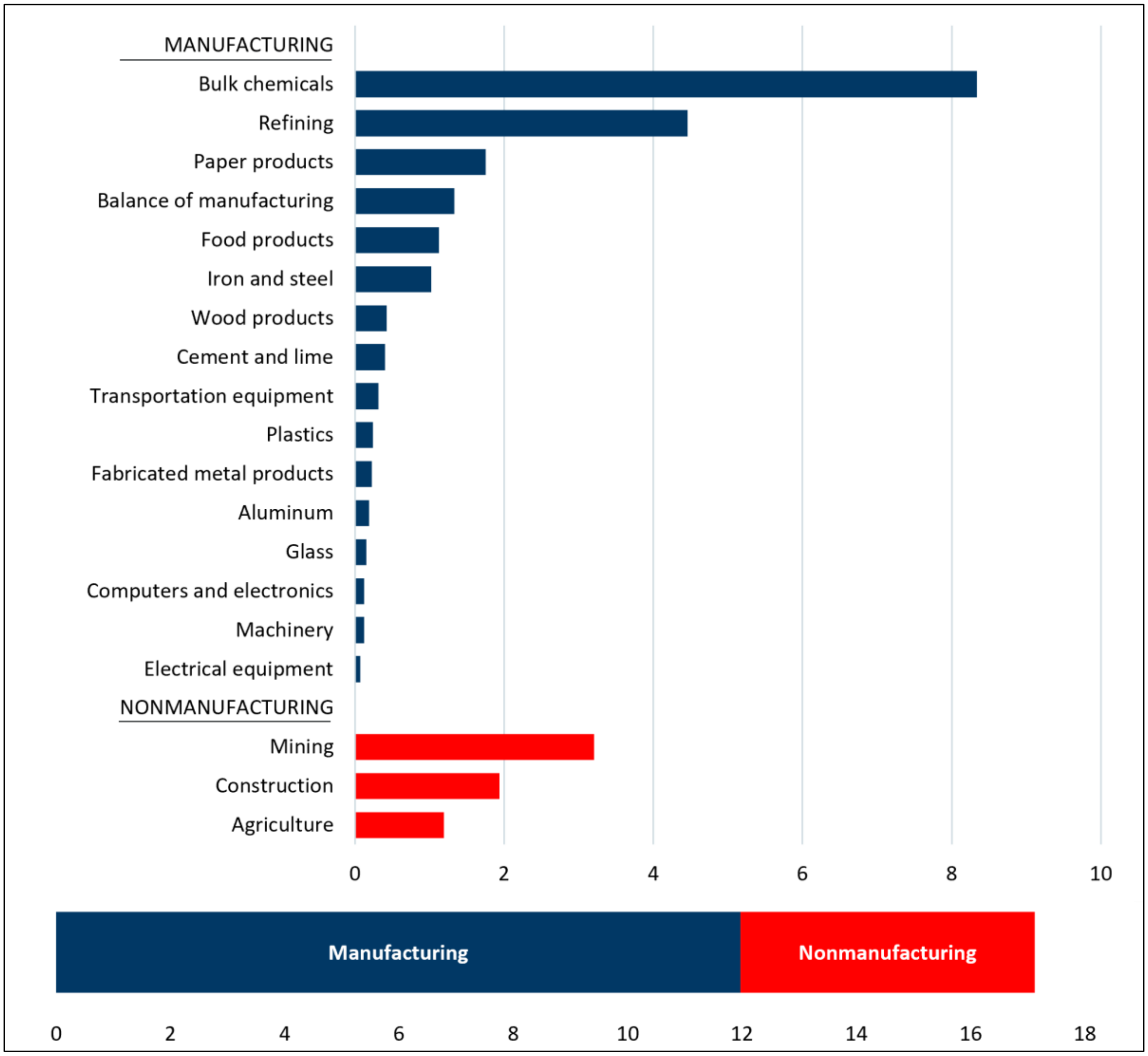
138 42 U.S.C. §7507. As of January 2024, 17 other states and the District of Columbia had adopted California's GHG emission standards under the provisions of Section 177 of the CAA; the states account for approximately 40% of all U.S. new vehicle sales.

139 Letter from Senator Mike Crapo et al. to Ms. Sophie Shulman, Deputy Administrator, National Highway Traffic Safety Administration, January 23, 2024, https://www.crapo.senate.gov/download/nhtsacafestandards01242024.

Efficiency in Industry and Manufacturing

Figure 18. U.S. Industrial Sector Energy Consumption in 2022

Quadrillion Btu (Quads)



Source: CRS using EIA, *Annual Energy Outlook*, Reference Case Projection Tables 24-34, March 2023.

Notes: Nonmanufacturing (in red) includes mining, agriculture, and construction sectors. Manufacturing includes other sectors (in blue). Energy consumption for manufacturing includes energy for combined heat and power plants that have a nonregulatory status and small on-site generating systems.

According to the EIA, the industrial sector consumed about 34% of U.S. total energy in 2022.[140] Approximately three-quarters of the energy consumption from this sector is associated with manufacturing (**Figure 18**). The bulk chemicals subsector consumes the most energy of 16

[140] See EIA, *Annual Energy Outlook*, Reference Case Projection Table 2, "Energy Consumption by Sector and Source," 2023, https://www.eia.gov/outlooks/aeo/excel/aeotab_2.xlsx.

manufacturing subsectors, with an estimated 8.3 Quads in 2022.[141] In 2010, the National Academies estimated that implementing existing, cost-effective efficiency technologies in the industrial sector could reduce energy consumption by 14%-22%.[142] A more recent study by EIA estimated that industrial sector energy intensity could be reduced by 44% globally between 2018 and 2040.[143] Policy options to increase energy efficiency in the industrial sector include mandatory equipment energy conservation standards and voluntary programs such as the Better Plants program or ENERGY STAR program.[144]

Possible Transition to Hydrogen[145]

Hydrogen currently fulfills important applications in chemical plants and oil refineries, with roughly 1% of primary energy used towards its manufacture, but does not deliver energy services to firms and consumers other than in demonstration-scale quantities. Possible uses of hydrogen include a reimagined transportation system operating on hydrogen fuel cells; industrial process where hydrogen is burned for heat; and provision of thermal comfort in buildings using fuel cells or combustion appliances. Nonetheless, cost and performance of hydrogen-utilizing technologies and their technological readiness are not yet on par with current energy technology, and any transition would have its own costs.

Hydrogen Production Pathways

Approximately 99% of hydrogen produced in the United States today (10 million metric tons annually) is sourced from fossil fuels, mostly natural gas.[146] Although cost can fluctuate based on the price of feedstock, hydrogen produced from fossil fuels without carbon capture and storage is generally the least expensive production pathway in the United States.[147] Steam methane reforming (SMR) of natural gas is the most widespread production pathway, producing 95% of U.S. hydrogen and 76% of global hydrogen. Coal gasification produces around 4% of hydrogen in the United States, and 22% of hydrogen globally.[148] Ethanol, bio-oils or other liquid biomass can be converted to hydrogen through a process similar to SMR called *biomass-derived liquid reforming*, although biomass-derived liquids are more difficult to reform than natural gas.[149]

---

[141] EIA, *Annual Energy Outlook*, Reference Case Projection Table 27, "Bulk Chemical Industry Energy Consumption," 2023, https://www.eia.gov/outlooks/aeo/tables_ref.php.

[142] National Academy of Sciences, National Academy of Engineering, and National Research Council, *Real Prospects for Energy Efficiency in the United States*, 2010, p. 15, https://doi.org/10.17226/12621.

[143] Energy intensity refers to energy use per unit of gross value added. The projection is for International Energy Agency (IEA) countries and other major economies as determined by IEA. IEA, *Energy Efficiency 2018: Analysis and Outlooks to 2040*, 2018, p. 101, https://www.iea.org/reports/energy-efficiency-2018.

[144] Better Plants is a voluntary program administered by DOE for industrial scale energy users (e.g., manufacturers) who voluntarily set a goal such as reducing energy intensity by 25% over a 10-year period. For more information on Better Plants, see https://betterbuildingssolutioncenter.energy.gov/better-plants.

[145] Martin Offutt, Analyst in Energy Policy, and Lexie Ryan, Analyst in Energy Policy, were the authors of this section.

[146] DOE, Office of Fossil Energy (renamed to the Office of Fossil Energy and Carbon Management), *Hydrogen Strategy: Enabling A Low-Carbon Economy*, July 2020, p. 5, https://www.energy.gov/sites/prod/files/2020/07/f76/USDOE_FE_Hydrogen_Strategy_July2020.pdf; DOE, Hydrogen and Fuel Cell Technologies Office, "Hydrogen Production," https://www.energy.gov/eere/fuelcells/hydrogen-production, accessed November 22, 2023.

[147] Ibid., *Hydrogen Strategy*, Figure 5, "Current Hydrogen Production Cost Ranges and Averages by Technology and Equivalent Prices for Fossil Sources with CO_2 Capture and Storage."

[148] Ibid.

[149] DOE, Hydrogen and Fuel Cell Technologies Office, "Hydrogen Production: Biomass-Derived Liquid Reforming," (continued...)

Producing hydrogen from fossil fuels emits greenhouse gases.[150] According to one presentation by DOE, methane SMR can emit up to 10 kg CO_2 equivalent per kg of hydrogen produced.[151] In the future, fossil fuel production pathways could be paired with carbon capture and storage, which may capture as high as 90% of carbon emissions.[152]

Approximately 1% of hydrogen produced in the United States, and 2% globally, is produced via *electrolysis*, in which electricity splits water in an electrolyzer.[153]

Other mid- to long-term pathways, including waste streams, direct solar energy, and algae/cyanobacteria, are not yet commercially viable but offer long-term potential for hydrogen production with low or no greenhouse gas emissions.[154]

Hydrogen "Colors"

Some hydrogen producers, marketers, governments, and other organizations refer to hydrogen using an emblematic color spectrum. Although the labels are not standardized, hydrogen produced via electrolyzers using renewable electricity is generally referred to as "green hydrogen"; some organizations view "green hydrogen" as the only acceptable form of hydrogen.[155] Some refer to hydrogen produced from fossil fuels as "blue hydrogen," if the separated carbon is captured and sequestered. If no carbon capture is used, hydrogen produced from coal may be "brown hydrogen" and hydrogen produced from natural gas or petroleum may be referred to as "gray hydrogen."[156] "Pink hydrogen" may refer to hydrogen produced with nuclear energy. "Turquoise hydrogen" may refer to pyrolysis of hydrocarbons to produce hydrogen and solid carbon.

What Is "Clean" Hydrogen?

Congress, along with federal agencies, has used carbon intensity to define "clean" hydrogen. The Inflation Reduction Act of 2022 (P.L. 117-169) defines hydrogen that qualifies for a new tax credit as "hydrogen which is produced through a process that results in a lifecycle greenhouse gas emissions rate of not greater than 4 kilograms of carbon dioxide equivalent (CO_2e) per kilogram of hydrogen." Clean hydrogen is not limited to a specific production pathway. Through the regional clean hydrogen hubs program established by the Infrastructure Investment and Jobs Act (IIJA, P.L. 117-58), Congress called for the establishment of clean hydrogen hubs that use a variety of pathways: fossil fuels (paired with carbon capture), renewable energy, and nuclear energy. IIJA defines

https://www.energy.gov/eere/fuelcells/hydrogen-production-biomass-derived-liquid-reforming, accessed November 22, 2023.

[150] For hydrogen, these include CO_2, CH_4 and N_2O. DOE, Hydrogen and Fuel Cell Technologies Office, *Learn to Use the GREET Model for Emissions Life Cycle Analysis*, November 2021, Slide 8, https://www.energy.gov/sites/default/files/2021-11/h2iq-hour-10282021.pdf.

[151] Ibid., Slide 12.

[152] Thomas Koch Blank and Patrick Molly, "Hydrogen's Decarbonization Impact for Industry," *Rocky Mountain Institute*, January 2020, https://rmi.org/wp-content/uploads/2020/01/hydrogen_insight_brief.pdf.

[153] DOE, Office of Fossil Energy, *Hydrogen Strategy: Enabling A Low-Carbon Economy*, July 2020, p. 5, https://www.energy.gov/sites/prod/files/2020/07/f76/USDOE_FE_Hydrogen_Strategy_July2020.pdf; DOE, Hydrogen and Fuel Cell Technologies Office, "Hydrogen Production: Electrolysis," https://www.energy.gov/eere/fuelcells/hydrogen-production-electrolysis, accessed November 22, 2023.

[154] DOE, Office of Energy Efficiency and Renewable Energy, "Hydrogen Production Pathways," https://www.energy.gov/eere/fuelcells/hydrogen-production-pathways, accessed November 22, 2023.

[155] For example, "The Sierra Club only supports the use of green hydrogen—hydrogen made through electrolysis that is powered by renewable energy." Cara Bottoff, "Hydrogen: Future of Clean Energy or a False Solution?," *Sierra Club*, January 4, 2022, https://www.sierraclub.org/articles/2022/01/hydrogen-future-clean-energy-or-false-solution.

[156] CRS Report R46436, *Hydrogen in Electricity's Future*, by Richard J. Campbell; EIA, "Hydrogen Explained," https://www.eia.gov/energyexplained/hydrogen/production-of-hydrogen.php, last updated June 23, 2023.

clean hydrogen as "hydrogen produced with a carbon intensity equal to or less than 2 kilograms of carbon dioxide-equivalent produced at the site of production per kilogram of hydrogen produced." DOE's Clean Hydrogen Production Standard (CHPS), developed to meet the IIJA requirements, establishes a target of 4.0 $kgCO_2e/kgH2$ for lifecycle greenhouse emissions.[157] CHPS is not a regulatory standard, but hydrogen hubs funded through the IIJA are required by the law to "demonstrably aid achievement" of the CHPS by mitigating emissions as much as possible.

What a Hydrogen Economy Might Look Like

In a hydrogen economy (i.e., replacing the current system of fossil fuel-consuming devices that provide modern energy services), there could be potential applications in all sectors of energy consumption—transportation, industry, and buildings (residential and commercial).[158] Some advocates of a hydrogen economy focus on established energy applications and target the replacement of the fuels currently in use—for example, the replacement of petroleum-fueled internal combustion engines with hydrogen-consuming fuel cell vehicles. Further examples include the use of hydrogen in steelmaking and, in manufacturing, for high-temperature heat to support various processes; as an energy storage medium in electric power; and as a substitute for natural gas in residential buildings.

Potential Benefits

Many multi-national and international commitments and goals refer to a hydrogen economy and its potential in energy transitions. Examples of such commitments include the 2030 Climate Target Plan of the European Union, the U.S. goal of net-zero greenhouse gas emissions by 2050, and the Paris Agreement.[159]

For industrial applications, hydrogen is a viable alternative to fossil fuels as it burns with characteristics favorable to providing high-temperature heat, with a flame temperature of about 2,100 degrees Celsius (°C) and emissions of water vapor and potentially nitrogen oxides (NO_x).[160] Four industry subsectors responsible for roughly half of industrial greenhouse gas (GHG) emissions—ethylene, ammonia, cement, and steel manufacture combined—generate roughly one-

[157] DOE, "Clean Hydrogen Production Standard Guidance," https://www.hydrogen.energy.gov/library/policies-acts/clean-hydrogen-production-standard, accessed November 22, 2023.

[158] For statistical purposes, analysts generally organize final consumption or "end use" of energy—the point at which it performs a useful service and is not merely being extracted, refined, packaged, or transported—into three sectors: transportation, industry, and buildings (residential and commercial). K. Riahi, F. Dentener, and D. Gielen, et al., "Chapter 17: Energy Pathways for Sustainable Development," in *Global Energy Assessment—Toward a Sustainable Future* (Cambridge, UK and New York, NY, USA: Cambridge University Press, 2012), p. 1228; T. Bruckner, I.A. Bashmakov, and Y. Mulugetta, et al., "Energy Systems," in *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. O. Edenhofer, R. Pichs-Madruga, Y. Sokona (Cambridge, UK and New York, NY, USA: Cambridge University Press, 2014).

[159] European Commission, *EU Climate Target Plan 2030: Building a Modern, Sustainable and Resilient Europe*, September 2020, https://ec.europa.eu/clima/eu-action/european-green-deal/2030-climate-target-plan_en; U.S. Department of State and Executive Office of the President, *The Long-Term Strategy of the United States: Pathways to Net-Zero Greenhouse Gas Emissions by 2050*, Washington, DC, November 2021, https://www.whitehouse.gov/wp-content/uploads/2021/10/US-Long-Term-Strategy.pdf; *Paris Agreement to the United Nations Framework Convention on Climate Change*, adopted by Conference of Parties No. 21, Decision 1/CP.21, U.N. Doc. FCCC/CP/2015/10/Add.1 (December. 12, 2015), annex 1, http://unfccc.int/resource/docs/2015/cop21/eng/10a01.pdf.

[160] Combustion of hydrogen might necessitate use of NO_x reduction technologies. See U.S. EPA, Technology Transfer Network, *Nitrogen Oxides (NOx): Why and How They Are Controlled*, https://www3.epa.gov/ttncatc1/cica/other7_e.html.

third of their CO_2 emissions using high-temperature heat (i.e., above 500°C in that study), some of which could be replaced with hydrogen.[161]

Hydrogen has been envisaged as a way to decarbonize the transportation sector.[162] Most current passenger vehicles operate off-grid of any energy supply, such as the electric power grid, with fuel stored on board the vehicle, usually in the form of gasoline or diesel fuel. With on-board fuel storage, fuel cell electric vehicles (FCEVs) and other hydrogen vehicles can provide personal mobility without the need to recharge like electric vehicles. The hydrogen to fuel those vehicles can, depending on the primary resource and its method of conversion, reduce the carbon intensity[163] per passenger mile of mobility.

Combustion of hydrogen can provide space conditioning (thermal comfort), hygienic services (hot water and clothes drying), and cooking services for occupants of architectural spaces. In such applications, hydrogen gas could in principle be blended into natural gas transmission and distribution infrastructure to reach end-users. A second strategy would involve electrifying the appliances and using a hydrogen fuel cell to provide the necessary electric power on site.

Direct CO_2 emissions from combustion of fuel in buildings amounted to 8.2% of global CO_2 emissions from all energy-related sources in 2022.[164] Hydrogen combustion can reduce CO_2 emissions in proportion to the amount of natural gas it replaces; blending in green hydrogen at 5% to 20% by volume would reduce the greenhouse gas emissions of this application by 2% to 7% (the reduction in percentage is because the same volume of hydrogen at environmental conditions has lower energy than methane).[165]

Potential Challenges

A transition to a hydrogen economy would require adapting or replacing large parts of today's energy system. Hydrogen-consuming appliances, vehicles, and devices are, however, at various stages of development, and some hydrogen applications may be more feasible than others. The large build-out that would be needed to establish a hydrogen economy can only occur with technologies that are sufficiently mature and can be manufactured in volume. One evaluation of the so-called technology readiness level (TRL) of the component parts of a hydrogen economy finds that fuel cells and the refueling stations are at a high level of readiness, but short of that needed for widespread deployment.[166] Hydrogen to provide high-temperature heat for industrial applications is at a lower level of readiness, consistent with prototypes. For applications in buildings, the TRL is similarly prototype-level for blending hydrogen into natural gas supply

[161] Arnout de Pee, Dickon Pinner, and Occo Roelofsen, et al., *Decarbonization of Industrial Sectors: The Next Frontier*, McKinsey Sustainability, Amsterdam, The Netherlands, June 2018, p. 7, https://www.mckinsey.com/business-functions/sustainability/our-insights/how-industry-can-move-toward-a-low-carbon-future.

[162] N.P. Brandon and Z. Kurban, "Clean Energy and the Hydrogen Economy," *Philosophical Translations of the Royal Society A*, vol. 375, June 12, 2017; National Research Council and National Academy of Engineering, *The Hydrogen Economy: Opportunities, Costs, Barriers and R&D Needs*, Washington, DC, 2004.

[163] Carbon intensity can be measured in tons of carbon dioxide equivalent per megawatt-hour (tCO2-eq/MWh) or other unit of energy, for example, tCO2-eq per Joule (tCO2-eq/J).

[164] Direct CO_2 emissions from buildings were 3 gigatons and total CO_2 emissions were 36.8 gigatons in 2022. International Energy Agency, *Tracking Buildings: CO_2 Emissions*, July 11, 2023, https://www.iea.org/energy-system/buildings; IEA, *CO_2 Emissions in 2022: Key Messages*, March 2023, https://www.iea.org/reports/co2-emissions-in-2022.

[165] Energy Transitions Commission, *Making the Hydrogen Economy Possible: Accelerating Clean Hydrogen in an Electrified Economy*, Version 1.2, April 2021, p. 21.

[166] IEA, *ETP Clean Energy Technology Guide*, September 21, 2022, https://www.iea.org/articles/etp-clean-energy-technology-guide.

pipelines, but is at a higher level, comparable to fuel cell vehicles, for arrangements that use hydrogen directly.

Appendix A. Selected U.S. Government Entities and Their Energy-Related Roles

U.S. Army Corps of Engineers (Corps, USACE)—part of the Department of Defense, the Army Corps of Engineers manages both federal water resource development projects and regulated activities affecting certain waters and wetlands, including activities associated with infrastructure. Corps permits are required where energy infrastructure crosses certain waters, Corps projects, or Corps-controlled lands.

Bureau of Land Management (BLM)—part of the Department of the Interior, BLM has oversight of federal lands and manages onshore oil, natural gas, and renewable energy permitting and operations.

Bureau of Ocean Energy Management (BOEM)—part of the Department of the Interior, BOEM oversees the safe and environmentally responsible development of energy and mineral offshore resources.

Bureau of Safety and Environment Enforcement (BSEE)—part of the Department of the Interior, BSEE oversees offshore worker safety, environmental stewardship, and resource conservation.

U.S. Coast Guard—part of the Department of Homeland Security, the Coast Guard has oversight of marine terminals used for the import and export of oil and natural gas as well as the security of certain hazardous fuel shipments by water.

U.S. Commodity Futures Trading Commission (CFTC)—CFTC has oversight of futures markets, including those for energy. CFTC was given additional oversight responsibilities for futures and derivatives under Dodd-Frank legislation.

U.S. Department of Energy (DOE)—a Cabinet-level agency responsible for developing and implementing national energy policy, energy research and development, basic science, energy emergency preparedness and security, and defense-related nuclear activities.

U.S. Energy Information Administration (EIA)—an agency within DOE, it provides independent data and analysis on the U.S. energy sector.

U.S. Environmental Protection Agency (EPA)—EPA has a broad range of authorities and responsibilities that may impact energy production, transportation, and consumption, particularly as the agency enforces environmental statutes and regulations and sets national standards. EPA has oversight/enforcement of all or part of the Clean Water Act; Clean Air Act; Comprehensive Environmental Response, Compensation, and Liability Act; and the Oil Pollution Act, among other laws.

Federal Energy Regulatory Commission (FERC)—an independent federal agency which regulates the interstate transmission of electricity, natural gas, and oil. FERC also issues permits for LNG terminals and interstate natural gas pipelines as well as licensing nonfederal hydropower projects.

U.S. Fish and Wildlife Service—Fish and Wildlife has responsibilities for environmental oversight on energy issues such as wind and hydropower production, and pipeline rights-of-way through jurisdictional lands.

U.S. Forest Service—part of the Department of Agriculture, the Forest Service is responsible for managing energy and mineral resources, and infrastructure development on federal onshore areas that it owns.

Maritime Administration (MARAD)—an agency within the Department of Transportation that regulates offshore LNG and oil terminals, and oversees programs that incentivize the offshore wind industry, including the Port Infrastructure Development (PID) grant program and the Federal Ship Financing Program (Title XI of the Merchant Marine Act of 1936).

National Highway Traffic Safety Administration (NHTSA)—part of the Department of Transportation, NHTSA regulates vehicle fuel economy through the CAFE program in coordination with EPA's vehicle GHG program.

National Oceanic and Atmospheric Administration (NOAA)—part of the Department of Commerce, NOAA has jurisdiction over pipeline project construction in coastal and/or ocean areas.

U.S. Nuclear Regulatory Commission (NRC)—an independent regulatory commission responsible for licensing and regulation of nuclear power plants and other nuclear facilities.

Office of Energy Efficiency and Renewable Energy (EERE)—part of the Department of Energy that focuses on energy efficiency, such as appliance standards, and renewable energy.

Office of Fossil Energy and Carbon Management (FECM)—part of the Department of Energy focusing advancing technologies to reduce the climate and environmental effects from fossil fuel use, including carbon capture, utilization, and storage, and U.S. oil and gas production. It also has input into the construction of liquefied natural gas import and export terminals.

Office of Nuclear Energy—part of the Department of Energy responsible for nuclear energy research and federal nuclear waste storage and disposal facilities.

Pipeline and Hazardous Materials Safety Administration (PHMSA)—part of the Department of Transportation, PHMSA administers the regulatory program, through the Office of Pipeline Safety (OPS), to assure the safe transportation of natural gas, petroleum, and other hazardous materials by pipeline. OPS develops regulations and other approaches to risk management to assure safety in design, construction, testing, operation, maintenance, and emergency response of pipeline facilities.

Appendix B. Selected Energy Laws

Table B-1. Selected Energy Related Laws

Year	Law	Description
1920	Mineral Leasing Act, P.L. 66-146	Governs leasing of public lands for development of deposits of coal, petroleum, natural gas, and other minerals.
1920	Federal Water Power Act, P.L. 66-280	Originally coordinated development of hydroelectric projects. In 1935, the law was renamed the Federal Power Act. It created the Federal Power Commission (now FERC) and expanded its jurisdiction to include all interstate electricity transmission and wholesale power sales.
1938	Natural Gas Act, P.L. 75-688	Regulates rates for interstate transmission and sales of natural gas. Requires approval by now-DOE and its precursors for natural gas import and export facilities.
1953	Outer Continental Shelf Lands Act, P.L. 83-212	Defines the outer continental shelf under U.S. jurisdiction and empowers the Secretary of the Interior to grant leases for resource development.
1954	Atomic Energy Act, P.L. 83-703	Authorizes nuclear energy research and development, and establishes licensing requirements for the use of nuclear materials, such as in nuclear power plants.
1974	Energy Reorganization Act, P.L. 93-438	Established the Nuclear Regulatory Commission (NRC), splitting the responsibility for nuclear weapons and civilian nuclear power regulation between what is now DOE and NRC, respectively.
1975	Energy Policy and Conservation Act, P.L. 94-163	Established the Strategic Petroleum Reserve, mandated vehicle fuel economy standards, and extended oil price controls.
1977	Department of Energy Organization Act, P.L. 95-91	Established the Department of Energy as a Cabinet-level organization, and established FERC as the successor to the Federal Power Commission and made it an independent agency within DOE.
1978	National Energy Act, P.L. 95-617 - 621	Included five energy-related statutes: Energy Tax Act, Natural Gas Policy Act, National Energy Conservation Policy Act, Power Plant and Industrial Fuel Use Act, and the Public Utility Regulatory Policies Act.
1980	Energy Security Act, P.L. 96-294	Emphasized alternative energy sources that could be produced domestically to improve U.S. energy security.
1992	Energy Policy Act of 1992, P.L. 102-486	Created framework for competitive wholesale electricity markets.
2005	Energy Policy Act of 2005, P.L. 109-58	Offered tax benefits for energy efficiency and alternative fuel vehicles, increased required amounts of renewable fuel in gasoline, and encouraged more domestic energy production.
2007	Energy Independence and Security Act, P.L. 110-140	Increased vehicle fuel efficiency standards, and revised standards for appliances and lighting.
2015	Consolidated Appropriations Act, 2016, P.L. 114-113	Repealed the crude oil export prohibition contained in the Energy Policy and Conservation Act of 1975.
2017	Tax Cuts and Jobs Act, P.L. 115-97	Established an oil and gas program in the Arctic National Wildlife Refuge.

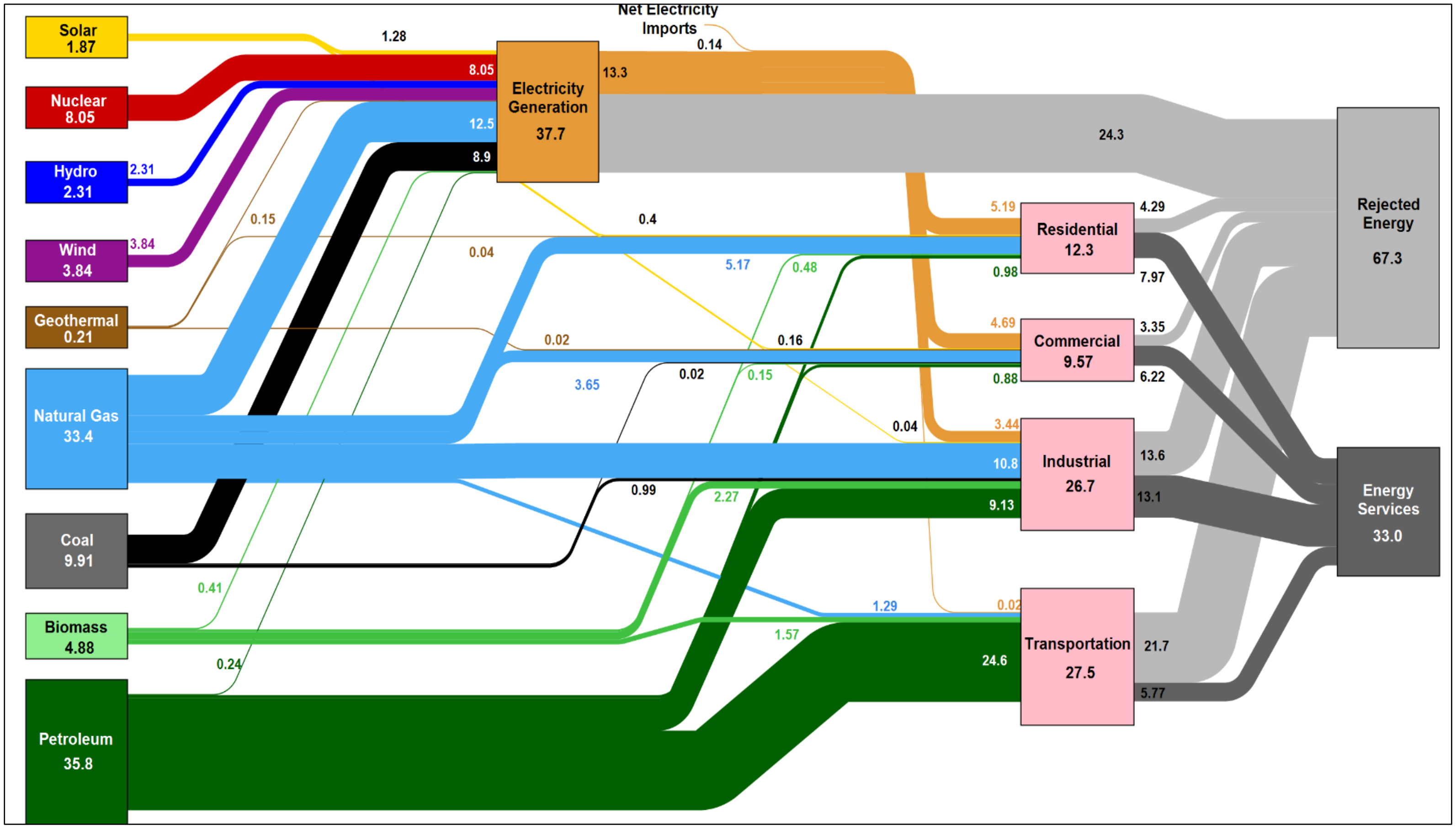
Year	Law	Description
2020	Energy Act of 2020, Division Z of the Consolidated Appropriations Act, 2021, P.L. 116-260	Authorized a range of DOE energy research, development, and demonstration programs for nuclear power, renewable energy, energy storage, and carbon capture and storage. Funds for many of these programs were appropriated in the Infrastructure Investment and Jobs Act.
2021	Infrastructure Investment and Jobs Act, P.L. 117-58	Authorized and appropriated funds for a wide range of infrastructure projects, including approximately $76 billion for energy and minerals-related research, demonstration, technology deployment, and incentives.
2022	P.L. 117-167, commonly referred to as the CHIPS and Science Act	Appropriated funds to support the domestic production of semiconductors and authorized various programs and activities of the federal science agencies, including the Department of Energy.
2022	P.L. 117-169, commonly referred to as the Inflation Reduction Act	Among other provisions, established new and expanded tax credits and other incentives for a range of energy technologies, including consumer rebates, zero-carbon electricity, nuclear power, sustainable aviation fuel (SAF), electric vehicles, and clean hydrogen.

Source: Compiled by CRS using information from congressional databases and the John A. Dutton E-Education Institute, College of Earth and Mineral Sciences, Pennsylvania State University, https://www.e-education.psu.edu/geog432/node/116.

Notes: The list in this table is not comprehensive and the descriptions highlight certain provisions in the legislation and not the entire law. Many of the above laws have been amended, sometimes extensively, since their initial enactment. The Department of Energy lists on its website laws which it administers, https://energy.gov/gc/laws-doe-administers-0.

Appendix C. U.S. Energy Consumption

Figure C-1. Estimated U.S. Energy Consumption in 2022: 100.3 Quadrillion British Thermal Units (Quads)



Source: Department of Energy and Lawrence Livermore National Laboratory, https://flowcharts.llnl.gov/commodities/energy.

Notes: "Primary energy" consists of the energy inputs on the left side of the figure. "Rejected Energy," on the left, is the portion of energy that goes into a process and comes out, usually as waste heat, to the environment.

Appendix D. List of Abbreviations

Btu—British thermal unit

CAFE—Corporate Average Fuel Economy standards

CCUS—carbon capture, utilization, and storage

CHPS – clean hydrogen production standard

DRM—demonstrated reserve base

GDP—gross domestic product

GHG—greenhouse gas

IIJA—Infrastructure Investment and Jobs Act

IRA—Inflation Reduction Act

LED—light-emitting diode

LNG—liquefied natural gas

LWR—light water reactor

MTE—CAFE midterm evaluation

MW—megawatts

NGL—natural gas liquids

OCS—outer continental shelf

PHMSA—Pipeline and Hazardous Materials Safety Administration

RES—renewable electricity standard

RGGI—Regional Greenhouse Gas Initiative

RPS—renewable portfolio standard

PRB—Powder River Basin

PV—photovoltaic

Quad—quadrillion Btu

ROWs—rights-of–way

SAF—sustainable aviation fuel

SMR—small modular reactor

SPR—Strategic Petroleum Reserve

TWh—Terawatt-hours

ZEC—zero-emission credit

Author Information

Brent D. Yacobucci, Coordinator
Section Research Manager

Ashley J. Lawson
Specialist in Energy Policy

Kelsi Bracmort
Specialist in Natural Resources and Energy Policy

Martin C. Offutt
Analyst in Energy Policy

Phillip Brown
Specialist in Energy Policy

Paul W. Parfomak
Specialist in Energy Policy

Corrie E. Clark
Specialist in Energy Policy

Michael Ratner
Specialist in Energy Policy

Mark Holt
Specialist in Energy Policy

Lexie Ryan
Analyst in Energy Policy

Disclaimer