21st Century U.S. Energy Sources: A Primer

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Summary

Since the start of the 21st century, the U.S. energy system has seen tremendous changes. Technological advances in energy production have driven changes in energy consumption, and the United States has moved from being a growing net importer of most forms of energy to a declining importer—and possibly a net exporter in the near future. The United States remains the second largest consumer of energy in the world, behind China.

The U.S. oil and natural gas industry has gone through a "renaissance" of production. Technological improvements in hydraulic fracturing and horizontal drilling have unlocked enormous oil and natural gas resources from tight formations, such as shale. Oil has reached a level of production not seen in decades, and is projected to surpass the previous peaks of the early 1970s. Natural gas has set new production records almost every year since 2000. In conjunction with the rise in oil and natural gas production, U.S. production of natural gas liquids has also increased. The rise in production of these fuel sources has also corresponded with increased consumption and exports of each.

The rise in U.S. oil and natural gas production has taken place mostly onshore and on nonfederal lands. Nonfederal crude oil production nearly doubled over the past decade. While production on federal land has increased, it has not grown as fast as nonfederal oil production, causing the federal share of total U.S. crude oil production to fall from its peak of nearly 36% in 2009 to about 22% in 2015 (the latest data available). U.S natural gas production shifted even more dramatically, with total U.S. production nearly doubling since 2006, while production on federal lands declined by almost 26% over the same time period. The federal share decreased from 28% in 2006 to 15% in 2015.

The electric power industry is in the process of transformation, especially with natural gas becoming the main electric generation fuel in 2016 and the growth in renewable forms of energy. The electricity infrastructure of the United States is aging. Uncertainty exists about how to modernize the grid and what technologies and fuels will be used to produce electricity in the future. Unresolved questions about transmission and reliability of the grid are arising due to potential cybersecurity threats and continuing interest in renewable energy and other low carbon sources of electricity. Concerns about reliability and electricity prices are complicated by environmental regulations and the rising availability of natural gas for electric power production.

While renewable energy is currently a relatively small portion of the total U.S. energy sector, renewables production and consumption have increased since the turn of this century. As a source of total primary energy, renewable energy increased 97% between 2001 and 2016. Unlike some other energy commodities (e.g., crude oil), renewable energy is available in a variety of distinct forms that use different conversion technologies to produce usable energy products (e.g., electricity, heat, and liquid fuels). Therefore, it is important to distinguish between renewable fuel sources and uses.

The United States has the largest coal resources in the world. Coal is used primarily for electricity generation. Although its prices have stayed low, coal has faced increasing competition from natural gas and renewables. U.S. consumption peaked in 2007 and has since declined by 35%. Meanwhile, nuclear output has stayed flat during the time period, but has faced significant stress as a future source of electric power generation.

Energy production and consumption have been issues of interest to Congress for decades. Current topics of concern to Congress include exports, imports, independence, security, infrastructure, efficiency, the environment, and geopolitics. Legislation has been introduced in both houses of Congress to address these issues and others.

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Introduction: A Reversal of Fortune

The United States has been an integral part of the global energy sector for many decades. It is a global 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, coal, nuclear power, and renewable energy.

Since the beginning of the 21st century, the U.S. energy sector has undergone tremendous changes. It has gone 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. 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 contacts. The report is mainly organized around the major fuels and energy sources used in the United States. It also highlights the role of the federal government, particularly the use of federal lands in energy production. It does not focus on energy infrastructure, security, energy efficiency, or environmental issues, although those areas are also critical to the U.S. energy sector.

Issues for Congress

Policy Goals

Energy policy in the United States has focused on three major goals: assuring a secure supply of energy, keeping energy costs low, and protecting the environment. In pursuit of those goals, government programs have been developed to improve energy efficiency, to promote the domestic production of conventional energy sources, and to develop new energy sources, particularly renewable sources.

Implementing these programs has been controversial because of varying importance given to different aspects of energy policy by different stakeholders. For some, dependence on imports of foreign energy, particularly from the Persian Gulf, is the primary concern; for others, the continued use of fossil fuels, whatever their origin, is of greatest concern. The extent to which producing and burning fossil fuels contributes to global climate change is particularly controversial. Another dichotomy is between those who see government intervention in the energy sector as a positive force, and those who do not and seek government intervention to be restricted as much as possible.

Legislation from Previous Congresses

Energy policy has often been legislated in large, complex 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 the most recent comprehensive general legislation, 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 of 35 miles per gallon by 2020, and expanded the renewable fuels standard (RFS) to require 9.0 billion gallons of biofuels in transportation in 2008, rising to 36 billion gallons by 2022.[1] EISA also included new efficiency standards for appliances and for light bulbs, the latter being particularly controversial in the 112th Congress.[2]

In the 114th Congress, both the House and Senate considered broad energy legislation, as well as specific topics of key interest. The two primary bills were S. 2012, the Energy Policy and Modernization Act, and H.R. 8, the North American Energy Security and Infrastructure Act of 2015. After the House passed S. 2012 with the text of H.R. 8, a conference committee met to consider the two versions of S. 2012 but did not resolve the differences before the 114th Congress adjourned. Both bills addressed a variety of energy topics, including energy efficiency in federal buildings, data centers, manufacturing, and schools; water conservation/efficiency; regulation and development of nonfederal hydropower; electric grid cybersecurity; and review of the Strategic Petroleum Reserve (SPR). The House bill also included topics such as electric grid physical security and a study of electricity markets; the Senate bill also included provisions on helium and critical minerals, electric grid energy storage, and loan programs. Furthermore, both bills contained major natural resources provisions, including a title on forestry management in the House and permanent reauthorization of the Land and Water Conservation Fund in the Senate.[3]

U.S. Energy Profile

The United States is the second largest consumer of energy in the world, behind China.[4] U.S. primary energy consumption (see **Figure 1**) has held relatively steady since 2000, falling 1%; 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 at the expense of coal. Nuclear generation has stayed flat.

The change in the fuel mix has centered on the sector where there are fuel substitutes, which in the U.S. case is electricity (see "The Electric Power Sector"). Electric power generation in 2016 came from coal (30%), natural gas (34%), nuclear (20%), renewables (15%), and petroleum (<1%), according the U.S. Energy Information Administration (EIA).[5] This is a significant change from 2000, when coal accounted for 52% of the electricity fuel mix and natural gas was 16%, nuclear was still almost 20%, and renewables were 9%. Industrial use of energy has also experienced changes, but not to the same degree as electric power generation in recent years. On the other end of the spectrum, energy in transportation is dominated by petroleum, which made up 92% of the fuel used in transportation in 2016, which is down from 97% in 2000.[6]

[1] For more information, see CRS Report R42721, *Automobile and Truck Fuel Economy (CAFE) and Greenhouse Gas Standards*, by (name redacted), (name redacted), and (name redacted) .

[2] For more information, see CRS Report R43815, *Energy Efficiency: DOE's Regional Standards for Indoor (Non-Weatherized) Residential Gas Furnaces*, by (name redacted) and (name redacted)

[3] For a discussion of major provisions in both bills, see CRS Report R44291, *Energy Legislation: Comparison of Selected Provisions in S. 2012 as Passed by the House and Senate*, by (name redacted) .

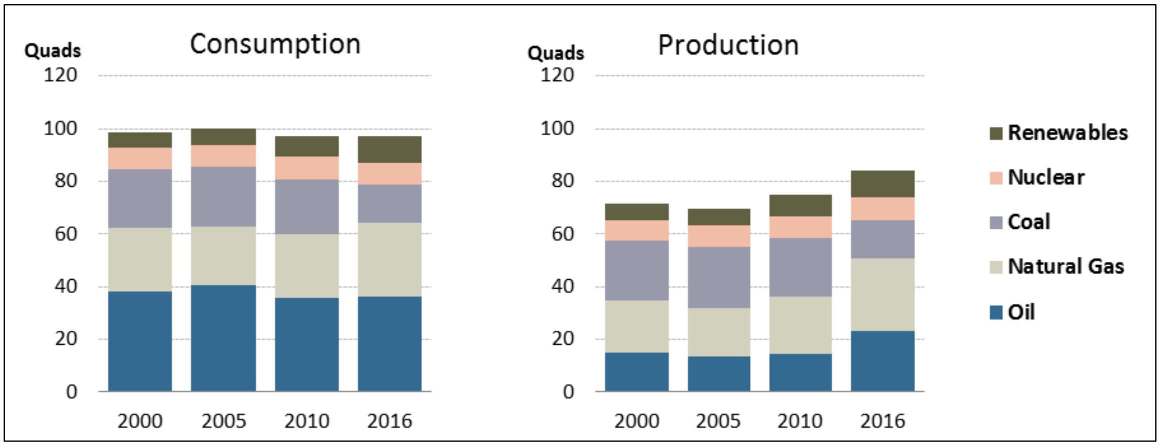
[4] BP, *BP Statistical Review of World Energy*, June 2016, p. 41.

[5] U.S. Energy Information Administration, *Net Generation for United States, Annual*, Electricity Data Browser, https://www.eia.gov/electricity/data/browser/#/topic/0?agg=2&fuel=vtvv&linechart=ELEC.GEN.ALL-US-99.A&columnchart=ELEC.GEN.ALL-US-99.A&map=ELEC.GEN.ALL-US-99.A&freq=A&ctype=linechart&ltype=pin&rtype=s&maptype=0&rse=0&pin=.

[6] Lawrence Livermore National Laboratory, *Energy Flow Chart*, 2017, https://flowcharts.llnl.gov/.

Figure 1. U.S. Primary Energy Consumption and Production by Fuel 2000-2016

Quadrillion British Thermal Unit (Quads)



Source: Data compiled by CRS from U.S. Energy Information Administration data, https://www.eia.gov/totalenergy/data/browser/?tbl=T01.03#/?f=A and https://www.eia.gov/totalenergy/data/browser/?tbl=T01.02#/?f=A.

Notes: Renewables include hydroelectric power, geothermal, solar, wind, and biomass.

U.S. energy production between 2000 and 2016 increased 18%, a tremendous amount considering that historically the United States was viewed as a growing importer of energy. (See **Figure 1**.) On a percentage basis, renewables have increased the most, by 66% during the time frame, although still accounting for one of the smallest parts of U.S. energy production. Oil has risen the next fastest, growing 56%, followed by natural gas at 39%. The increase in production of both these resources comes from innovations in extraction from "tight" formations, such as shale (see text box below, "Shale Resources Make the Difference"). Coal, on the other hand, is the only fuel to have declined during the time period, by about 36%.

Shale Resources Make the Difference

The United States has seen a resurgence of oil and natural gas production, mainly driven by technology improvements—especially in hydraulic fracturing and directional drilling. The United States has been the world's largest producer of natural gas since 2009 and of petroleum liquids since 2014. Production from shale formations comprised 56% of U.S. natural gas production in 2015 and 48% of oil production, the latest available data. The contribution of shale resources to both oil and natural gas production is expected to grow.

The determination of whether a formation is unconventional or conventional depends on its geology. Unconventional formations are fine-grained, organic-rich, sedimentary rocks—usually shales and similar rocks. The shales and rocks are both the source of and the reservoir for oil and natural gas, unlike conventional petroleum reservoirs. 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."[7] In contrast, conventional oil and natural gas deposits occur in porous and permeable sandstone and carbonate reservoirs. Under pressure exerted by water, the hydrocarbons migrated upward from organic sources until an impermeable cap-rock (such as shale) trapped it in the reservoir rock. Although the unconventional formations may be as porous as other sedimentary reservoir rocks, their extremely small pore sizes and lack of permeability make them relatively resistant to hydrocarbon flow. The lack of permeability means that the oil and gas typically remain in the source rock unless natural or artificial fractures occur. Hydraulic fracturing technology now allows these vast resources to be economically produced.

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

Energy Resources on Federal Lands[8]

Federal lands account for a significant amount of total U.S. energy production.[9] For example, in 2015 (the latest year for this data), as a percentage of total U.S. energy production, approximately 22% of crude oil, 15% of natural gas, and 42% of coal came from federal lands.[10] How to balance energy production on federal lands against other resource values has long been a fundamental question for Congress.

Much of the onshore federal estate is open to energy and mineral exploration and development, including Bureau of Land Management (BLM) and many Forest Service (FS) lands. However, many National Park Service (NPS) lands and areas within the National Wilderness Preservation System, as well as certain other federal lands, have been specifically withdrawn from exploration and development.[11]

Development of oil, natural gas, and coal on federal lands is governed primarily by the Mineral Leasing Act of 1920 (MLA).[12] Geothermal leasing on federal lands is conducted under the authority of the Geothermal Steam Act of 1970, as amended.[13] Development of solar and wind energy sources on BLM and FS lands is governed primarily by right-of-way authorities under Title V of the Federal Land Policy and Management Act (FLPMA).[14]

Offshore federal resources, within and beyond the U.S. Exclusive Economic Zone (EEZ), are also open for exploration and development. The federal government is responsible for managing energy resources in approximately 1.7 billion acres of waters belonging to the United States. These offshore resources are governed by the Outer Continental Shelf Lands Act of 1953 (OCSLA), as amended.[15]

Federal lands also are available for renewable energy projects. BLM manages the solar and wind energy programs on about 20 million acres for each program and has the authority to manage about 240 million acres for geothermal leasing on federal lands.[16] Geothermal capacity on federal lands represents 40% of U.S. total geothermal electric generating capacity.

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[8] (name redacted), CRS Specialist in Energy Policy, was the lead author of this section. He can be contacted at [redacted]@crs.loc.gov or 7-.....

[9] For additional information on federal land issues related to energy projects, see CRS Report R40806, *Energy Projects on Federal Lands: Leasing and Authorization*, by (name redacted)

[10] Office of Natural Resources Revenue (onrr.gov), Production Data. Calendar year data obtained October 2016.

[11] The Mining in the Parks Act of 1976 (16 U.S.C. §§1901 et seq.) closed all NPS units to the location of new mining claims, although existing claims must still be honored (see 36 C.F.R. Part 9B). P.L. 95-495 §11(a) is an example of a wilderness designation that withdrew an area from mining and mineral exploration.

[12] 30 U.S.C. §181.

[13] 30 U.S.C. §§1001-1028.

[14] 43 U.S.C. §§1761-1771.

[15] 43 U.S.C. §§1331 et seq.

[16] Bureau of Land Management (BLM), "New Energy for America," at (solar) https://www.blm.gov/programs/energy-and-minerals/renewable-energy/solar-energy; (wind) https://www.blm.gov/programs/energy-and-minerals/renewable-energy/wind-energy; and (geothermal) https://www.blm.gov/programs/energy-and-minerals/renewable-energy/geothermal-energy.

Oil and Natural Gas on Federal Lands

Oil production fluctuated on federal lands over the 10 years from 2006 to 2015, but overall increased by 26%.[17] However, because nonfederal crude oil production nearly doubled over the decade (primarily due to improved extraction technology, favorable geology, and the ease of leasing), the federal share of total U.S. crude oil production fell from its peak of nearly 36% in 2009 and 2010 to about 22% in 2015.

While annual U.S. natural gas production rose by about 10 trillion cubic feet (TCF) to 28.7 TCF since 2006, annual production on federal lands fell by about 1.6 TCF (or nearly 26%) to 4.6 TCF over the same time period. The federal share of natural gas production fell from almost 33% in 2006 to 16% in 2015. The big shale gas plays have been primarily on nonfederal lands and have attracted a significant portion of investment for natural gas development.

The MLA authorizes the Secretary of the Interior—through BLM—to lease the subsurface rights to virtually all BLM and FS lands that contain fossil fuel deposits, with the federal government retaining title to the lands.[18] Based on the federal government's 2008 inter-agency Phase III inventory report, 113 million acres of onshore federal lands are open and accessible for oil and gas development and about 166 million acres are off-limits or inaccessible.[19] The accessible federal land contains an estimated 11.5 billion barrels of oil and 136.5 TCF of natural gas, representing 38% and 59% of the estimated total federal resource potential, respectively. Federal land off-limits contains an estimated 19 billion barrels of oil and 95 TCF of natural gas, or 62% and 41% of the total resource potential, respectively.

For offshore oil and gas, OCSLA requires the Secretary of the Interior to submit five-year leasing programs that specify the time, location, and size of the areas to be offered. The Bureau of Ocean Energy Management (BOEM), which runs the offshore energy leasing program, administers approximately 3,600 active oil and gas leases on over 19 million acres in the outer continental shelf (OCS).[20] In preparing its five-year programs under the OCSLA, BOEM must consider the resource potential of individual OCS regions and planning areas along with other factors, such as potential environmental and socioeconomic impacts of oil and gas leasing.

Under the OCSLA,[21] the President may withdraw unleased lands on the OCS from leasing disposition. Congress also has established leasing moratoria; for example, the Gulf of Mexico

[17] 2015 is the latest data available.

[18] Exceptions include most BLM and FS lands classified as wilderness, lands incorporated in cities and towns, and lands that have otherwise been administratively or statutorily withdrawn from entry.

[19] U.S. Depts. of the Interior, Agriculture, and Energy, *Inventory of Onshore Federal Oil and Natural Gas Resources and Restrictions to Their Development (Phase III)*, May 2008, https://web.archive.org/web/20160930082235/http:/www.blm.gov/style/medialib/blm/wo/MINERALS__REALTY__AND_RESOURCE_PROTECTION_/energy/00.Par.28561.File.dat/EPCA2008hi_1.pdf.

The availability of public lands for oil and gas leasing can be divided into three categories: lands open under standard lease terms, open to leasing with restrictions, and closed to leasing. Areas are closed to leasing pursuant to land withdrawals or other mechanisms. Much of this withdrawn land consists of wilderness areas, military bases, national parks and monuments, and other unique and environmentally sensitive areas that are unlikely to be reopened to oil and gas leasing given their current status. Some lands are closed to leasing pending land use planning or National Environmental Policy Act (NEPA) compliance, while other areas are closed because of federal land management decisions on endangered species habitat or historical sites. Some of those restricted areas may be opened by future administrative decisions.

[20] BOEM Combined Leasing Report, October 1, 2016.

[21] 43 U.S.C. §1341.

Energy Security Act (GOMESA) established a moratorium on preleasing, leasing, and related activity in the eastern Gulf of Mexico through June 2022.

According to BOEM, the U.S. OCS contains *undiscovered technically recoverable resources* (UTRR) estimated at 89.9 billion barrels of oil and 327.5 TCF of natural gas.[22] The Gulf of Mexico contains about 54% of the UTRR for oil and an estimated 43% of the natural gas, with the vast majority of the resources in the Central Gulf of Mexico. The OCS around Alaska has the second largest UTRR, and about 90% of Alaska's UTRR estimates for oil and 80% for natural gas are contained in the Chukchi and Beaufort Seas.

Congress considers multiple issues related to offshore oil and gas exploration, including questions about allowing or deferring access to ocean areas and how increasing or restricting access may impact domestic energy markets and affect the risk of oil spills. Other issues concern the use of OCS revenues and the extent to which they should be shared with coastal states.

Federal Coal Resources

There are 309 federal coal leases on about 474,000 acres on federal public domain lands.[23] Coal production on federal lands has consistently accounted for about 40% of total U.S. coal production over the past decade. Production on federal lands peaked in 2008 at 487 million tons. Since then, federal coal production declined by 23% to 375 million tons in 2015, the latest year for this data.

On January 16, 2016, President Obama announced a moratorium on federal coal leasing (issued as Secretarial Order 3338) to examine the federal coal leasing program and to determine whether it needs to be "modernized." The Secretary of the Interior directed BLM to prepare a programmatic environmental impact statement (PEIS) of the coal leasing program to serve as the basis for a comprehensive review. On January 11, 2017, the Obama Administration published its scoping report[24] as a prelude to a comprehensive draft and final PEIS. However, on March 28, 2017, the Trump Administration issued an Executive Order that requires the Secretary of the Interior to "take all steps necessary and appropriate to amend or withdraw Secretary's Order 3338" and lift "any and all" moratoria on federal coal leasing.[25] The moratorium has drawn both support and opposition in Congress.

[22] BOEM, "Assessment of Undiscovered Technically Recoverable Oil and Gas Resources of the Nation's Outer Continental Shelf, 2016," fact sheet, at http://www.boem.gov/National-Assessment-2016/. BOEM defines *undiscovered technically recoverable resources* (UTRR) as "oil and gas that may be produced as a consequence of natural pressure, artificial lift, pressure maintenance, or other secondary recovery methods, but without any consideration of economic viability." By contrast, *undiscovered economically recoverable resources* (UERR) are defined as "the portion of the undiscovered technically recoverable resources that is economically recoverable under imposed economic and technologic conditions." Estimations of UERR will differ under different economic scenarios.

[23] BLM, "Coal Operations" and "Federal Coal Leasing," at https://www.blm.gov/live/pdfs/CoalListeningSessions%20PPT%208.07.15.pdf.

[24] Bureau of Land Management, *Federal Coal Program: Programmatic Environmental Impact Statement—Scoping Report, Volumes I and II,* January 2017.

[25] White House, "Presidential Executive Order on Promoting Energy Independence and Economic Growth," https://www.whitehouse.gov/the-press-office/2017/03/28/presidential-executive-order-promoting-energy-independence-and-economi-1.

Renewable Energy on Federal Land

Geothermal Energy

Geothermal energy is a renewable energy source produced from heat stored under the surface of the earth. BLM manages geothermal permitting and leasing requirements for federal lands, in consultation with FS. Under EPAct2005, states receive 50% of the revenue generated from rental and royalty payments from geothermal leases within their borders, counties receive 25%, and the remaining 25% goes to the U.S. Treasury.

Wind and Solar Energy

Wind and solar projects could require large tracts of land to replace or add significant electric generating capacity, in addition to new transmission capacity that may be needed. One issue for Congress is how to balance solar and wind project applications against other land uses. For example, in 2013, BLM finalized a rule allowing temporary withdrawal of subsurface mineral claims in areas with pending wind and solar project applications.[26] Another issue for Congress is how to manage the leasing process for wind and solar energy projects. In December 2016, BLM finalized amendments of the regulations governing the process by establishing preferred areas for solar and wind energy development and establishing specific competitive right-of-way leases, among other provisions.[27]

Woody Biomass

Removing woody biomass[28] from federal lands for energy production has received attention from stakeholders in the biomass supply chain for energy and wildfire management because of its potential widespread availability. Past administration efforts to promote and implement woody biomass energy production focused on developing policy principles, research and development, infrastructure, and capacity building.[29] FS and BLM both award woody biomass utilization research grants through EPAct2005.[30] Programs such as stewardship contracting and the collaborative forest landscape restoration program authorize both agencies to implement woody biomass utilization projects.

Offshore Renewable Energy Sources

BOEM is responsible for managing renewable ocean energy resources. BOEM has been in the process of estimating renewable ocean energy resources to facilitate leases for electricity

[26] BLM, "Segregation of Lands-Renewable Energy," 78 *Federal Register* 25204, April 30, 2013.

[27] BLM, "Competitive Processes, Terms, and Conditions for Leasing Public Lands for Solar and Wind Energy Development and Technical Changes and Corrections; Final Rule," 81 *Federal Register* 92122, December 19, 2016.

[28] Woody biomass is defined by FS and BLM as the trees and woody plants, including limbs, tops, needles, leaves, and other woody parts, grown in a forest, woodland, or rangeland environment that are the byproducts of forest management.

[29] See for example, Memorandum of Understanding on Policy Principles for Woody Biomass Utilization for Restoration and Fuel Treatments in Forests, Woodlands, and Rangelands, June 2003, at https://www.fs.fed.us/woodybiomass/documents/BiomassMOU_060303_final_web.pdf, Woody Biomass Utilization Desk Guide, September 2007, at http://www.forestsandrangelands.gov/Woody_Biomass/documents/biomass_deskguide.pdf.

[30] See for example, Forests and Rangelands, "Woody Biomass Utilization Opportunities," at http://www.forestsandrangelands.gov/Woody_Biomass/opportunities.shtml, April 10, 2017 (last modified).

generation from offshore wind, thermal power, and kinetic forces from ocean tides and waves.[31] As of October 2016, BOEM had issued 11 offshore wind energy leases in areas off the coasts of Massachusetts, Rhode Island, Delaware, Maryland, Virginia, and New Jersey.[32] One lease within the Offshore Renewable Energy Program, the Block Island Wind Farm off the coast of Rhode Island, which is a five-turbine, 30-Megawatt (MW) wind farm developed by Deepwater Wind, has achieved commercial production. Congress has considered whether to facilitate the development of offshore wind and other renewables through steps such as grants for research and development, project loan guarantees, extension of federal tax credits for renewable energy production, or oversight of regulatory issues for these emerging industries.

Oil: Moving Towards Self-Sufficiency[33]

Production of oil in the United States rose in the latter half of the time period 2000-2016, while consumption fluctuated. The rise in production is attributed to increased production from "tight" formations, discussed above. Petroleum is mostly consumed in transportation (72%), industrial use (23%), residential and commercial use (4%), and electric power generation (1%). Approximately 92% of transportation fuels come from petroleum. No other sector in the U.S. economy is so dominated by one fuel source as is transportation, which is why fuel efficiency of vehicles (see text box "Fuel Efficiency Standards for Vehicles") is so important. Energy independence and energy security are more associated with petroleum than with any other fuel.

Petroleum Refining: A Key Industry

The petroleum refining industry processes crude oil and other petroleum-based liquids to produce transportation fuels (including motor gasoline, diesel fuel, aviation gasoline, and jet fuel), home heating oil, petrochemical feedstocks, lubricants, and other products. The United States is the top-producing country of refined products. In 2016, most of the product mix was composed of transportation fuels, with home heating oil, petrochemical feedstocks, lubricants, and other products from liquefied refinery gases to asphalt and road oil making up the rest.

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[31] P.L. 109-58. For more information about deployment of renewable energy projects, see http://www.boem.gov/Renewable-Energy-Program/Smart-from-the-Start/Index.aspx. Estimates of OCS energy resources are available from a variety of sources, including BOEM, the Energy Information Administration, and industry sources. For a general analysis of OCS resources, see CRS Report R40645, *U.S. Offshore Oil and Gas Resources: Prospects and Processes*, by (name redacted) and (name redacted)

[32] See BOEM, Renewable Energy Programs at https://www.boem.gov/Renewable-Energy/. The 11 leases include nine individual lease sales and two noncompetitive leases. In addition, BOEM issued several "interim policy" leases for resource data collection and testing, prior to development of its renewable energy leasing regulations (see BOEM, "Interim Policy," at http://www.boem.gov/Renewable-Energy-Interim-Policy/). BOEM has subsequently held two additional wind auctions, one off of New York (December 2016) and one off of North Carolina (March 2017).

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Table 1. U.S. Refining Industry, 2000-2016

Year	Number of Refineries	Total Operable Capacity (million barrels per day)	Percent Utilization Rate
2000	158	16.511	92.6
2001	155	16.595	92.6
2002	153	16.785	90.7
2003	149	16.757	92.6
2004	149	16.894	93.0
2005	148	17.124	90.6
2006	149	17.338	89.7
2007	149	17.443	88.5
2008	150	17.593	85.3
2009	150	17.671	82.9
2010	148	17.583	86.4
2011	148	17.736	86.2
2012	144	17.322	88.7
2013	143	17.823	88.3
2014	142	17.924	90.4
2015	140	17.967	91.0
2016	141	18.317	N/A

Source: U.S. Energy Information Administration, Refinery Data, available at https://www.eia.gov/dnav/pet/pet_pnp_cap1_dcu_nus_a.htm. Updated June 22, 2016.

Notes: Number of refineries represents the total number of operable refineries on January 1 of each year. In any given year a number of these refineries may be idle, although operable, for some part of the year. Operable capacity is measured as million barrels per day of atmospheric distillation capacity per calendar day.

While the number of U.S. refineries (see **Table 1**) declined by 17, or 11%, since 2000, the industry has not been in decline. Capital investment in new technologies and processes has resulted in refinery capacity increasing by about 11% since 2000. The data suggest that refineries are becoming larger on average and more efficient. Utilization rates in the industry, which are the ratio of petroleum that runs through a refinery and its operating capacity, are high and relatively stable. However, the economic downturn that began in 2008-2009 resulted in reduced demand for petroleum products, keeping utilization rates below 90% until 2014.

The oil and natural gas producing industries and the petroleum refining industry are closely related because of their complementary relationship. There are few, if any, consumer uses for unrefined crude oil, and refiners must use crude oil to produce the useful products the refining process yields. Because of this symbiotic relationship, many times the sectors' contributions to the national economy are combined. For example, according to a 2016 American Petroleum Institute report, the oil and natural gas industries, which included production and refining, supported about 9.8 million jobs and accounted for 8% of U.S. gross domestic product.[34]

[34] American Petroleum Institute, "State of American Energy," January 6, 2016. The larger percentage of jobs is accounted for by oil and gas production activities which are more labor intensive than petroleum refining, while the (continued...)

Sources of Crude Oil

The U.S. refining industry draws on crude oil supplies from around the world as well as domestic production. **Table 2** shows key sources of industry supply.

Table 2. U.S. Sources of Crude Oil, 2000-2016

(million barrels per day)

Year	Total Imports	OPEC	Canada	Other Imports	U.S. Production
2000	9.07	4.54	1.34	3.19	5.82
2001	9.32	4.84	1.35	3.13	5.80
2002	9.14	4.08	1.44	3.62	5.74
2003	9.66	4.57	1.54	3.55	5.64
3004	10.08	5.04	1.61	3.43	5.44
2005	10.12	4.81	1.63	3.68	5.18
2006	10.11	4.78	1.80	3.53	5.08
2007	10.03	5.38	1.88	2.77	5.07
2008	9.78	5.41	1.95	2.42	5.00
2009	9.01	4.35	1.94	2.72	5.35
2010	9.21	4.55	1.97	2.69	5.47
2011	8.93	4.20	2.22	2.51	5.64
2012	8.52	4.03	2.42	2.07	6.48
2013	7.73	3.49	2.57	1.67	7.46
2014	7.34	3.00	2.88	1.46	8.76
2015	7.36	2.67	3.16	1.53	9.42
2016	7.88	3.18	3.26	1.44	8.88

Source: Energy Information Administration, U.S. production and import/export data, available at https://www.eia.gov/dnav/pet/pet_move_impcus_a2_nus_epc0_im0_mbblpd_a.htm, updated April 28, 2017.

Notes: Table 2 only shows crude oil data. Other petroleum-based liquids enter the refining industry. The United States generally imports crude oil from over 50 countries. OPEC refers to member nations of the Organization of the Petroleum Exporting Countries. Total Imports includes crude oil from OPEC, Canada, and other countries. Total Imports plus U.S. Production equals total crude oil consumed annually.

The data in **Table 2** show that from 2000 to 2008 U.S. production of crude oil was generally declining while U.S. imports of crude oil were increasing. Over the period, U.S. imports from the Organization of the Petroleum Exporting Countries (OPEC) were also generally increasing. This period was consistent with increasing oil import dependence and declining security.

(...continued)

greater percentage of the value of gross domestic product is accounted for by the refining industry, because crude oil and natural gas are intermediary products and, as such, are not directly added in the calculation of gross domestic product. The American Petroleum Institute study also considers jobs supported by the oil and natural gas industries, which include a wide variety of support activities not directly related to oil production or refining.

In 2009, U.S. production of crude oil began to increase, as did Canadian supplies of crude oil to the United States, which crossed the 2 million barrels per day (Mb/d) rate in 2011. As a result, U.S. imports from OPEC began to decline and the United States entered a period of declining oil import dependence and increasing security. The rise in crude oil production, in part, prompted a call from industry to lift restrictions on exporting crude oil. At the end of 2015, the President signed the Consolidated Appropriations Act, 2016 (P.L. 114-113), which lifted the restrictions on crude oil exports. Crude oil exports have risen steadily since the restrictions were lifted, reaching a new high of 1.1 million b/d in February 2017.[35]

Foreign Trade in Petroleum Products

In addition to unrefined crude oil, the United States also imports refined products (mostly gasoline), although the primary source of petroleum products for U.S. consumers remains the U.S. refining industry. Recently, the refining industry has increased its presence in foreign markets with increasing exports of refined products; the United States became a net exporter of petroleum products in 2011.

The data in **Table 3** show that since 2007, U.S. dependence on the world market for petroleum products has been declining. In addition, U.S. refiners now allocate almost 25% of their operable capacity to supply buyers in the world market. Considering U.S. crude oil imports in light of increasing petroleum product exports, the raw data may give a somewhat distorted picture of U.S. dependence on imported oil. This is because some of U.S. crude oil imports enter the refining industry for processing and re-enter the world market as petroleum product exports.

Issues for the Refining Industry

Continued reliance on the world oil market for crude oil supplies and petroleum products, as well as increasing U.S. exports of both crude oil and petroleum products, suggests that any change in U.S. tariff policy will affect the refining industry. The effects of changing U.S. tariff policy might result in a changing pattern of nations that the United States deals with for imports and exports, risking retaliation against U.S. goods, as well as affecting consumer prices for gasoline and other products.

Oil prices and the availability of various grades of crude oil will continue to affect the economic performance of the refining industry. Oil prices peaked at over $140 per barrel in 2008 and then began a decline that saw the price fall to below $40 per barrel in 2009. Recently, the price has been in the $50 per barrel range. Refiners need an oil price predictable enough so that they can make economically rational petroleum product pricing decisions. However, the price needs to be high enough that it remains profitable for oil producers to continue to invest in production and expand market supply to satisfy demand, and low enough to encourage consumption.

Environmental concerns affect the refining industry, including air, water, and land pollution. Permitting a new refinery is an expensive, slow process due to environmental and other challenges, which helps explain why it is more common to expand the capacity of existing facilities rather than construct new facilities.[36]

[35] U.S. Energy Information Administration, *Petroleum & Other Liquids: Exports*, April 28, 2017, https://www.eia.gov/dnav/pet/pet_move_exp_dc_NUS-Z00_mbblpd_m.htm.

[36] The Hyperion Refinery project in South Dakota and the Arizona Clean Fuels Yuma refinery project in Arizona were both abandoned after public opposition during the permitting process.

Table 3. U.S. Foreign Trade in Petroleum Products, 2000-2016

(million barrels per day)

Year	Imports	Exports
2000	2.38	0.95
2001	2.54	0.95
2002	2.39	0.97
2003	2.59	1.01
2004	3.05	1.02
2005	3.58	1.13
2006	3.53	1.29
2007	3.43	1.40
2008	3.13	1.77
2009	2.67	1.98
2010	2.58	2.31
2011	2.50	2.93
2012	2.07	3.13
2013	2.12	3.48
2014	1.89	3.82
2015	2.08	4.27
2016	2.18	4.67

Source: Energy Information Administration, U.S. import/export data, available at https://www.eia.gov/dnav/pet/pet_move_impcus_a2_nus_EPP0_im0_mbblpd_a.htm, updated April 28, 2017 and https://www.eia.gov/dnav/pet/pet_move_exp_dc_NUS-Z00_mbblpd_a.htm, updated April 28, 2017.

Notes: Petroleum products refer to a wide range of refinery outputs.

Fuel Efficiency Standards for Vehicles[37]

Two key federal statutes regulate the fuel efficiency of U.S. cars and trucks. First, the Energy Policy and Conservation Act (EPCA, P.L. 94-163) established Corporate Average Fuel Economy (CAFE) standards for passenger cars starting in model year (MY) 1978 and light trucks in MY1979. Over time, the statute has been amended to require tighter standards, to significantly modify the structure of the program, and to include heavy-duty trucks. Second, greenhouse gas emissions—which are closely linked with fuel consumption—are regulated under the Clean Air Act (CAA, 42 U.S.C. 7521 et seq.). In addition, the state of California, which has authority to set its own vehicle emissions standards, has established greenhouse gas standards, which other states have adopted. (States are preempted from setting their own fuel economy standards, and are generally preempted from setting their own emissions standards except that they may adopt the California standards.)

Because of concerns over three competing sets of regulations on the same topic, in 2009 the Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA) (which administer emissions and fuel economy standards, respectively) developed a set of memoranda of understanding among the agencies, the automakers, and California. The federal agencies would aim to integrate their standards as much as

[37] For more information, see CRS Report R40506, *Cars, Trucks, Aircraft, and EPA Climate Regulations*, by (name red acted) and (name redacted) , and CRS Insight IN10550, *Automakers Seek to Align Fuel Economy and Greenhouse Gas Regulations*, by (name redacted)

possible, California would accept vehicles complying with federal standards as meeting the state's standards, and the automakers would drop lawsuits they had initiated against California over the rules.

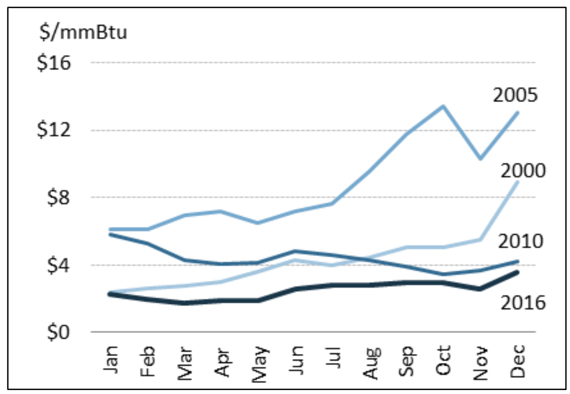
EPA and NHTSA first issued joint CAFE/emissions standards for MY2012-MY2016, on cars and light trucks, calling for significantly higher fuel economy than previously required. Some of this was in response to a requirement in the Energy Independence and Security Act of 2007 (EISA, P.L. 110-140), although the final standards achieved the EISA target early. In 2012, the agencies issued a second phase of light duty vehicle standards for MY2017-MY2025 for emissions and MY2017-MY2022 for fuel economy—EPCA prohibits NHTSA for setting standards for longer than five model years. If achieved, these standards would ultimately push car and light truck average fuel economy above 50 miles per gallon. Because of the long time frame of the emissions standards, and the need for a new rulemaking on fuel economy, the agencies committed to a Midterm Evaluation (MTE) of the MY2022-MY2025 portion of the greenhouse gas standards. On January 12, 2017, EPA decided to maintain the standards as promulgated. However, for the CAFE standards, a new rulemaking remains necessary. On March 15, 2017, President Trump announced that EPA and NHTSA would reinstate the MTE process.[38]

Natural Gas: A Growing Piece of the Energy Mix[39]

In the beginning of the 21st century, natural gas prices were on the rise (see **Figure 2**) and the United States was viewed as a growing natural gas importer. Multiple liquefied natural gas (LNG) import terminals were built during this time in preparation for increased demand. However, the market conditions also drove domestic producers to innovate. As prices reached their peak in 2008, domestic shale gas was brought to market. (See "U.S. Supply" below.) Improvements in technologies such as hydraulic fracturing and horizontal drilling made the development of unconventional natural gas resources such as shale and other lower-permeability rock formations possible.[40] Improved efficiency has lowered production costs, making shale gas economically competitive at almost any price and enabling large-scale exports.

Figure 2. Monthly U.S. Natural Gas Prices, 2000-2016

(dollars per million British thermal unit)



Source: EIA, Natural Gas Spot and Futures Prices (NYMEX), http://www.eia.gov/dnav/ng/ng_pri_fut_s1_m.htm.

Notes: Prices are spot prices and in nominal dollars.

As U.S. production increased and prices fell, U.S. consumption of natural gas grew, rising over 17% from 2000 to 2016. (See "U.S. Consumption" below.) The rise in consumption, though, did not keep pace with production, so companies turned to greater exports of natural gas, first by pipeline to Mexico and then as LNG to other parts of the world. (See "U.S. Exports" below.) As shown in **Figure 3**, supply and imports of natural gas were still greater than consumption and exports in 2016, in part because of growing use of storage.

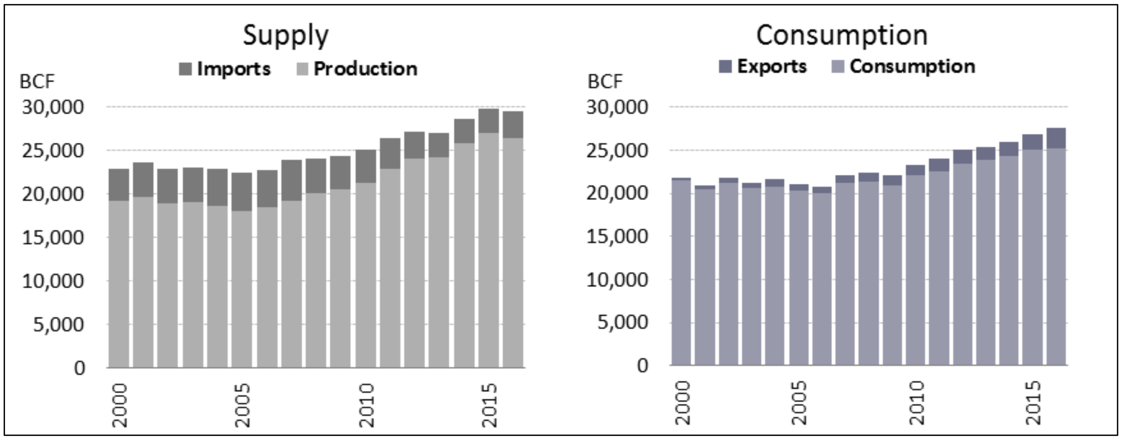
38 The White House, Office of the Press Secretary, *President Donald J. Trump: Buy American and Hire American for the United States Automobile Industry*, Washington, DC, March 15, 2017, https://www.whitehouse.gov/the-press-office/2017/03/15/president-donald-j-trump-buy-american-and-hire-american-united-states.

39 (name redacted), CRSSpecialist in Energy Policy, was the lead author of this section. He can be contacted at redacted@crs.loc.govor 7-.....

40 Federal Energy Regulatory Commission, "Energy Primer: A Handbook of Energy Market Basics," July 2015, p. 10.

Figure 3. U.S. Natural Gas Supply and Consumption, 2000-2016

(Billion Cubic Feet)



Source: EIA, http://www.eia.gov/naturalgas/data.cfm.

Notes: The difference between the two columns for a given year in each chart is the volume of natural gas that is held in storage.

U.S. Supply

The United States is the world's largest producer of natural gas. Since 2005, U.S. natural gas production has risen every year until 2016, even as prices declined. Between 2000 and 2016, production increased almost 38%. Production in 2016 was down from the 2015 total of 27,060 billion cubic feet (BCF), the highest ever U.S. production. 2016 showed the first decline since 2004. The large increase in natural gas production since 2005 is mostly attributed to the development of shale gas resources, specifically in the Marcellus and Utica formations in the northeastern United States; since 2012 the two formations have accounted for 85% of the increase in natural gas production.[41]

U.S. Consumption

The United States is the largest consumer of natural gas in the world, using about 25,265 BCF in 2016. Electric power generation made up 40% of U.S. natural gas consumption in 2016; industrial use accounted for 31%, residential use for 17%, and commercial use for 12%. There is a significant rise in the use of natural gas for electric power generation, which can be attributed to low natural gas prices due to the abundance of domestic gas resources, and to policies that promote the use of fuels with lower emissions. Demand for natural gas for power generation has more than doubled since 2000[42] and is expected to grow another 40% by 2040.[43]

The U.S. industrial sector increased its consumption of natural gas by 13% between 2010 and 2016.[44] As the United States continues to expand its resource base, the industrial sector will see a

[41] U.S. Energy Information Administration, "Marcellus, Utica Provide 85% of U.S. Shale Gas Production Growth since Start of 2012," July 28, 2015, https://www.eia.gov/todayinenergy/detail.cfm?id=22252.

[42] U.S. Energy Information Administration, *Annual Energy Outlook 2015*, 2015, p. 24.

[43] Ibid., p. 25.

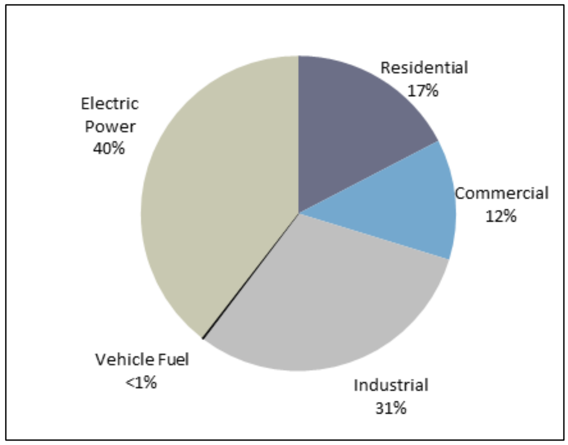
[44] U.S. Energy Information Administration, "Natural Gas Consumption by End Use," May 31, 2016, https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm.

wider array of fuel and feedstock choices, and manufacturing industries such as bulk or primary metals could also experience further growth.[45]

U.S. Exports[46]

Between 2000 and 2008, the United States prepared to increase imports of LNG based on forecasts of growing consumption, and companies began constructing LNG import terminals. However, the rise in prices gave the industry incentive to bring more domestic gas to market, reducing the need for import terminals. The result, as mentioned above, was the development of shale gas. Imports in 2016 were 35% below their peak in 2007; consequently there has been a push for modification and expansion of existing LNG terminals, as well as construction of new terminals, in order to expand U.S. export capacity. The first LNG shipments from the lower-48 occurred in February 2016 from the Sabine Pass LNG Terminal in Louisiana to Brazil, India, and the United Arab Emirates.

Figure 4. U.S. Natural Gas Consumption by Sector, 2016



Source: EIA, Natural Gas Consumption by End Use, updated April 28, 2017, http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm.

Natural Gas Liquids

Natural gas liquids (NGLs)[47] have taken on a new prominence as shale gas production increased and prices fell. As the price for dry gas dropped primarily because of the increase in supply, the natural gas industry turned its attention to producing more wet gas in order to bolster the value it receives. Historically, individual NGL products have been priced against oil, except for ethane. When oil prices were much higher relative to natural gas, it drove an increase of wet gas production, thereby maintaining the amount of dry gas as a production "byproduct" despite its low price.

Environmental Issues

Natural gas is the cleanest-burning of the fossil fuels. Unlike coal or oil, its combustion produces no sulfur oxides or hazardous air pollutants that would require pollution controls. The lone conventional pollutant that combustion of natural gas produces is NOx (nitrogen oxides). By contrast, coal combustion is the leading source of sulfur dioxide emissions and also produces about 20 hazardous air pollutants, including mercury.

45 U.S. Energy Information Administration, *Annual Energy Outlook 2016*, August 2016, p. MT-15.

46 For additional information on U.S. LNG exports, see CRS Report R42074, *U.S. Natural Gas Exports: New Opportunities, Uncertain Outcomes*, by (name redacted) et al.

47 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.

Combustion of natural gas also produces fewer emissions of greenhouse gases (GHGs) than other fossil fuels—about half the amount generated by coal in producing an equivalent amount of heat or power. However, the primary component of natural gas, methane, is itself a potent greenhouse gas, more than 25 times as potent as CO_2.[48] Thus, concerns have arisen regarding the release or leaks of methane from production, transmission, and processing of natural gas. As the use of natural gas continues to expand in the United States, reducing emissions of methane has become a more significant concern for policymakers.

The Electric Power Sector: In Flux[49]

The electric power industry is in the process of transformation. The electricity infrastructure of the United States is aging, and uncertainty exists around how to modernize the grid, and what technologies and fuels will be used to produce electricity in the future. Unresolved questions about transmission and reliability of the grid are arising due to potential cybersecurity threats as well as continuing interest in harnessing renewable energy and other low carbon sources of electricity. Concerns about reliability and electricity prices are complicated by environmental regulations and the rising production of electric power from unconventional resources such as shale gas. Congress has played a role already in this process, (e.g., tax credits for renewable energy), and may continue to be faced with policy issues regarding how the modernization of this industry will unfold. States have also played major roles in this area through renewable portfolio standards (RPS), and regional emissions trading programs, such as the Regional Greenhouse Gas Initiative (RGGI), among other programs.

Supply and Demand

The electric power sector of the United States 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. Electric power generation in the United States is currently dominated by the use of combustible fossil fuels, such as natural gas and coal. These fuels are burned to produce steam in boilers to turn steam turbine-generators or, in the case of natural gas, burned directly in a combustion turbine to produce electricity. Another major source of electricity is nuclear power (see "Nuclear Power: An Industry Facing Stress"), which uses heat from the fission of radioactive elements to produce steam to turn a generator. However, electricity can also be generated mechanically by wind turbines and hydropower, or by solar photovoltaic panels which convert light into electricity. Geothermal energy power plants use heat from underground to generate steam to run steam turbines. Generally, electricity must be used as soon as it is produced because the technologies and regulatory regimes to facilitate large-scale, economic energy storage are not yet widely available.

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.

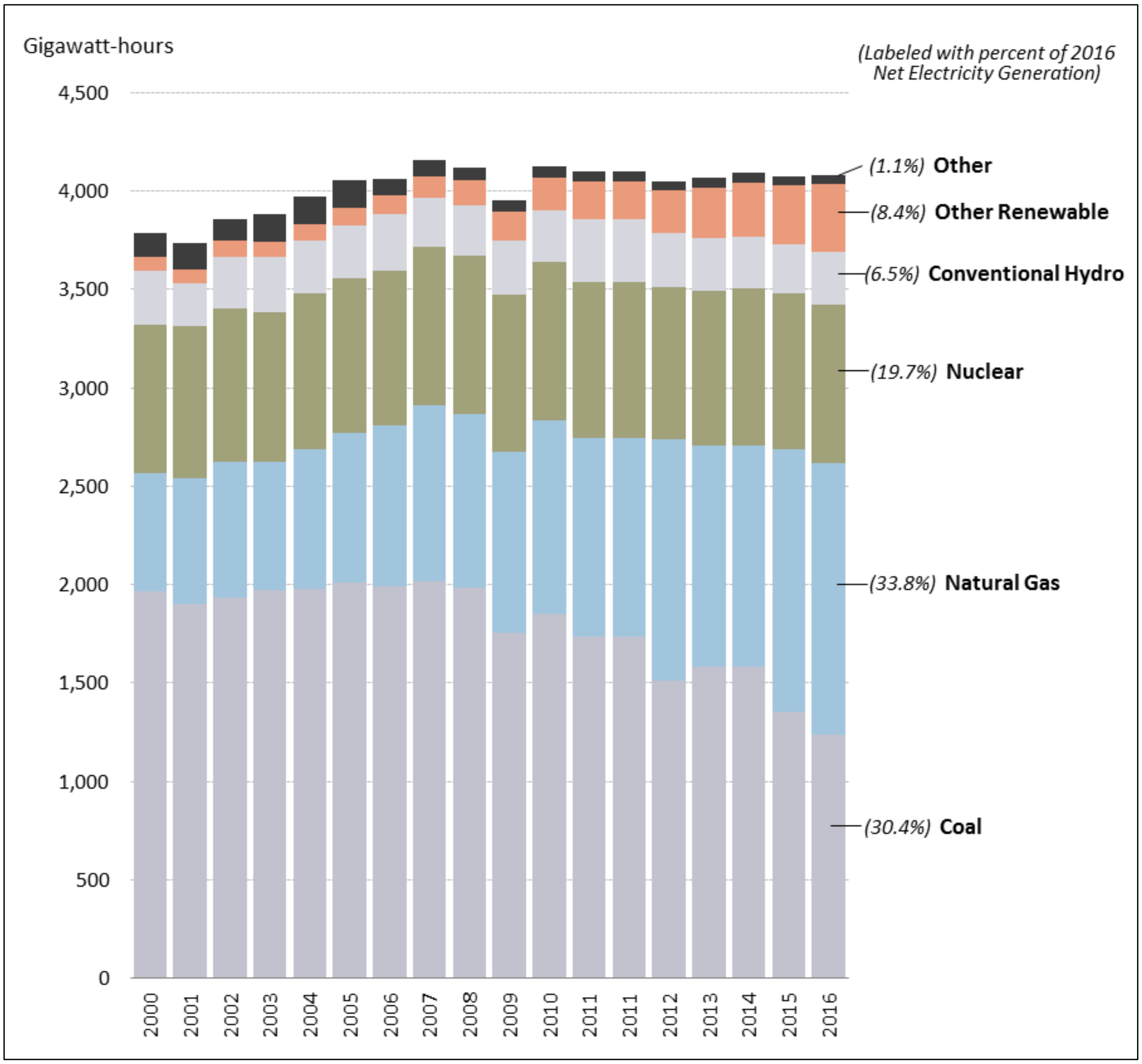
[48] Environmental Protection Agency, "Fact Sheet: EPA's Strategy for Reducing Methane and Ozone-Forming Pollution from the Oil and Natural Gas Industry," January 14, 2015, https://www.epa.gov/newsreleases/fact-sheet-epas-strategy-reducing-methane-and-ozone-forming-pollution-oil-and-natural.

[49] Richard Campbell, CRS Specialist in Energy Policy, was the lead author of this section. He can be contacted at [redacted]@crs.loc.gov or 7-.....

Figure 5 illustrates the changing mix of fuels used for electric power generation from 2000 to 2016. The figure shows that, as of 2016, natural gas surpassed coal with about 34% to 30%, respectively, of net electricity generation, followed by nuclear power at almost 20%.

Figure 5. U.S. Net Electricity Generation by Fuel, 2000-2016

(Gigawatt-hours)



Source: Energy Information Administration, Table 1.1. Net Generation by Energy Source: Total (All Sectors), 2006-November 2016, at https://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_1_01. EIA, Net generation for all sectors annual at https://www.eia.gov/electricity/data/browser/#/topic/0?agg=2.

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. "Renewable" sources include wood, black liquor, other wood waste, biogenic municipal solid waste, landfill gas, sludge waste, agriculture byproducts, other biomass, geothermal, solar thermal, solar photovoltaic energy, and wind. Data for the year 2000 was obtained from EIA, Detailed State Data, at https://www.eia.gov/electricity/data/state/. The data set does not include Petroleum Coke as a separate category.

The overtaking of coal by natural gas in 2016 reflects the changing economics of power generation. Electricity production has largely been influenced by regional resources and policies at the state level. 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, improvements in natural gas combined-cycle generation technology since the year 2000,[50] and the costs of compliance with environmental regulations (discussed later in this section), have led to older, less-efficient coal plants being used less or retired from service. Also discussed earlier, the use of hydraulic fracturing and directional drilling technology since 2008 has led to an increased supply and availability of natural gas. The resulting cheaper prices for natural gas have added market pressure to shift away from coal to natural gas for power generation.

U.S. Consumption

For many years, the growth in sales of electricity could be directly related to growth in the economy. However, with energy efficiency in homes and appliances increasing, a decoupling of growth in electricity demand from growth in gross domestic product (GDP) has occurred.[51] According to EIA, the linkage has been declining over the last 60 years, as U.S. economic growth is outpacing electricity use.[52] The trend is illustrated by **Figure 6**, which shows growth in electricity use and growth in GDP over the period.

EIA's projections point to a continued decline in electricity use relative to economic growth. While there may be years of relative growth in the future, EIA does not expect a "sustained return to the situation between 1975 and 1995, when the two growth measures were nearly equal in value, or the earlier period in which the growth rate in electricity use far exceeded the rate of economic growth."[53] EIA attributes several factors as drivers of this trend, including "slowing population growth, market saturation of major electricity-using appliances, improving efficiency of several equipment and appliance types in response to standards and technological change, and a shift in the economy toward less energy intensive industry."[54]

With growth in demand for electricity having been essentially flat for many years, the need for new power plants has been delayed in many parts of the country. The projections for future demand growth in most regions of the United States are declining. However, even a compounded annual electric power growth rate of 1% can mean an increase in electricity demand of 27% over the next 25 years, which may result in a need for new power generation.[55]

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[50] There has been a 22% power efficiency improvement in natural gas power generation since 2000. Jude Clement, *U.S. Natural Gas Electricity Efficiency is Always Improving*, April 10, 2016, https://www.forbes.com/sites/judeclemente/2016/04/10/u-s-natural-gas-electricity-efficiency-continues-to-improve/#6a954ba135a4.

[51] Gross domestic product can be defined as the total value of the goods and services produced by the people of a nation during a year, not including the value of income earned in foreign countries. See http://www.merriam-webster.com/dictionary/gross%20domestic%20product.

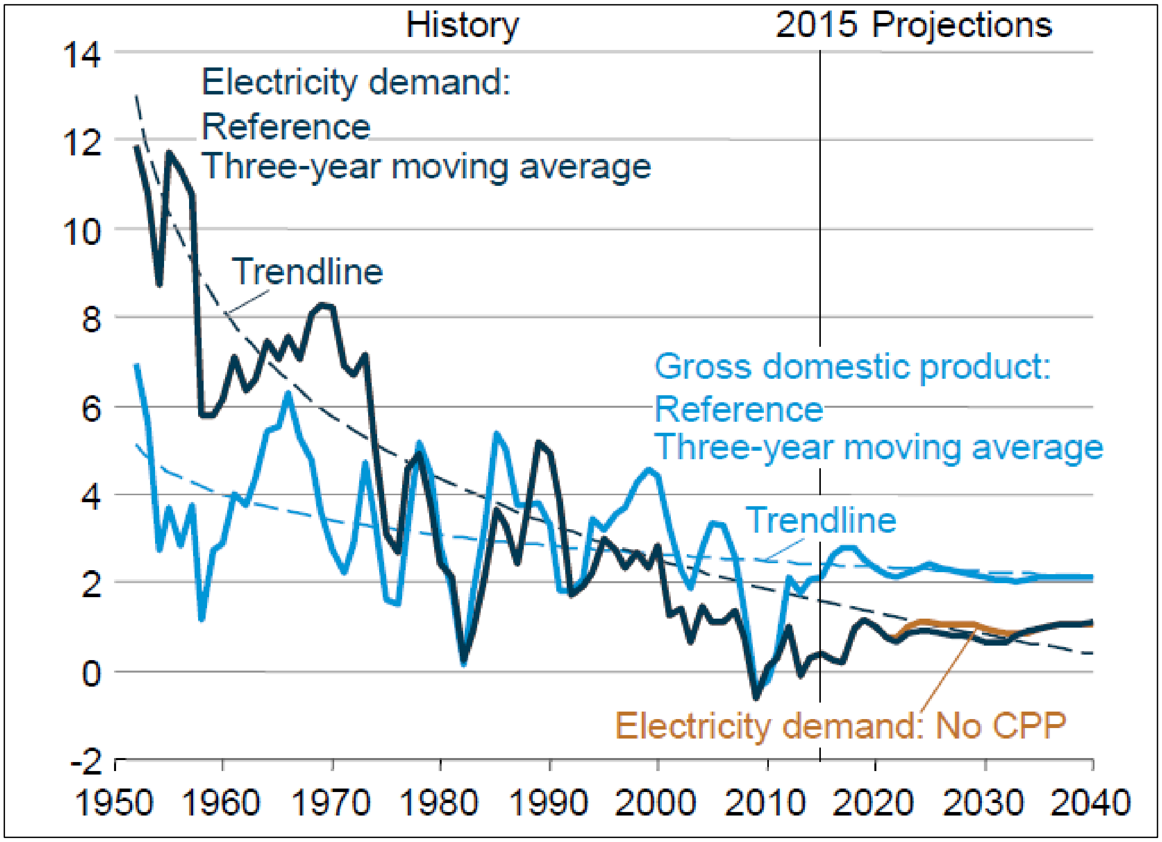
[52] Energy Information Administration, *U.S. Economy and Electricity Demand Growth Are Linked, but Relationship Is Changing*, March 22, 2013, http://www.eia.gov/todayinenergy/detail.cfm?id=10491.

[53] Ibid.

[54] Ibid.

[55] U.S. Energy Information Administration, *Annual Energy Outlook 2016 with Projections to 2040*, August 2016, pp. MT-15, https://www.eia.gov/outlooks/archive/aeo16/pdf/0383(2016).pdf.

Figure 6. Projected Growth in U.S. Electricity Use and Gross Domestic Product



Source: U.S. Energy Information Administration, *Annual Energy Outlook 2016*, August 2016, https://www.eia.gov/outlooks/archive/aeo16/pdf/0383(2016).pdf.

Notes: Projections of energy use and gross domestic product growth shown after 2015. Clean Power Plan (CPP).

Environmental Issues

With the passage of the Clean Air Act (CAA) amendments in 1970 and major amendments in 1977 and 1990, Congress required the Environmental Protection Agency (EPA) to establish standards to reduce potential health and environmental impacts of air pollution by limiting emissions.[56] These environmental regulatory requirements have been evolving in the last decade as EPA continues implementation of the act's requirements. Much industry attention has focused recently on the pending finalization of some of these regulations, and their potential to contribute to retirement decisions for some coal-burning power plants. Particular attention has focused on regulations to reduce mercury and air toxics emissions and to address emissions of sulfur dioxide and nitrogen oxides that cross state borders and contribute to air quality problems downwind. EPA began addressing these issues with the Clean Air Interstate Rule in 2005, and has

[56] The Clean Air Act, codified as 42 U.S.C. 7401 et seq., seeks to protect human health and the environment from emissions that pollute ambient, or outdoor, air. For more details see CRS Report RL30853, *Clean Air Act: A Summary of the Act and Its Major Requirements*, by (name redacted) .

subsequently strengthened the standards through the Cross-State Air Pollution Rule (CSAPR) and the Mercury and Air Toxics Standards (MATS), both of which went into effect in 2015.[57]

The electric utility industry also faces uncertainty as a result of the potential for controls on emissions of greenhouse gases (GHGs). In 2015 (the most recent data), electric power generation was responsible for 29% of U.S. domestic carbon dioxide emissions (the primary anthropogenic GHG).[58] EPA promulgated the Clean Power Plan in 2015 to reduce these emissions. The rule was stayed by the Supreme Court, however, and the Trump Administration has begun a review with an eye toward revoking or revising the rule. Meanwhile, at least 10 states have moved ahead with state or regional regulations to reduce power plant GHG emissions.

In seeking to address environmental issues, some utilities are increasing their deployment of renewable energy technologies to meet a portion of their power demands. Renewable energy sources have the potential to provide inexpensive, almost limitless electricity with minimal adverse environmental impacts. However, some of the technologies used today to generate electricity from renewable energy sources, like wind and solar, are variable in nature, and produce higher-cost power than conventional fossil or nuclear sources of electricity (if environmental externalities are not considered). Nuclear power is also considered to be a carbon-free source of electricity.

Coal: Declining Use[59]

The Trump Administration has made it clear that it would like to help revive the U.S. coal industry. Within the first two months, the Administration has rolled back or initiated reversing several coal-related regulations that were finalized under the Obama Administration, including the Clean Power Plan (CPP). This effort coincides with the emergence of three of the largest coal producers from Chapter 11 bankruptcy, higher coal prices, lower inventories, and higher natural gas prices—factors that could lead to coal being more competitive as a fuel source for electricity generation. Coal will likely remain an essential component in the U.S. energy supply picture, but how big a role it will play is an open question.

Coal Reserves and Production

The United States has the largest coal reserves and resources in the world. The U.S. Energy Information Administration (EIA) estimated in 2016 that there were about 255 billion short tons (BST) of recoverable domestic coal reserves. The total demonstrated U.S. resource base (DRB) was estimated at about 477 BST.[60] According to the National Mining Association, the federal government owns about one-third of U.S. domestic reserves.[61]

[57] For additional information, see CRS Report R43851, *Clean Air Issues in the 114th Congress*, by (name redacted) .

[58] Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks*, April 2017, https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.

[59] (name redacted), CRS Specialist in Energy Policy, was the lead author of this section. He can be contacted at [redacted]@crs.loc.gov or 7-.....

[60] EIA, *Annual Coal Report 2015*, November 2016. Also, for a discussion on coal resources see, *Inventory of Assessed Federal Coal Resources*, Prepared by the Departments of Agriculture, Energy, and Interior, August 2007. (42% of the DRB is located in the PRB and an estimated 203.5 billion short tons in the PRB is on federal lands.) The demonstrated resource base is defined by the U.S. Geological Survey as measured and indicated reserves plus sub-economic resources.

[61] National Mining Association, *2010 Coal Producers Survey*, May 2011.

EIA statistics show that more than half of U.S. coal reserves are located in the West, with Montana and Wyoming together accounting for 43%. The top five producing states—Wyoming, West Virginia, Kentucky, Illinois, and Pennsylvania—account for 70% of U.S. coal production.

Even though U.S. coal production has remained strong since 2000 (at or near 1 BST per year until 2014), and reached its highest level of production in 2008 (1.17 BST), coal is losing its share of overall U.S. energy production primarily to natural gas in electricity generation. Coal production declined precipitously in 2015 and 2016—a record decline of about 28% over the two-year period (see **Table 4**).[62] EIA short-term projections show coal production under 800 million tons in both 2017 and 2018. 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 cost associated with coal-fired power plants, a warmer-than-usual winter heating season in 2015 (resulting in high coal inventories), and lower demand for U.S. coal exports (see **Table 4**).

Coal mining employment declined from 169,300 in 1985 to 71,500 in 2000 (a 57% decline), then rose to a recent high of 86,100 in 2010 before falling again to 65,900 in 2015.[63]A similar pattern was true for the number of coal mines, as the vast 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 45% from 2000 to 2015 (from 1,513 to 834). 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.[64]

Coal Consumption

Coal consumption in the United States was consistently near or over 1 billion short tons per year since 2000 (peaking in 2007 at 1.128 BST /year) until 2012, when demand fell below 900 million short tons (pre-1990 levels). As shown in **Table 4**, consumption has declined further since then, reaching a low of 729 million short tons in 2016. The EIA projects annual coal consumption to be below 800 million short tons through 2017. Power generation is the primary market for coal, accounting for over 90% of total consumption. With the retirement of many coal-fired power plants and the building of new gas-fired plants, accompanied by lower demand for electricity, 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.[65] Thus, coal would likely be a smaller portion of total U.S. energy consumption for years to come, replaced by natural gas and renewable energy, particularly as fuel used for power generation. As noted earlier, in 2016, natural gas overtook coal as the number one energy source for power generation.

EIA projects a range of coal consumption into the year 2050—from less than 600 million short tons/year (based on the Obama Administration's Clean Power Plan) to about 800 million short tons/year. But in either case (declining or flat), coal is projected to be a smaller share of the total U.S. energy mix.

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[62] EIA, *Short Term Energy Outlook, Coal*, January 12, 2016 and January 10, 2017.

[63] EIA, *Annual Coal Report*, Various Years with 2015 being the latest year for data.

[64] Ibid.

[65] 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. The IEA 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.

Coal Exports

One of the big questions for the industry is how to penetrate the overseas coal market, particularly for steam coal, to compensate for declining domestic demand. EIA forecasts coal exports to continue declining in the short term (2015-2017) but to increase to 94 million tons annually by 2040 in the EIA reference case.[66] 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.

Table 4. U.S. Coal Production, Consumption, and Exports, 2000-2017

(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	49.7
2007	1,146.6	1,128.0	59.2
2008	1,171.8	1,120.5	81.5
2009	1,084.4	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	728.2	729.5	60.3
2017 (Est.)	753.5	740.0	52.0

Source: EIA, *Monthly Energy Review*, April 2017, p. 97, https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf.

Notes: Coal production in 2008, 1,171.8 short tons, was a record level. Est = estimate.

Several key factors are likely to influence how much coal will be exported from the United States in the future, one of which is the building of export terminals, particularly for coal from the Powder River Basin (PRB) in Wyoming and Montana. Another major factor is the level of global demand for metallurgical coal, which is used to make steel. Historically, metallurgical coal has

[66] According to the EIA, "the reference case projection assumes trend improvement in known technologies, along with a view of economic and demographic trends reflecting the current central views of leading economic forecasters and demographers. It generally assumes that current laws and regulations affecting the energy sector, including sunset dates for laws that have them, are unchanged throughout the projection period."

been the primary coal exported by the United States and primarily to the European market, which has been in decline.[67]

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. However, the Canadian export terminals have reached capacity.[68]

PRB coal producers have been searching for a potential domestic export link to the growing Asian market through the Pacific Northwest, so far without success. Three port terminal projects for exporting coal in Washington and Oregon had permit applications before the U.S. Army Corps of Engineers (the Corps), although none have advanced.[69] Two, the Gateway Pacific Terminal and Coyote Island Terminal projects, have been cancelled due to permit denials.[70] Washington State's Department of Ecology is preparing the final environmental impact statement for the Millennium Bulk Terminal. In the meantime, the state of Washington denied the Millennium project a permit to build on state land.[71]

U.S. Coal-Producing Industry

The U.S. coal industry is highly concentrated, with just a handful of major producers, operating primarily in five states (Wyoming, West Virginia, Kentucky, Illinois, and Pennsylvania). In 2015, the top five coal mining companies were responsible for about 57% of U.S. coal production, led by Peabody Energy Corp. with 19% and Arch Coal, Inc., with 14.6% (see **Table 5**). Other major producers include Cloud Peak Energy, Alpha Natural Resources, LLC, and Murray Energy Corp.

Three of the top five coal producers filed for Chapter 11 bankruptcy protection over the past two years: Alpha (August 2015), Arch (February 2016), and Peabody (April 2016). Other major producers, such as Patriot Coal, Walter Energy, and James River Coal, have filed as well. All told, over 50 coal producers have filed for bankruptcy with a total of $19.3 billion in debt being reorganized. The top-two largest producers, both of which filed for bankruptcy, accounted for 34% of U.S. coal production in 2015.

Arch Coal, ANR, and Peabody Energy have emerged from Chapter 11 bankruptcy with a plan to move forward, all three shedding substantial debt. Opponents are critical of the plan and of the

[67] Tom Sanzillo and David Schlissel, *IEEFA 2017 U.S. Coal Outlook*, Institute for Energy Economics and Financial Analysis (IEEFA), January 19, 2017.

[68] Bruce Kelly, "Which Way(s) West for Coal?" *Railway Age*, March 2012, p. 18.

[69] 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 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 Harbors Act of 1899. The proposed projects in Washington and Oregon will involve such activities and must obtain either or both a Section 404 and Section 10 permit from the Corps, before the project can proceed. Discussion of the Corps permit requirements is beyond the scope of this report. For information regarding applicable authorities, obligations, or regulatory requirements applicable to the Corps obligations to permit coal export terminals, contact Nicole Carter at 7-.... .

[70] Gateway Pacific Terminal Project at Cherry Point Proposal, Project Update: On February 7, 2017, the applicant withdrew all permit applications, State of Washington, Department of Ecology, http://www.ecy.wa.gov and George Plaven, "Port of Morrow Agree to Withdraw Coyote Island Terminal Application," *East Oregonian*, November 10, 2016, online edition. The Oregon Department of State Lands rejected a key permit to build in the river in 2014.

[71] Natasha Geiling, "Washington State Denies Lease Permit for Proposed Coal Export Terminal," January 4, 2017, http://think progress.org.

long-term viability and reliability of the coal industry. A major challenge for the coal industry will be to get the level of financing needed for new or expanded projects and to become profitable.

Table 5. Leading U.S. Coal Producers

2015		2005		2000	
Producer	**Percent of Total**	**Producer**	**Percent of Total**	**Producer**	**Percent of Total**
Peabody Energy Corp.	19.6	Peabody Coal Co.	17.8	Peabody Coal Co.	13.1
Arch Coal, Inc.	14.6	Rio Tinto Energy America	10.9	Arch Coal, Inc.	10.1
Cloud Peak	8.4	Arch Coal, Inc.	10.4	Kennecott Energy	9.9
Alpha Natural Resources	7.8	CONSOL Energy, Inc.	5.8	CONSOL Energy, Inc.	6.9
Murray Energy Corp.	6.2	Foundation Coal	5.7	RAG	5.9

Source: EIA, Annual Coal Report, 2000, 2005 and 2015, latest release November 2016, https://www.eia.gov/coal/annual/pdf/acr.pdf.

As U.S. energy policy and environmental regulations are constantly debated, there is ongoing congressional interest in the role of coal in meeting U.S. and global energy needs. The question may not be whether the domestic production of coal will continue but, rather, how much U.S. coal will be burned, what type, and under what regulatory framework.

Nuclear Power: An Industry Facing Stress[72]

Nuclear power has steadily supplied about one-fifth of annual U.S. electricity generation during the past three decades. In 2016, nuclear reactors generated 19.7% of U.S. electricity supply, behind only coal and natural gas.[73] Ninety-nine reactors are currently operating at 60 plant sites in 30 states. They generated electricity at 92.5% of their total capacity in 2016, the highest of any generation source.[74] Total net generation of nuclear power in 2016 was 805 billion kilowatthours.[75]

One new power reactor began commercial operation in 2016: Watts Bar 2 in Tennessee, the first new U.S. reactor since its twin unit began operating in 1996. Four more power reactors are currently under construction in Georgia and South Carolina, at the Vogtle and Summer plant sites, respectively. Three additional new reactors have received licenses from the Nuclear Regulatory Commission (NRC), and seven other license applications are under review, but construction of those projects is uncertain.

[72] (name redacted), CRS Specialist in Energy Policy, was the lead author of this section. He can be contacted at [redacted]@crs.loc.gov or 7-.....

[73] Energy Information Administration, *Monthly Energy Review*, Table 7.2a, "Electricity Net Generation: Total (All Sectors)," p. 109, https://www.eia.gov/totalenergy/data/monthly/pdf/sec7_5.pdf.

[74] Energy Information Administration, *Electric Power Monthly*, October 2016, Tables 6.7.A and 6.7.B.

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

Despite the strong performance of existing nuclear plants, the U.S. nuclear industry has faced significant stress recently. Six reactors have permanently closed during the past five years, and nine others have been threatened by their owners with shutdown during the next several. Most of the closed and threatened nuclear power plants sell 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 falling wholesale power prices and stagnant demand, combined with relatively high operating and capital costs in some cases, particularly at plants with a single reactor. (For more information, see CRS Report R44715, *Financial Challenges of Operating Nuclear Power Plants in the United States*, by (name redacted) and (name redacted))

Further uncertainty about the future of the U.S. nuclear power industry has been created by the March 29, 2017, bankruptcy filing by Westinghouse Electric Company, the lead contractor for the four new U.S. reactors currently under construction. Cost overruns and schedule delays at those projects were a major cause of the Westinghouse bankruptcy, and their completion is now in doubt. (For more information, see CRS Insight IN10689, *Westinghouse Bankruptcy Filing Could Put New U.S. Nuclear Projects at Risk*, by (name redacted))

Nuclear power supporters 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 carbon dioxide emissions. Nuclear power accounted for 61.6% of U.S. zero-carbon electricity generation in 2015, the latest year available.[76] A major government effort to preserve nuclear power as a carbon-free electricity source is being implemented by the state of New York, which is providing payments in the form of zero emission credits (ZECs) to four upstate reactors that had been at risk of retirement. The state of Illinois enacted legislation in December 2016 to provide ZECs to prevent the planned closure of three at-risk reactors. Nuclear power incentives at the federal level have also been proposed, such as an investment tax credit or the extension of an existing nuclear energy production tax credit.[77]

However, nuclear power opponents contend that such drawbacks as accident risk, high costs, and radioactive waste outweigh the technology's benefits. Focusing on renewable energy and energy efficiency would be far more effective in reducing carbon emissions, they argue.[78]

All but three of today's 99 nuclear power reactors (**Figure 7**) 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 expires 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. Further 20-year renewals, for a total operating life of 80 years, are also allowed, although none have yet been requested.[79]

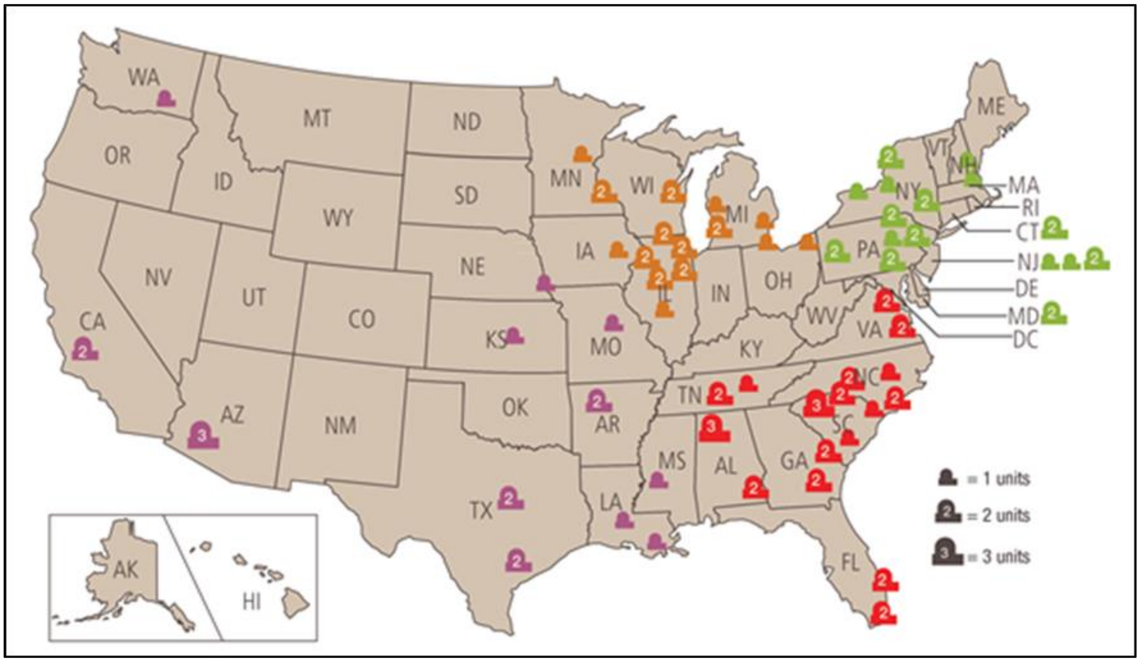
[76] Energy Information Administration, "Net Generation for All Sectors, Annual," Electricity Data Browser, online database, May 9, 2016, http://www.eia.gov/electricity/data/browser/. Excludes biomass.

[77] For further information about at-risk nuclear plants, see CRS Report R44715, *Financial Challenges of Operating Nuclear Power Plants in the United States*, by (name redacted) and (name redacted)

[78] Nuclear Information and Resource Service, "Nukes and Climate Change," web page, viewed November 21, 2016, https://www.nirs.org/climate/.

[79] Nuclear Regulatory Commission, "Reactor License Renewal," web page, April 14, 2016, http://www.nrc.gov/reactors/operating/licensing/renewal.html.

Figure 7. U.S. Operating Commercial Nuclear Power Reactors



Source: Adapted from Nuclear Regulatory Commission, "Map of Power Reactor Sites," April 21, 2017, https://www.nrc.gov/reactors/operating/map-power-reactors.html.

Notes: Plant colors indicate NRC regions.

Renewable Energy: Inroads in the Energy Mix[80]

Federal policies supporting the use of renewable energy mainly date back to the mid-1970s, the years following the 1973 oil embargo and energy price volatility that resulted. At that time, support for renewable energy was generally oriented towards achieving energy security goals. Although energy security remains a policy objective, much of the current debate about supporting renewable energy deployment is related to environmental policies, such as reducing greenhouse gas emissions from electric power plants.

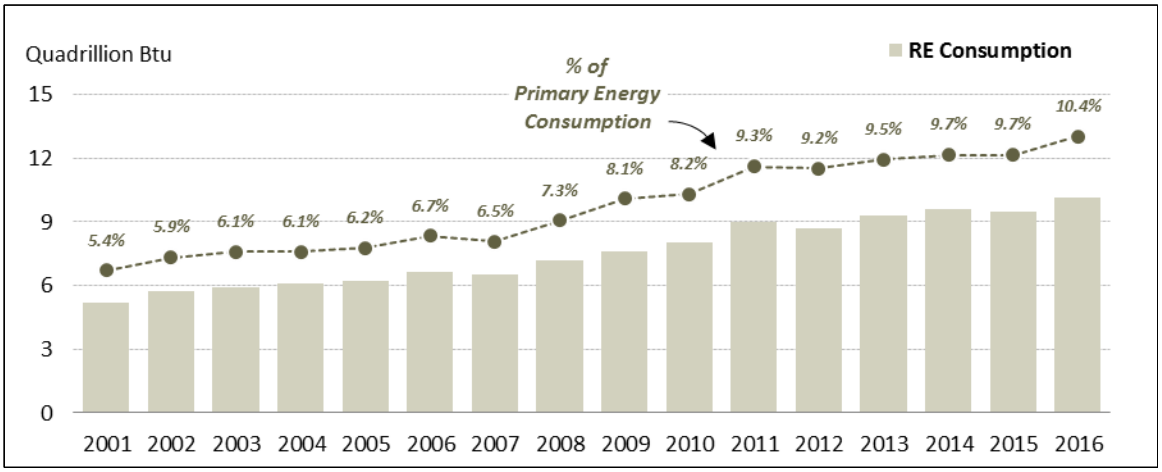
While renewable energy is currently a relatively small portion of the total U.S. energy sector, renewables production and consumption have increased since the turn of this century. Renewable energy consumption has increased 97% between 2001 and 2016, as illustrated in **Figure 8**.[81] During this same period, the contribution of renewable energy to total primary energy almost doubled, rising from 5.4% to approximately 10.4%.[82]

[80] (name redacted), CRS Specialist in Energy Policy, and (name redacted), Specialist in Natural Resources and Energy Policy, were the lead authors of this section. They can be contacted at redacted@crs.loc.gov, 7-...., or redacted@crs.loc.gov , 7-.....

[81] Energy Information Administration, *February 2017 Monthly Energy Review*, February 24, 2017.

[82] Ibid. As a point of reference, the contribution of renewable energy, as categorized by EIA (which includes hydro), to total energy consumption in 1949—the first year EIA reports such data—was 9%.

Figure 8. Renewable Energy Consumption in the United States



Source: Compiled by CRS using data from the Energy Information Administration's *Monthly Energy Review*, April 25, 2017, https://www.eia.gov/totalenergy/data/monthly/.

Unlike other energy commodities (e.g., crude oil), renewable energy is available in a variety of distinct forms that use different conversion technologies to produce usable energy products (e.g., electricity, heat, and liquid fuels). Hydroelectric, biofuels, wood biomass, wind, waste, solar, and geothermal are the renewable energy categories that are tracked and reported by the Energy Information Administration.[83] Each energy product derived from renewable sources has unique market and policy considerations.[84]

Renewable energy is consumed within the electric power, industrial, transportation, residential, and commercial sectors. As indicated in **Table 6**, the contribution of the different renewable energy sources to each sector varies. For example, nearly all hydro is consumed in the electric power sector and most of the industrial sector renewable energy use is in the form of biomass.

Table 6. U.S. Renewable Energy Consumption by Sector and Source, 2016

Trillion Btu

	Residential	Commercial	Industrial	Transportation	Electric Power	Total
Hydro	0	1	12	0	2,465	**2,478**
Geothermal	40	20	4	0	162	**226**
Solar	161	72	17	0	337	**587**
Wind	0	1	1	0	2,109	**2,111**
Biomass	373	157	2,283	1,434	509	**4,756**
Total	**574**	**251**	**2,317**	**1,434**	**5,582**	**10,158**

Source: Energy Information Administration, *Monthly Energy Review*, April 2017.

[83] The Energy Information Administration's Monthly Energy Review (MER) provides data and statistics for renewable energy sources and their contribution to various sectors. For more information, see https://www.eia.gov/totalenergy/data/monthly/.

[84] For example, renewable electricity generation is supported by state-level renewable portfolio standards—where available—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.

Much of the growth in renewable energy consumption since 2001 has been within the electric power—mostly non-hydro renewable electricity generation—and transportation (renewable fuels) sectors. The industrial sector is the second largest renewable energy consumer, although consumption levels have been in a relatively narrow range from 1985 to 2016 and, as mentioned above, the majority of renewable energy consumed in the sector is biomass. 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. Rather, the following sections discuss renewable transportation fuels and renewable electricity generation trends since 2001 and provide some context about the policy and market dynamics that have contributed to the growth of these separate and distinct markets.

Renewable Transportation Fuels

Renewable energy production and consumption in the transportation sector is 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. Generally, although it can vary by vehicle type and access to high level ethanol-gasoline blends, ethanol content represents approximately 10% of gasoline by volume. Biodiesel is a direct substitute for diesel fuel refined from petroleum.

U.S. ethanol and biodiesel production and consumption in the United States have experienced growth over the last 16 years. 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.[85] U.S. ethanol production has steadily increased from approximately 1.8 billion gallons in 2001 to slightly more than 15 billion gallons in 2016.[86] Ethanol consumption increased from 1.7 billion gallons in 2001 to more than 14 billion gallons in 2016.[87] During the same period biodiesel production increased from 9 million gallons in 2001 to approximately 1.6 billion gallons in 2016.[88] Biodiesel consumption increased from 10 million gallons in 2001 to approximately 2.0 billion gallons in 2016.[89] 2016 ethanol consumption volumes are roughly seven times that of biodiesel.

Renewable Electricity

U.S. renewable electricity generation, including hydropower and non-hydro renewables, doubled between 2001 and 2016. The contribution of renewable energy to the U.S. power sector increased from 9% in 2001 to 15% in 2016.[90] While hydroelectricity generation has represented 6% to 8% of total U.S. electric power generation since 2001, essentially all of the growth in renewable electricity generation during this period was from non-hydro renewables.[91]

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[85] For more information, see CRS Report R43325, *The Renewable Fuel Standard (RFS): In Brief*, by (name redacted)

[86] U.S. Department of Energy, *Monthly Energy Review*, Table 10.3, March 2017.

[87] Ibid.

[88] U.S. Department of Energy, *Monthly Energy Review*, Table 10.4, March 2017.

[89] Ibid.

[90] Energy Information Administration, *Electric Power Monthly*, Table 1.1, April 25, 2017.

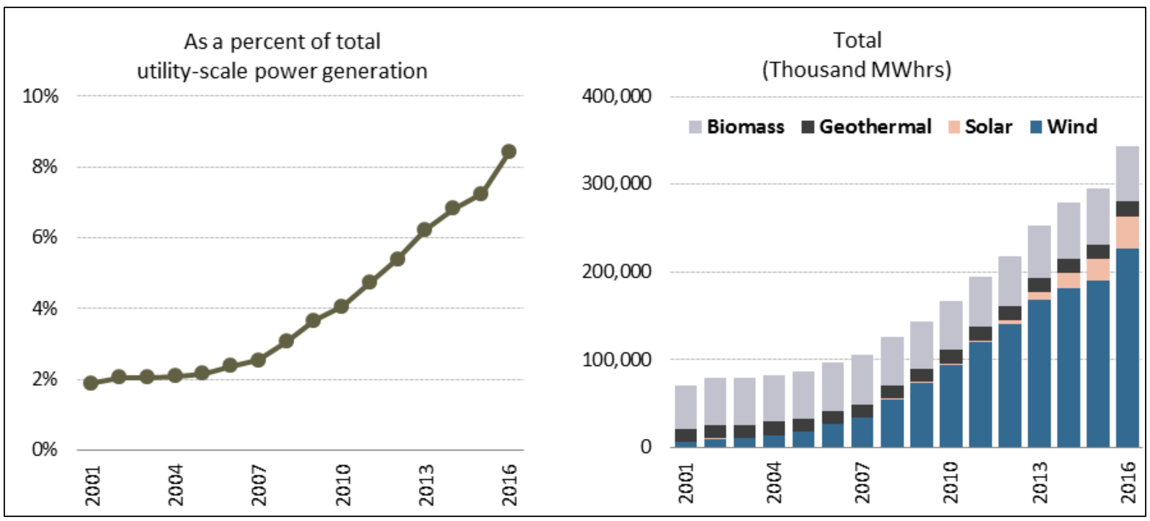
[91] Due to the established nature of hydroelectricity, and a lack of significant increase or decrease to the nation's energy portfolio over the last 10 years, this section limits discussion of renewable electricity to non-hydro renewables.

Non-Hydro Utility-Scale Renewable Electricity

Non-hydro renewable energy as a fuel source for electricity generation has been supported by policies at both the state and federal level. Renewable portfolio standard (RPS) policies instituted in many states have been the demand catalyst for renewable power.[92] Tax incentives—in the form of investment[93] and production tax credits,[94] 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. As a result of these state and federal programs and incentives, in addition to technology cost declines and conversion efficiency improvements, the use of non-hydro renewable sources of energy (i.e., wind, solar, geothermal, and biomass) to generate electric power in the United States increased considerably between 2001 and 2016. In 2016 non-hydro renewable energy sources provided more than 8% of total U.S. electric power generation (see **Figure 9**).

While electricity generation from biomass and geothermal has remained essentially flat, growth in non-hydro renewable electricity generation has been dominated by wind and solar. Electricity generation from wind energy increased by a factor of 33 times between 2001 and 2016, growing from less than 7 million Megawatthours (MWh) to more than 226 million MWh. Electricity generation from solar energy increased by more than a factor of 60 between 2001 and 2016, growing from 0.6 million MWh to nearly 37 million MWh (see **Figure 9**).

Figure 9. Utility-Scale Non-Hydro Renewable Electricity Generation



Source: EIA, Electricity Data Browser, online database accessed March 14, 2017.

In terms of new utility-scale electric power capacity additions, non-hydro renewable electricity installations—the majority being solar and wind—exceeded that of coal and natural gas combined

[92] For additional information about Renewable Portfolio Standard policies, see the Database of State Incentives for Renewables and Efficiency (DSIRE), http://www.dsireusa.org, and the DSIRE summary map of state renewable policies available at http://ncsolarcen-prod.s3.amazonaws.com/wp-content/uploads/2017/03/Renewable-Portfolio-Standards.pdf, accessed April 26, 2017.

[93] For additional information about investment tax credits for renewable electricity generation technologies, see CRS In Focus IF10479, *The Energy Credit: An Investment Tax Credit for Renewable Energy*, by (name redacted) .

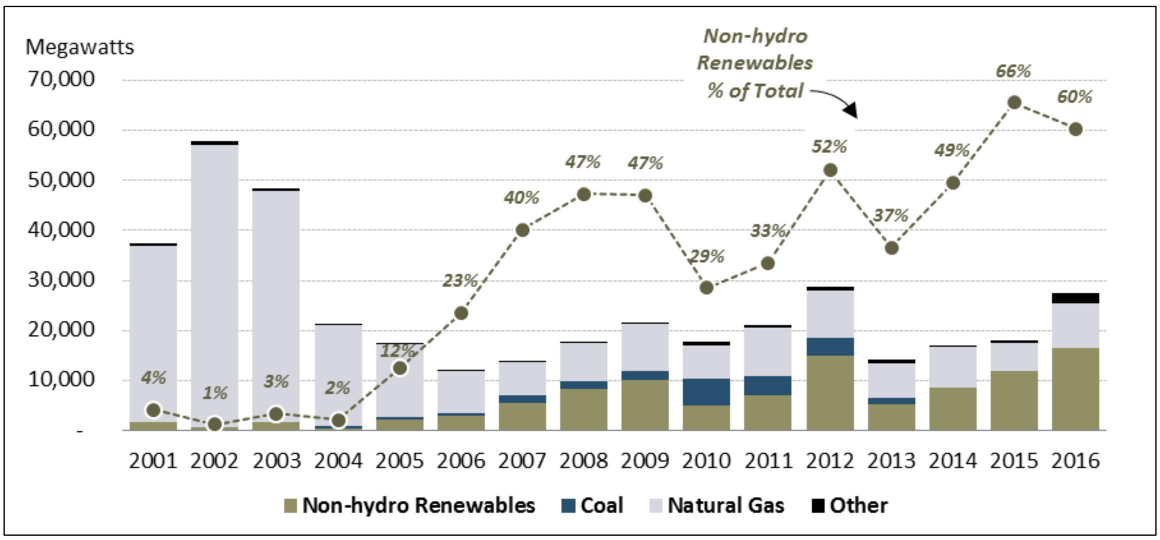
[94] For additional information about production tax credits for renewable electricity production, see CRS Report R43453, *The Renewable Electricity Production Tax Credit: In Brief*, by (name redacted) .

in 2015 and 2016. During calendar year 2016, approximately 60% of gross capacity additions were non-hydro renewables (see **Figure 10**).

The relatively large contribution of non-renewable energy electricity capacity additions in recent years can be attributed to multiple factors. First, prior to Congress passing a multi-year extension and phase-out of tax credits for wind and solar electricity in 2015, project developers for wind and solar power projects accelerated development activities in order to capture tax credit incentives before their scheduled expiration date. Second, the cost of electricity generated by wind and solar technologies has declined, primarily due to improvements in conversion efficiency and equipment cost reductions. Finally, the U.S. electricity sector is a mature market; overall sector growth is projected to be small.

U.S. electric power demand has been relatively flat for several years and is projected to continue along a rather flat trajectory in the near to medium term. As a result, the amount of new power generation capacity needed each year has declined. When combining a low-growth market with increased capacity installations motivated by state requirements and federal financial incentives, it is understandable that policy-supported renewable electricity would make a large contribution to annual capacity additions.

Figure 10. Gross Utility-Scale Electric Power Capacity Additions



Source: Energy Information Administration, *Electric Power Annual*, years 2001 to 2015. Information for 2016 was calculated from EIA's Preliminary Monthly Electric Generator Inventory that is included in the monthly Form EIA-860M survey. Final annual numbers for 2016 capacity additions will be published in the fall of 2017.

Distributed Solar Electricity Generation

In addition to the increased use of solar energy as a utility-scale electric power sector energy source, distributed solar electricity generation—solar power generated at a residential, commercial, or industrial location—has also increased significantly. Distributed solar generation grew by a factor of 150 times between 2001 (129 million kWh) and 2016 (19,467 million kWh).[95] This rapid growth is the result of several policy and market factors, including (1) state-level policies that encourage residential solar development (solar "carve-outs" and net-metering

[95] Energy Information Administration, *Monthly Energy Review*, April 2017.

policies), (2) federal tax incentives, (3) decreasing costs of solar electricity generation equipment, (4) price competition with retail prices instead of lower wholesale prices, and (5) solar leasing business models that eliminate the need for homeowners and commercial users to pay for the upfront cost of a solar generation system.

Appendix A. Key U.S. Government Agencies

Army Corps of Engineers (Corps)—part of the Department of Defense, the Army Corps of Engineers manages land and water resource development. Corps permits are required where energy infrastructure crosses certain waterways, 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 and natural gas operations.

Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEMRE)—part of the Department of Interior, BOEMRE oversees the safe and environmentally responsible development of energy and mineral resources on the Outer Continental Shelf.

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.

Energy Information Administration (EIA)—an independent part of DOE, it is the main collector and disseminator of the U.S. energy sector data.

Environment Protection Agency (EPA)—EPA has a broad range of responsibilities regarding energy as it enforces environmental regulations and sets national standards. EPA has oversight/enforcement of all or part of the Oil Pollution Act, Resource Conservation and Recovery Act (RCRA), Clean Water Act, Clean Air Act, Energy Policy Act, Energy Independence and Security Act, Shore Protection 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 liquefied natural gas terminals and interstate natural gas pipelines as well as licensing 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.

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

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

Office of Fossil Energy—part of the Department of Energy focusing on production from U.S. oil fields. 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.

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.

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. Key Energy Laws

Table B-1. Select 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	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 now DOE and its precursors approval 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 has 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 between 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 placed the Federal Energy Regulatory Commission (FERC) within DOE.
1978	National Energy Act, P.L. 95-617 - 621	Responded to the 1973 oil crises, and included five 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, P.L. 102-486	Created framework for competitive wholesale electricity markets.
2005	Energy Policy Act, 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.

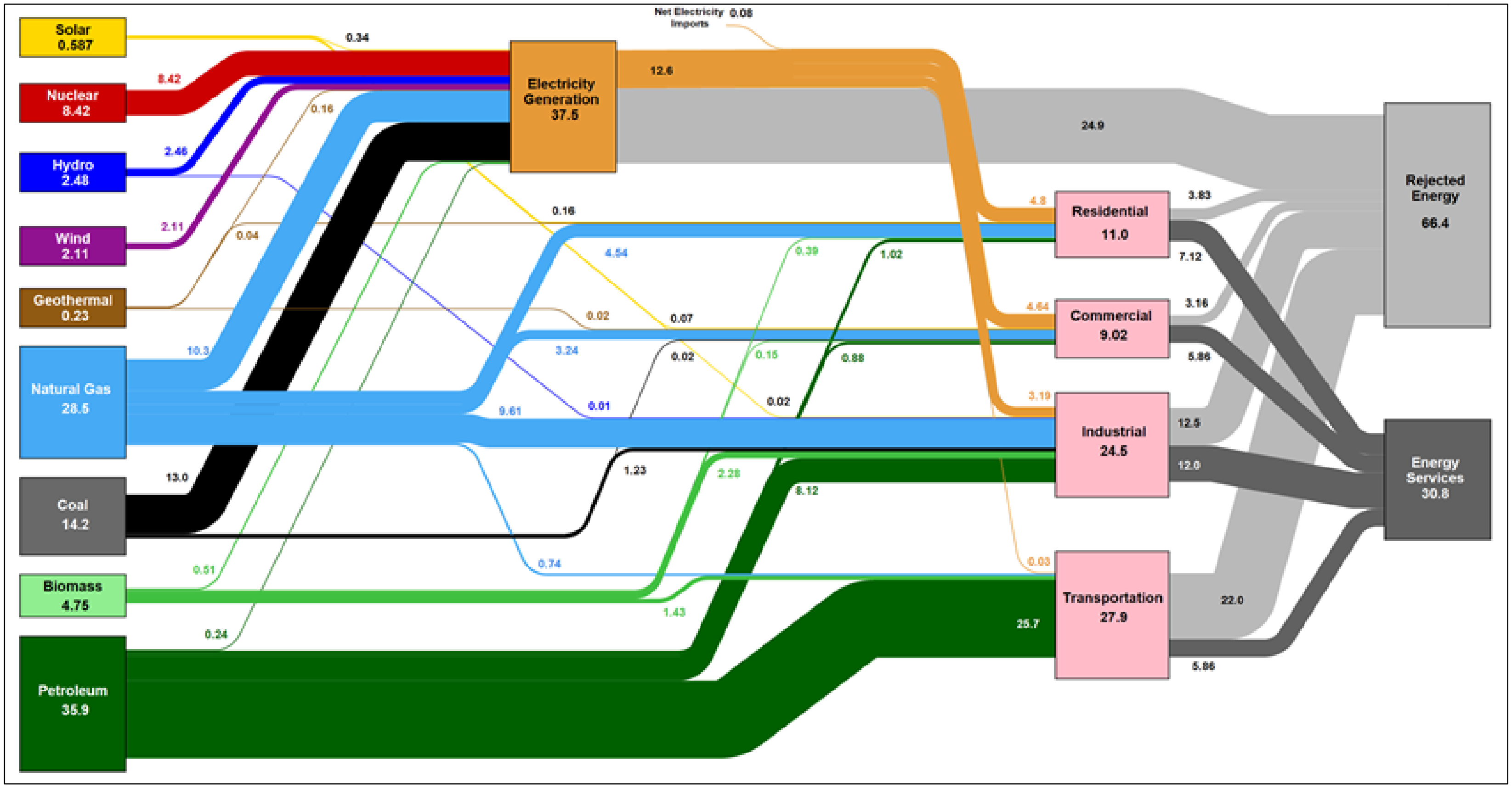
Source: Compiled by CRS using information from congressional databases and the John A. Dutton E-Education Institute, College of Earth and Mineral Sciences, Pennsylvania State University, https://www.e-education.psu.edu/geog432/node/116.

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 passage. The Department of Energy lists on its website laws which it administers, https://energy.gov/gc/laws-doe-administers-0.

Appendix C. 2016 U.S. Energy Consumption

Figure C-1. Estimated U.S. Energy Consumption in 2016

Total = 97.3 Quads



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

Notes: Rejected Energy is the portion of energy that goes into a process and comes out, usually as waste heat, to the environment. Units = quadrillion British thermal units (Quads).

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