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IER INSTITUTE FOR ENERGY RESEARCH

HARD FACTS

An Energy Primer

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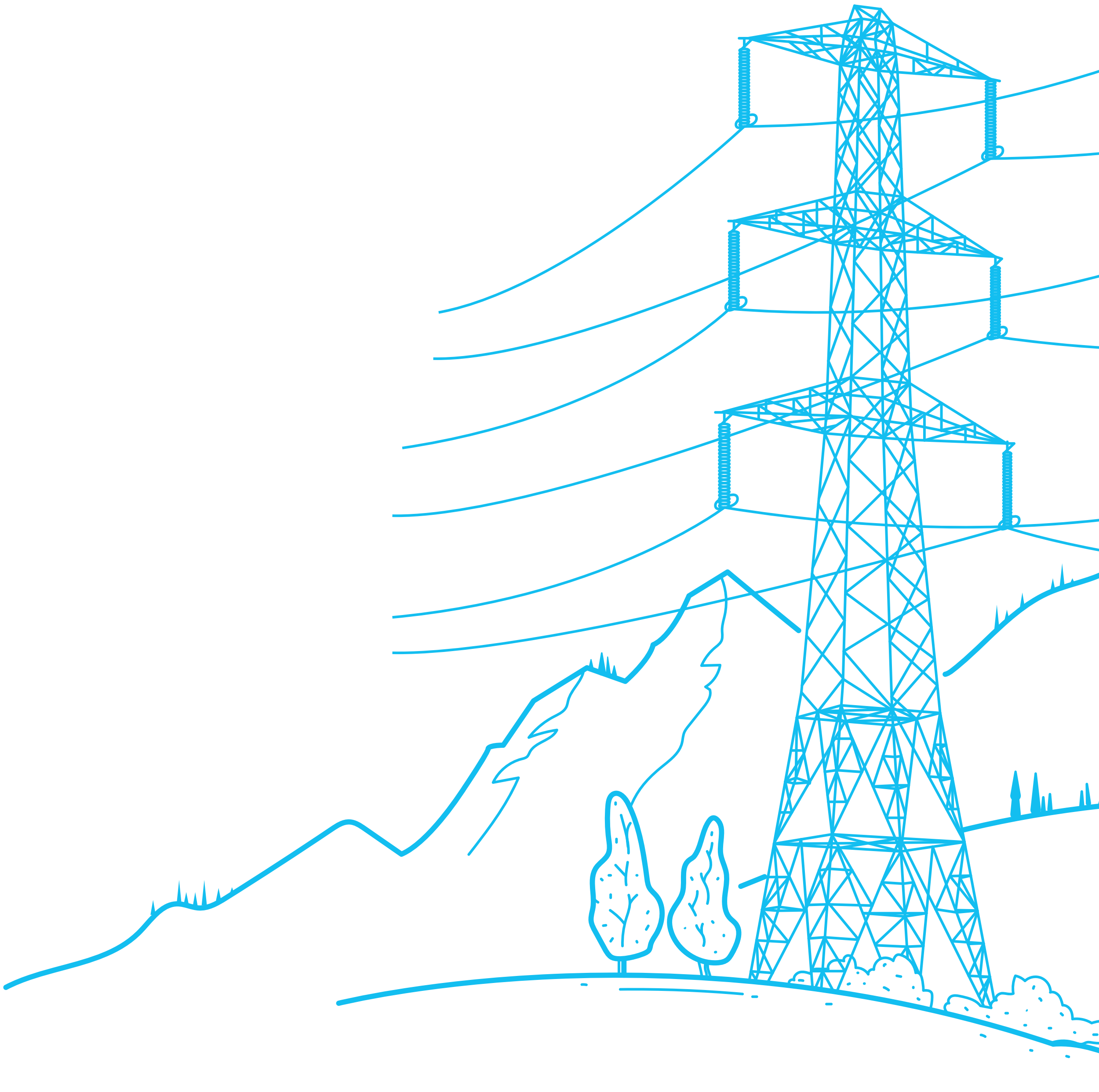
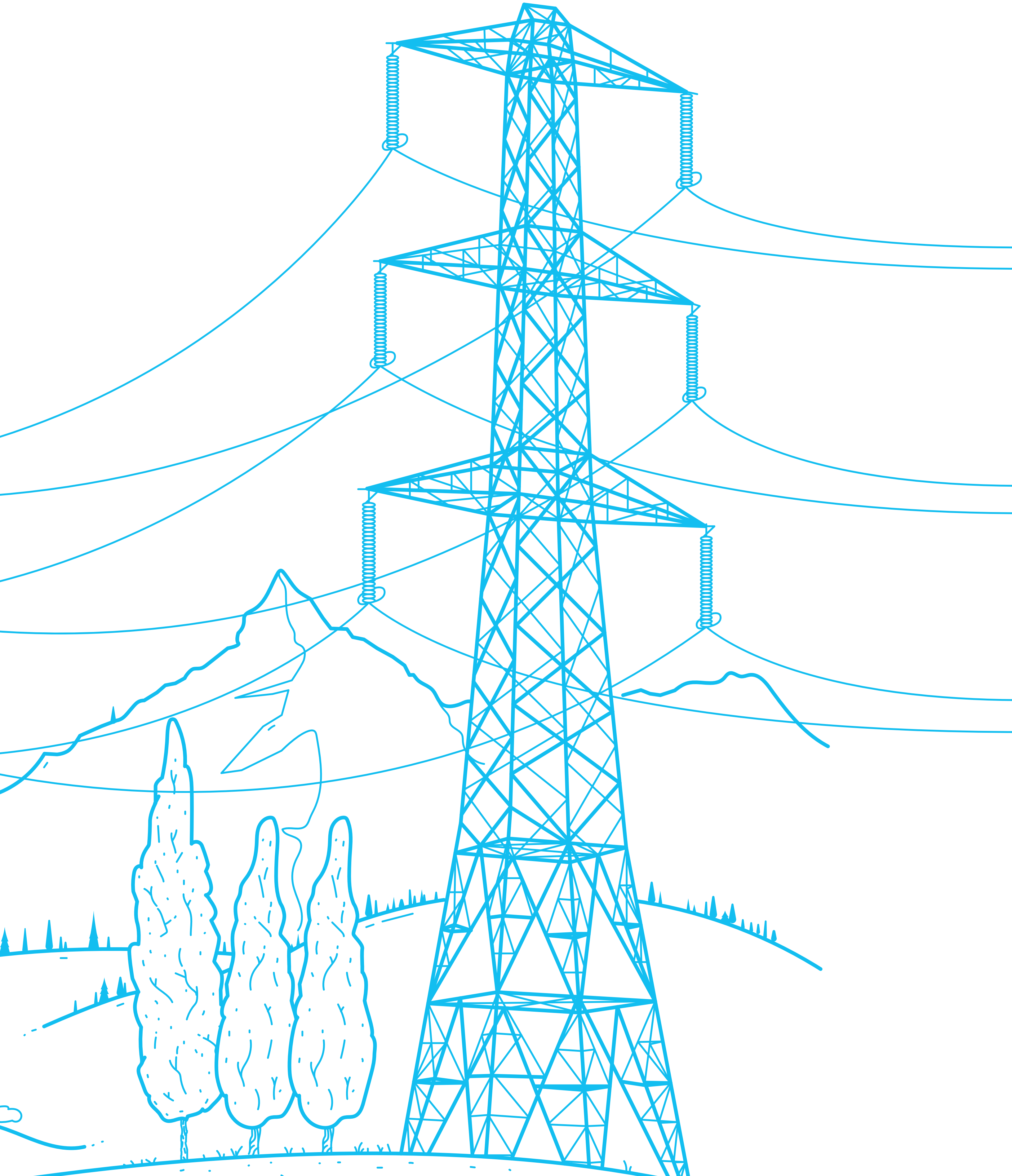
AFFORDABLE AND RELIABLE ENERGY IS ESSENTIAL TO THE ECONOMY





Affordable and Reliable Energy is Essential to the Economy

Affordable, reliable energy is the foundation of a free and prosperous society because it is essential to everything that makes progress and opportunity possible. Nothing is more fundamental to unlocking human creativity and potential than the availability of affordable and reliable supplies of energy. Energy heats our homes, fuels our transportation, and powers the technology that contributes to our overall well-being. To put it simply, affordable energy enriches our lives and those of our loved ones, neighbors, friends, and fellow citizens by allowing us to do more.[1] There are, however, significant obstacles to maintaining a reliable and affordable supply of energy.

Since the oil embargo of the 1970s, U.S. energy policy has been driven primarily by the threat of looming future crises, none of which have since come to pass.[2] The threat of rising energy prices, resource depletion, and environmental collapse continue to prompt aggressive plans by policymakers to fundamentally reshape energy markets. Different elements of these plans have been cobbled together over several decades, leading to inefficient, contradictory, and self-defeating policies that place America's ability to access reliable and affordable energy at risk.[3] As a result, the energy market is dominated by a complicated collection of subsidies, tax incentives, and regulations, which limit competition and stifle economic growth. Over time, these policies have fundamentally changed the nature of the U.S. energy industry, creating a culture wherein economic and political elites advance their interests through the political sphere, passing the costs of their policies on to everyday citizens.[4]

In spite of this, the industry has persevered. In 2017, the proved reserves of natural gas increased 36 percent to a record high of 464.3 trillion cubic feet.[5] This expansion of proved reserves was a result of new technology that allowed for precision drilling techniques combined with the practice of hydraulic fracturing. These technological advancements allowed us to obtain natural gas from rock formations known as shale. Thanks to these technological breakthroughs, and the boldness it took to invest in them, American energy consumers have access to low-cost fuel, and, in 2017, the U.S. became a net exporter of natural gas, which has contributed to economic growth both in the U.S. and abroad.[6]

Hard Facts is a comprehensive energy primer that provides an essential foundation for a more informed discussion about American energy policy. People must recognize that the U.S. has access to an abundance of energy resources that can continue to provide the world with reliable and affordable energy provided our policy framework emphasizes the institutions of a free society: private property, competitive market exchange, and the rule of law.

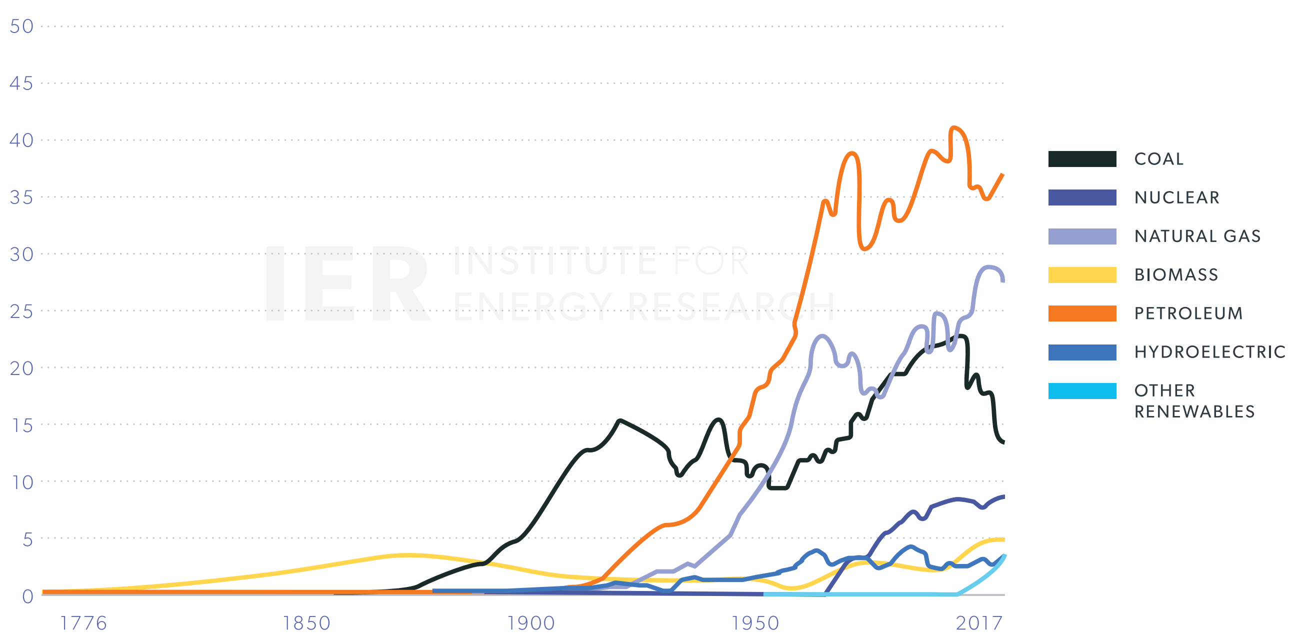
Energy has been the driving force behind the massive improvements in human living standards that began nearly 200 years ago.

A Brief History of Energy in the United States

Energy has been the driving force behind the massive improvements in human living standards that began nearly 200 years ago.[7] As the graph below shows, renewable energy, particularly from wood, was the dominant energy source prior to the Industrial Revolution. Then, between 1880 and 1918, America's energy use quadrupled. This growth was largely fueled by coal, which by the end of this period produced nearly 75 percent of the energy used in the United States.[8]

ENERGY CONSUMPTION IN THE UNITED STATES (1776-2017)

quadrillion British thermal units



Source: U.S. Energy Information Administration, *Monthly Energy Review*

In the period after World War I, the biggest development in the energy industry was the mass production of the automobile, and by 1950 petroleum surpassed coal as the largest energy source in the United States. As petroleum consumption grew, natural gas also became a major source of energy as these two resources were developed alongside one another. By the late 1950s, natural gas consumption surpassed coal. In 1957, nuclear electric power was introduced as a new source of electricity generation. Nuclear power experienced consistent growth until the year 2000, and today there are 58 commercially operating U.S. nuclear power plants with 98 active nuclear reactors.[9]

Since the early 1970s, there has been a significant political push to return to renewable energy, mainly in the form of wind and solar; this political movement has grown since the mid 2000's and has played a major role in supporting federal energy subsidies and state-level renewable portfolio mandates. In fiscal year 2016 (the most recent year data is available), 93 percent of federal energy subsidies went to renewable energy and nuclear, while 7 percent went to coal, oil, and natural gas combined.[10] Federal subsidies to support non-renewable energy and nuclear power in FY 2016 totaled $7.047 billion, while those for fossil fuels totaled $489 million, despite much higher production from these energy sources. The percentages of federal subsidies along with total energy produced by source is demonstrated in the chart below:

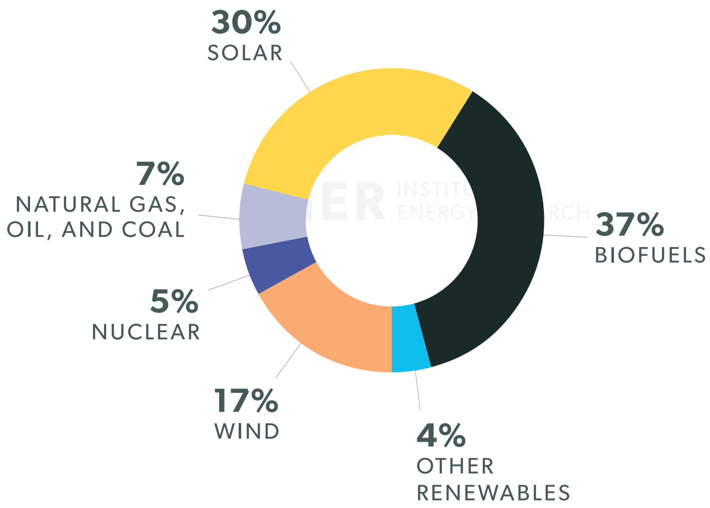
Source	Percentage of federal energy subsidies (2016)	Percentage of total U.S. energy production (2016)
BIOMASS	37 PERCENT	5.9 PERCENT
SOLAR	30 PERCENT	.06 PERCENT
WIND	17 PERCENT	2.4 PERCENT
COAL, OIL, AND NATURAL GAS	7 PERCENT	78 PERCENT
NUCLEAR	5 PERCENT	10 PERCENT
OTHER	4 PERCENT	3.64 PERCENT

Source: EIA

Biofuel subsidies totaled $2.8 billion in fiscal year (FY) 2016 while wind subsidies totaled $1.3 billion and solar subsidies totaled $2.2 billion.

Subsidies and special treatment for certain industries are unavoidable in a mixed-market economy as the federal government's power to regulate and spend opens the door to rent-seeking and political favoritism. That said, it is important for taxpayers to recognize that they are getting much less in return from federal subsidies that go to wind, solar, and biomass. In 2016, these sources received 84 percent of the federal subsidies, but only accounted for 8.36 percent of total U.S. energy. Biofuel subsidies totaled $2.8 billion in fiscal year (FY) 2016 while wind subsidies[11] totaled $1.3 billion and solar subsidies totaled $2.2 billion. Both wind and solar continue to be eligible for tax credits—the production tax credit for wind and the investment tax credit for solar.[12] In FY 2016, tax expenditures accounted for 80 percent of total renewable energy subsidies. In FY 2016, federal subsidies and support for coal, oil, and natural gas totaled $489 million.[13] In FY 2016, certain tax provisions related to oil and natural gas yielded positive revenue flow for the government, resulting in a negative net subsidy of $773 million for oil and natural gas, based on estimates from the U.S. Department of Treasury.[14] Federal subsidies and support for coal totaled $1.26 billion in FY 2016. Wind and solar power did contribute slightly greater shares in 2018 as a result of continued subsidies, mandates, and lower production costs.[15]

SHARE OF ENERGY SUBSIDIES, FY 2016



Source: EIA (eia.gov/analysis/requests/subsidy/pdf/subsidy/pdf)

Overview of Electricity Generation in the United States

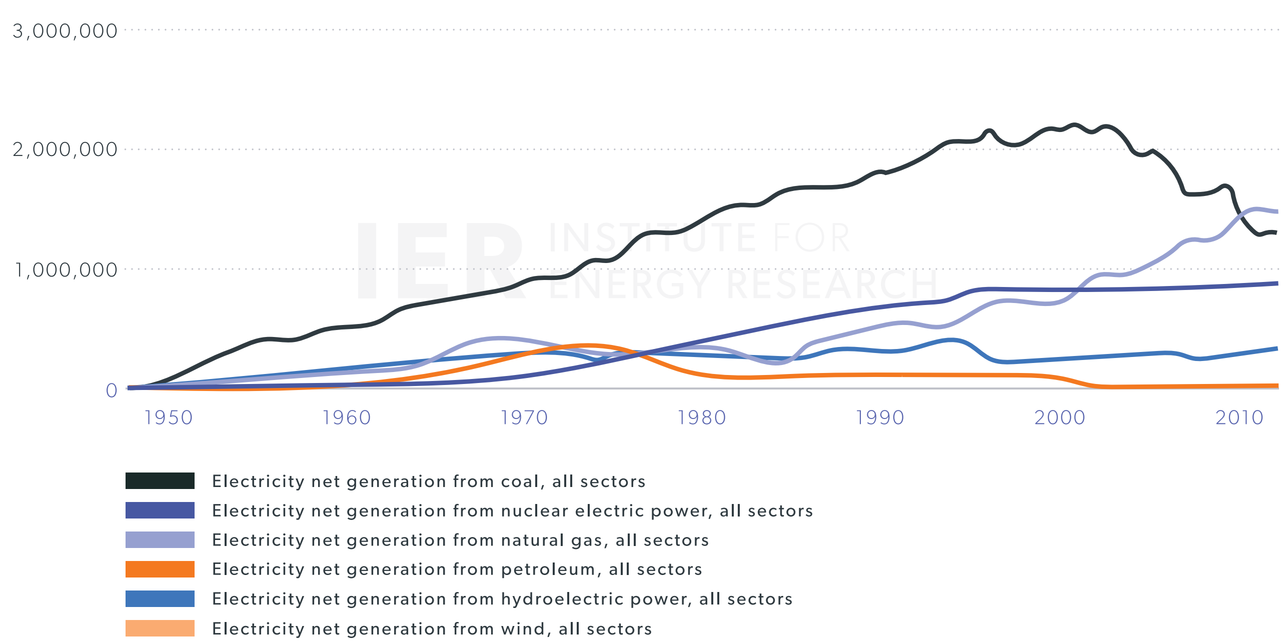
Americans have traditionally relied on a variety of sources for their electricity. In 2018, power plants in the U.S. generated about 4,178 billion kilowatt hours of utility-scale electricity.[16] Nearly 63 percent of that generation came from natural gas and coal; 19 percent from nuclear energy; 7 percent from hydroelectricity; 6.6 percent from wind; and 1.6 percent from solar. To the right is a complete breakdown of the U.S. electricity generation mix by source.

Since 2007, the U.S. electricity market has changed dramatically as coal has lost a significant share of the generation market. This shift can be attributed to a number of factors including lower natural gas prices, the increased adoption of state-level subsidies, mandates for renewable energy, and federal emissions regulations. The changes in U.S. electricity market are demonstrated in the graph below.

Today, the U.S. uses energy from a wide array of sources. In the sections that follow, we provide an overview of each energy source as well as information about their current use in our energy mix.

TABLE 7.2A ELECTRICITY NET GENERATION: TOTAL (ALL SECTORS)

Million Kilowatthours



Source: U.S. Energy Information Administration, *Monthly Energy Review*

U.S. ELECTRICITY GENERATION BY SOURCE, AMOUNT, AND SHARE OF TOTAL IN 2018

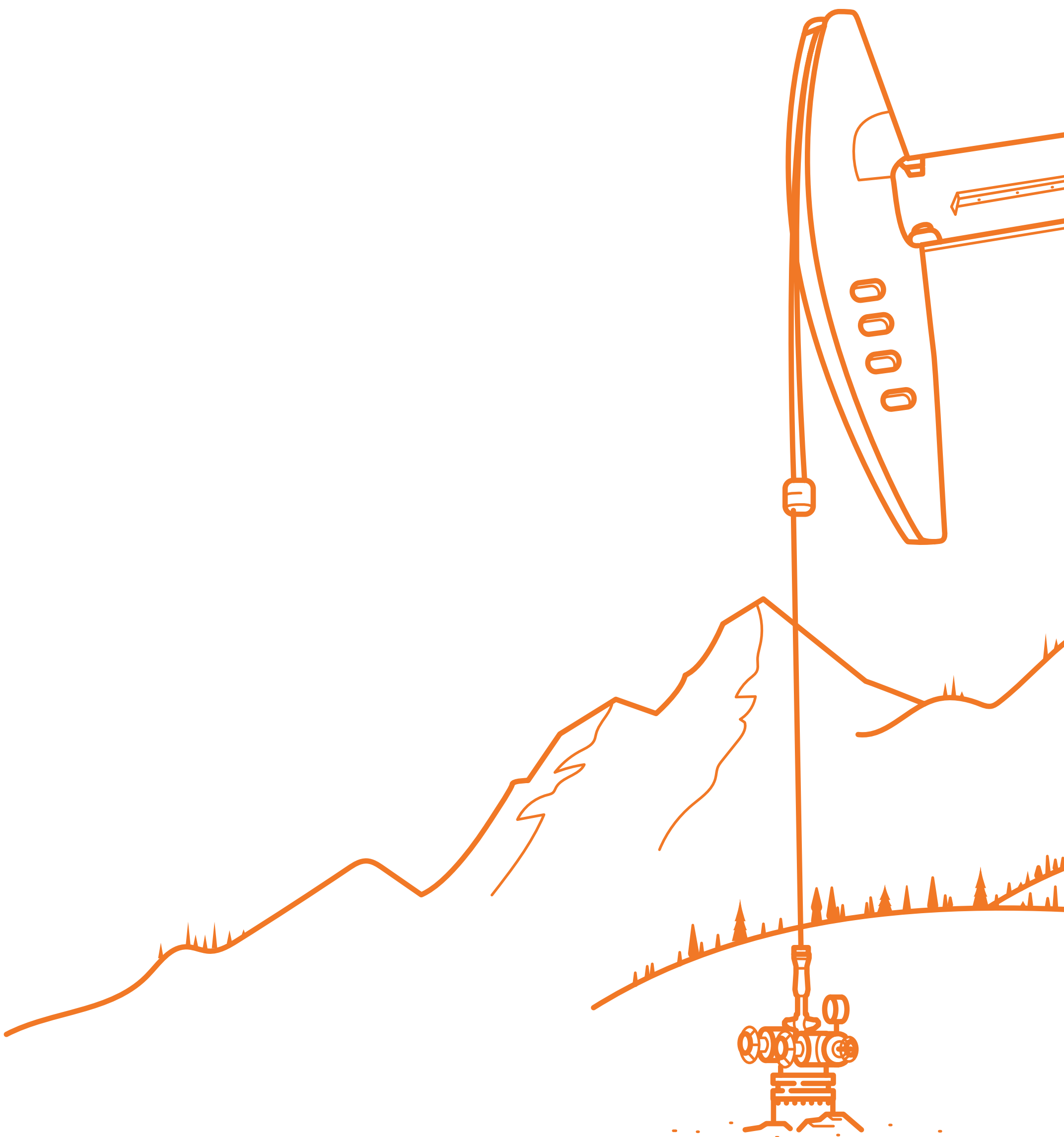
ENERGY SOURCE	BILLION KWH	SHARE OF TOTAL
Total - all sources	4,178	
Fossil fuels (total)	2,653	63.6%
Natural Gas	1,469	35.2%
Coal	1,146	27.5%
Petroleum	25	0.6%
Petroleum liquids	16	0.4%
Petroleum coke	9	0.2%
Other gases	13	0.3%
Nuclear	807	19.4%
Renewables (total)	703	16.9%
Hydropower	293	7.0%
Wind	273	6.5%
Biomass (total)	58	1.4%
Wood	41	1.0%
Landfill gas	11	0.3%
Municipal solid waste (biogenic)	7	0.2%
Other biomass waste	-1	<0.1%
Solar (total)	64	1.5%
Photovoltaic	60	1.4%
Solar thermal	4	0.1%
Geothermal	16	0.4%
Pumped storage hydropower[3]	-6	-0.1%
Other sources	13	0.3%

[1]Includes utility-scale electricity generation which is electricity generation from power plants with at least one megawatt (or 1000 kW) of total electricity generating capacity.

[2]Small-scale solar photovoltaic systems are electricity generators with less than one megabyte of electricity generating capacity that are usually at or near the location where the electricity is consumed. Most small-scale solar boutique systems are installed on building rooftops.

[3]Pumped storage hydroelectricity generation is negative because most pumped storage electricity generation facilities use more electricity than they produce on an annual basis. Most pumped storage systems use fossil fuels or nuclear energy for pumping water to the storage component of the system.

PETROLEUM



Petroleum

- Petroleum provided 36.5 percent of the total energy consumed in the U.S in 2018.
- Petroleum generates less than 1 percent of our electricity.
- At the end of 2017, the U.S. had slightly more than 39.1 billion barrels of proved crude oil reserves—84 percent higher than 10 years ago.
- U.S. oil production in 2018 averaged almost 11 million barrels per day, with production in November and December hitting almost 12 million barrels per day. Oil production in 2018 was 1.6 million barrels per day higher than in 2017 (a 17 percent increase). EIA forecasts U.S. crude oil production will average 12.3 million barrels per day in 2019.[17]
- In the past decade, U.S. companies have drilled 114,000 wells in the Permian Basin of Texas alone; many of them are profitable at crude oil prices as low as $30 a barrel.

Petroleum Use in the United States

Oil is the most used energy source in the U.S., accounting for 36.5 percent of the total energy consumed in 2018.[18] Due to advances in technology, improved efficiency, and economic factors, EIA forecasts U.S. crude oil production will average 12.3 million barrels per day in 2019, up 1.3 million from the 2018 level, and will rise by 0.9 million barrels per day in 2020 to an annual average of 13.2 million barrels per day.[19] In the past year, crude oil production in the United States has surpassed both Saudi Arabia and Russia.[20]

In 2018, U.S. crude oil production grew 17 percent from the previous year, surpassing the previous record for growth that was set in 1970. This continues a trend of U.S. crude oil production that has progressed rapidly since 2011, with much of this year's growth occurring in the Permian region in western Texas and eastern New Mexico. Crude oil production in Texas averaged 4.4 million barrels per day, making up 40 percent of the national total in 2018. Other areas experiencing significant growth included the Federal Offshore Gulf of Mexico and the Bakken region that stretches across North Dakota and Montana. In the same period, production in Colorado, Oklahoma, and North Dakota each grew by more than 95,000 barrels per day from 2017 to 2018.[21] Production in Alaska decreased by 16,000 barrels per day and in California by 13,000 barrels per day. This marked the fourth consecutive year that production declined in California.[22]

Petroleum's popularity is due in large part to its energy density and transportability, making it our most utilized transportation fuel. In 2018, refiners sold a little less than 24.3 million gallons of motor gasoline per day—a slight decrease from 2017 when they sold about 24.5 million gallons per day.[23] Although petroleum is the primary source of energy for transportation, it is rarely used for electricity generation because there are less-costly generating options. Less than 1 percent of our electricity comes from petroleum.

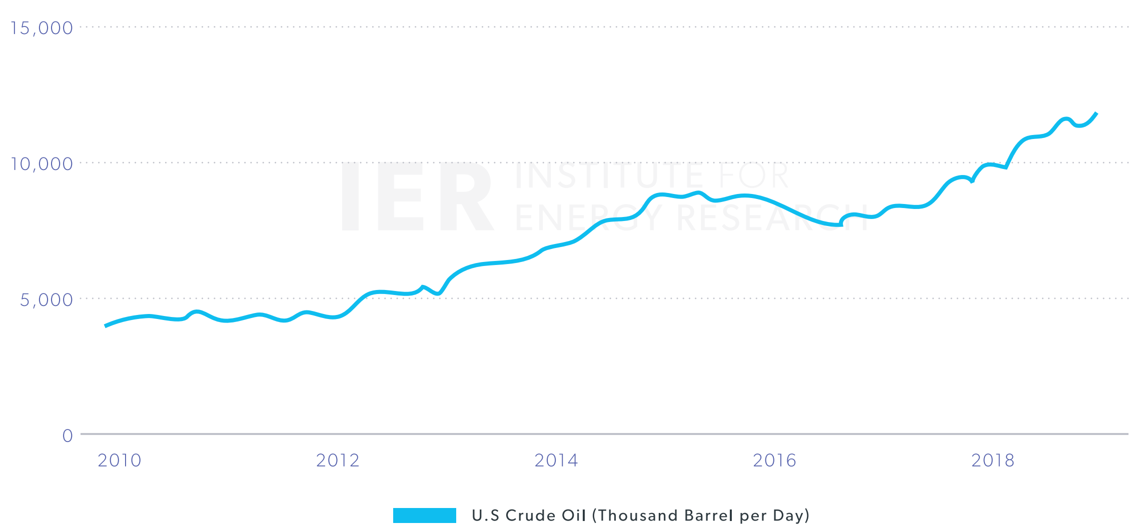
America's Oil Exports

In December of 2015, Congress lifted the ban on exporting U.S. crude oil, allowing crude oil to be exported to countries outside of North America for the first time since the mid-1970s. American producers started exporting oil only 15 days after the ban was lifted, launching an American energy revolution. The removal of the export ban led to increased production and investment in infrastructure, which in turn has led to a dramatic growth in U.S. oil exports. During the week ending on November 30, 2018, the U.S. exported a net of 211,000 barrels per day; this marked the first time the U.S. exported more oil than it imported since 1973.[24] In 2018, total U.S. petroleum exports increased for the sixteenth consecutive year, with exports of gas liquids (such as propane) driving most of the growth. For the year, U.S. crude oil exports rose to 2 million barrels per day, nearly twice the 1.2 million barrels per day rate in 2017.[25]

The U.S. Gulf Coast region became a net exporter of crude oil in late 2018. Monthly net trade of crude oil in the Gulf Coast region shifted from a high of 6.6 million barrels per day of net imports in 2007 to 40,000 barrels per day of net exports in December of 2018.[26] However, the changes in net exports in this region cannot be explained by new production alone. A large majority of the new crude oil production in the Gulf Coast is light, sweet crude, but

U.S. CRUDE OIL PRODUCTION

thousand barrels per day



Source: U.S. Energy Information Administration

EXPORTS

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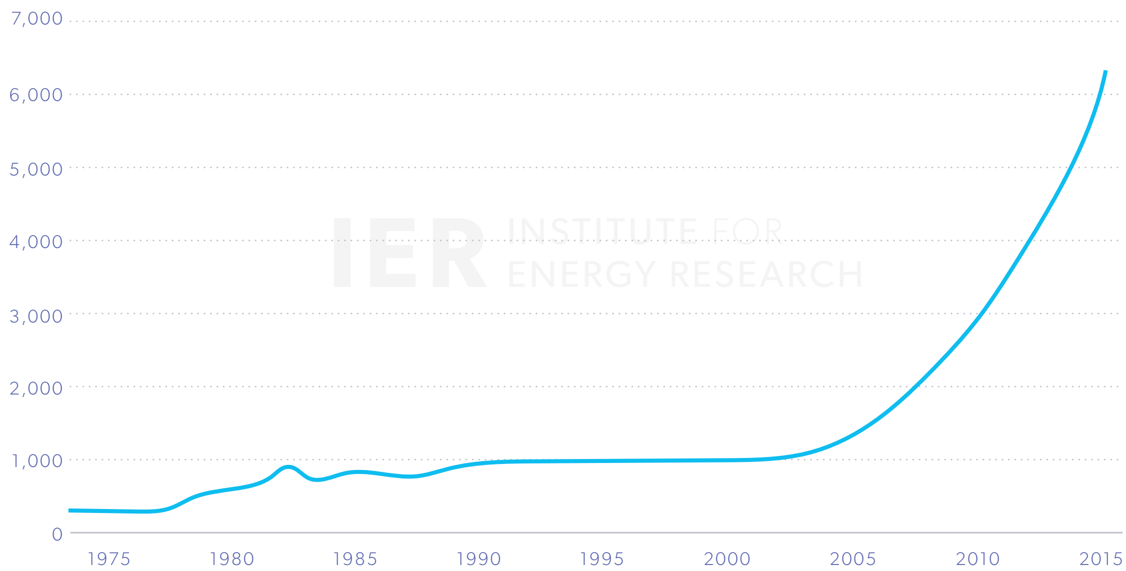
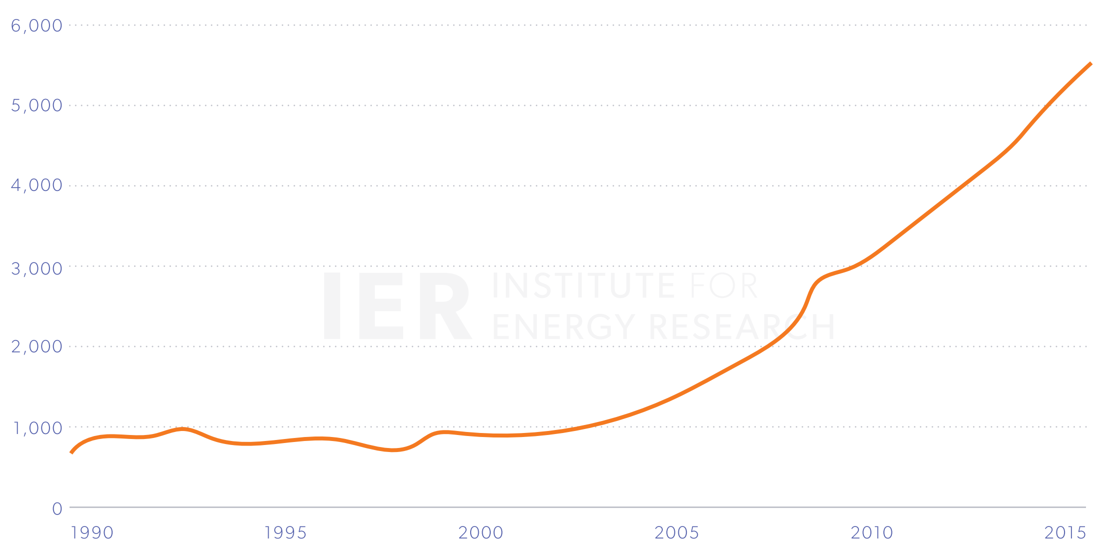


U.S Exports of Crude Oil and Petroleum Products

Source: U.S. Energy Information Administration

U.S. PETROLEUM PRODUCT EXPORTS (1990-2018)

thousand barrels per day



U.S Exports of Crude Oil and Petroleum Products

Source: U.S. Energy Information Administration, *Petroleum Supply Monthly* a majority of the refineries in the Gulf Coast region are designed to process heavy, sour crude. This incongruity means that large portions of the new production must be exported from the region, which contributes to the changes in the net exports data.[27]

It is also important to note that the destination of export volumes changed significantly throughout the year. In 2018, 378,000 barrels per day of U.S. crude oil were exported to Canada, making it the largest importer of U.S. crude oil.[28] Importantly, South Korea surpassed China to become the second-largest destination for U.S. crude oil exports, as the U.S. did not export any crude oil to China from August through October of 2018.[29]

The U.S. exported a record high average of 951,000 barrels per day of motor gasoline (including blending components) to 44 countries in 2018. These record exports came despite high levels of domestic consumption of motor gasoline, averaging 9.3 million barrels per day.[30]

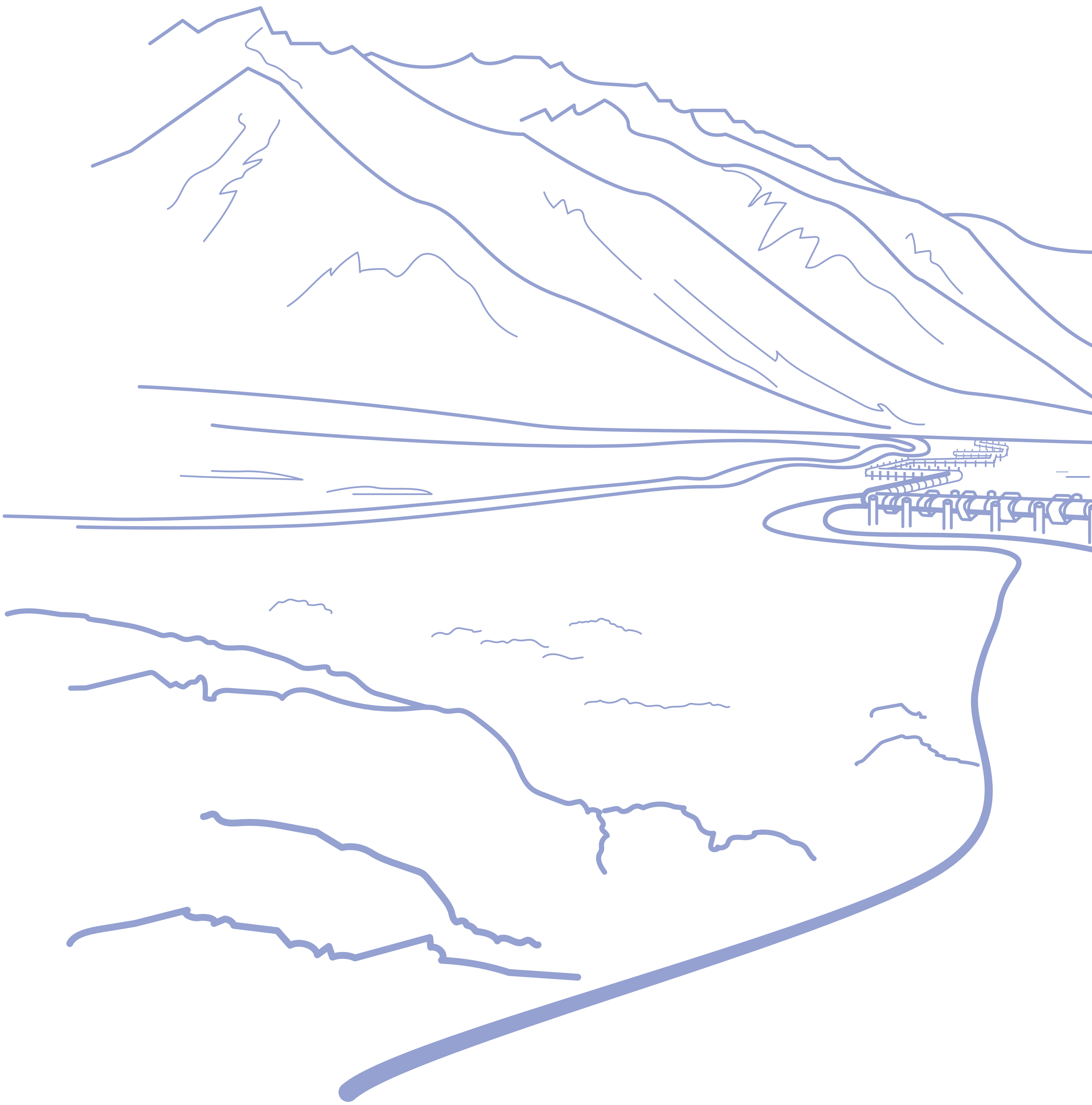
Petroleum Prices and Reserves

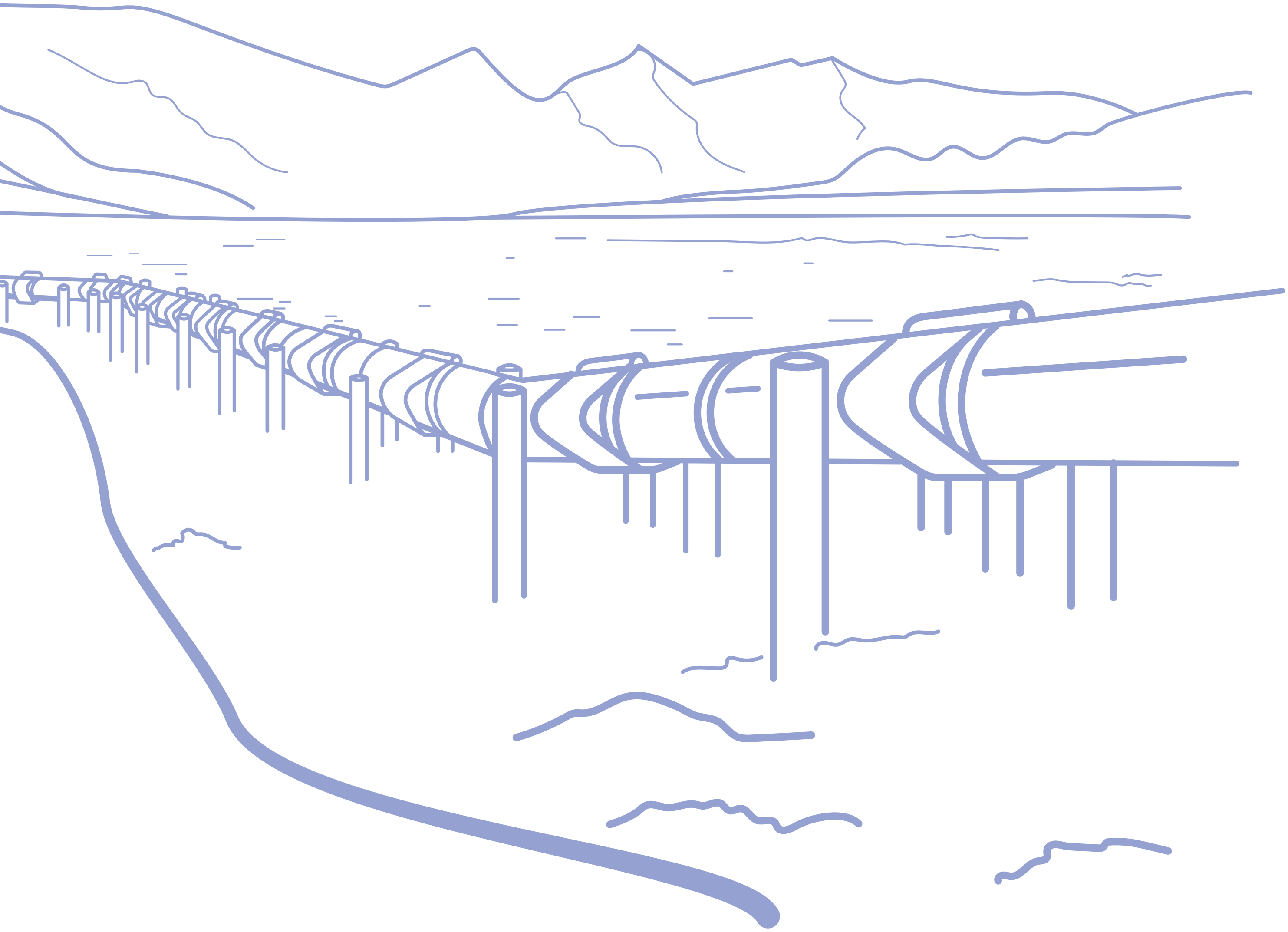
The average annual spot price for a barrel of West Texas Intermediate (WTI) crude oil in Cushing, Oklahoma increased from $42.59 in 2016 to $51.03 in 2017.[31] At the end of 2017, the WTI spot price exceeded $60 per barrel for the first time since 2015.[32] Rising prices incentivized more exploration and increased the amount of recoverable oil reserves (oil that is economic to produce, given current prices and technology).

The combination of these economic conditions along with improvements in technology led to a record increase of proved reserves. It is easy to confuse proved reserves with the total amount of resources available on the planet, so it is important to clarify the distinction here. Proved reserves are the estimated reserves that are easily accessible and recoverable with today's technology and economic conditions. Therefore, proved reserves are only a small fraction of the amount of a resource that is available on Earth, and it is a figure that tends to grow as our economy demands more of a resource. If we consider the history of proved oil reserves in the U.S., in 1980, the U.S. had about 29.8 billion barrels of proved oil reserves. In 2017, proved reserves of crude oil (reserves that claim an approximate certainty level of successful recovery of at least 90 percent) in the U.S. increased 19.5 percent from the previous year to 39.2 billion barrels.[33]

In Texas alone, producers added 3.3 billion barrels of crude oil and lease condensate proved reserves; this was the largest net increase of proved reserves among all states. The increase in Texas was driven primarily by the development of the Permian Basin and the Wolfcamp/Bone Spring shale play. Following Texas, the crude oil lease condensate proved reserves of New Mexico and the Federal Offshore Gulf of Mexico added net gains of 1 billion and 729 million barrels of oil respectively.

NATURAL GAS





Natural Gas

- In 2018, natural gas accounted for about 30.6 percent of the total energy consumed in the U.S.
- 35.2 percent of electricity generated in the U.S. was from natural gas.
- In 2018, the U.S. produced an average of 101.3 billion cubic feet of natural gas per day, the highest volume on record.
- U.S. natural gas production increased every month except June in 2018, eventually reaching a record monthly high of 107.8 billion cubic feet per day in December.
- As natural gas production increased, so did the volume of natural gas exports—both through liquefied natural gas and pipelines.
- The U.S. remained a net exporter of natural gas in 2018, having achieved that standing in 2017 for the first time in nearly 60 years.

Overview of Natural Gas in the United States

In 2018, natural gas production in the U.S. grew by 10 billion cubic feet per day to a record average gross withdrawal of 101.3 billion cubic feet per day. This was an 11 percent increase from 2017, the previous record.[36] In 2018, natural gas production measured as marketed production (the gross withdrawals minus the amount of gas used for repressuring, quantities vented or flared, and non-hydrocarbon gases removed after treating and processing) also reached record highs, averaging 95.0 billion cubic feet per day.[37]

In 2018, there was tremendous growth in natural gas production across the U.S. The Appalachian region remained the largest producer of natural gas, as the Marcellus and Utica/Point Pleasant formations in Ohio, West Virginia, and Pennsylvania continued to increase their production. Together, they produced 28.5 billion cubic feet of natural gas per day.[38] According to the U.S. Energy Information Administration, Texas was the single state with the largest increase in volumetric withdrawals of natural gas, producing 2.2 billion cubic feet per day more than in 2017. Most of this increase can be attributed to development in the Permian Basin and Haynesville Shale formation, which increased production 32 and 34 percent in natural gas production respectively.[39] Ohio was the state that saw the highest percentage increase in gross withdrawals of natural gas (34 percent) in 2018, averaging 6.5 billion cubic feet per day in 2018.

Consumption in the electric power sector grew by 15 percent to 29.1 billion cubic feet per day as more natural gas-fired power plants came online throughout the year and existing natural gas power plants were used more often.

Natural gas consumption reached a record high of 82.1 billion cubic feet per day in 2018. Consumption in the electric power sector grew by 15 percent to 29.1 billion cubic feet per day as more natural gas-fired power plants came online throughout the year and existing natural gas power plants were used more often.[40] In 2018, consumption in the residential, commercial, and industrial sectors also grew, by 13 percent, 10 percent, and 6 percent respectively as compared to 2017 levels.[41]

Natural Gas Reserves[42]

Proved reserves of natural gas in the U.S. increased by 123.2 trillion cubic feet to 464.3 trillion cubic feet at year-end 2017, the most recent year data is available.[43] Proved reserves of natural gas increased in each of the top eight natural gas reserves states with Pennsylvania leading the way, adding 28.1 trillion cubic feet of proved reserves.[44] Texas had the second largest net increase, adding 26.9 trillion cubic feet of proved reserves in 2017. The share of natural gas from shale compared to total U.S. natural gas proved reserves increased from 62 to 66 percent by the end of 2017.[45]

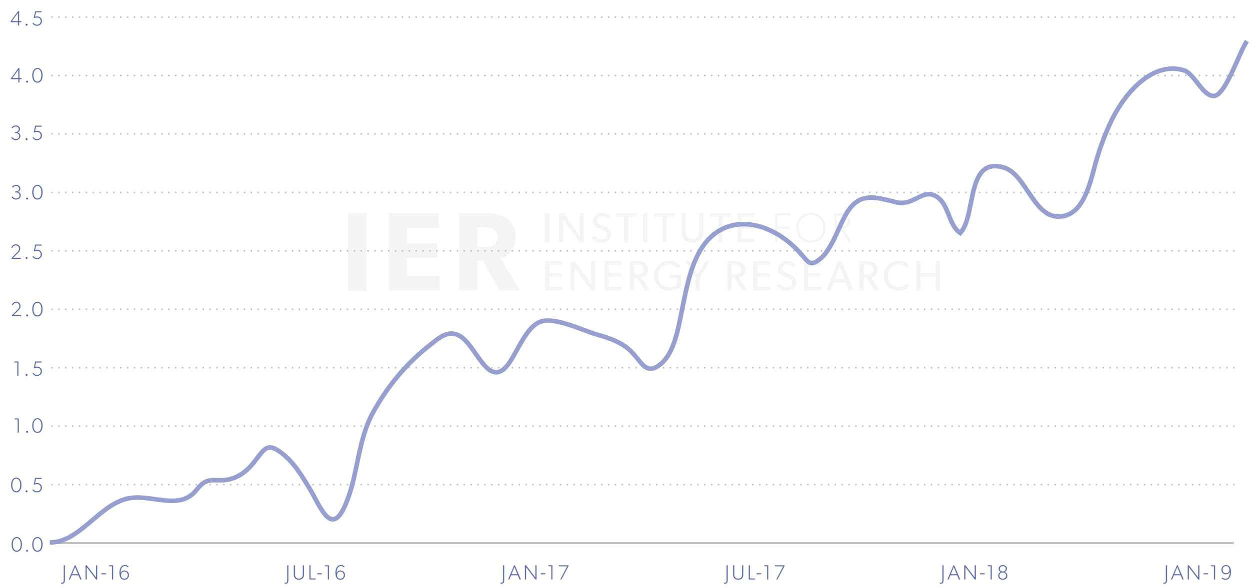
Natural Gas Imports and Exports

Exports grew along with production in 2018, as the U.S. was once again a net exporter of natural gas.[46] The volume of natural gas exports grew to 9.9 billion cubic feet per day in 2018.[47] Exports by pipeline and through liquefied natural gas (LNG) technology grew in 2018, reaching record highs in December of 7.7 billion cubic feet per day (pipelines) and 4.0 billion cubic feet per day (LNG) respectively.[48] In September of 2018, the U.S. exported more natural gas by pipeline than it imported by pipeline for the first time in 20 years.[49] U.S. natural gas exports by pipeline grew primarily due to expansions of cross-border pipeline capacity with Mexico; these expansions have provided an additional channel for natural gas production in the Permian Basin.

Another major development in natural gas in 2018 was the increase in LNG exports. The U.S. began exporting LNG from the lower 48 states in February of 2016 with the opening of the Sabine Pass Liquefaction Terminal in Louisiana.[50] Since then, the Sabine Pass facility has added four more liquefaction trains. In 2018, two other LNG export terminals also came online; the Cove Point facility in Maryland and the Corpus Christi facility in Texas both became operational late last year.[51] The EIA projects that U.S. LNG export capacity will reach 8.9 billion cubic feet per day by the end of 2019, making the United States the third largest exporter of LNG in the world.[52] The growth in U.S. LNG exports since 2016 is documented in the chart on the following page.

U.S. LIQUEFIED NATURAL GAS EXPORTS (JAN 2016-MAR 2019)

billion cubic feet per day



Source: U.S. Energy Information Administration, *Natural Gas Monthly*

Natural Gas Prices

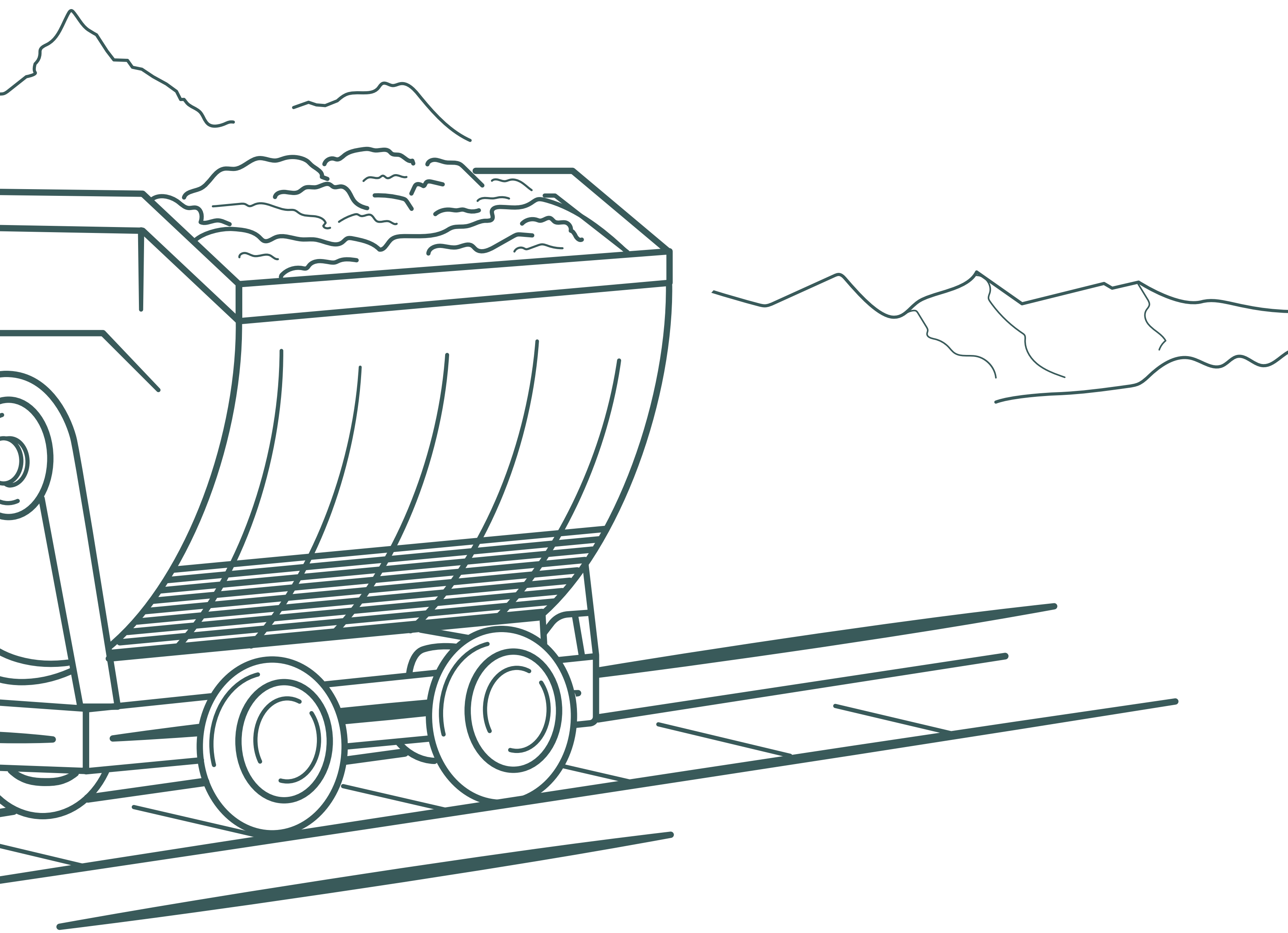
In 2018, the average annual natural gas spot price at the Henry Hub was $3.16 per million British thermal units, a 15-cent increase from the 2017 average.[53] Notably, in January of 2018, natural gas prices in the Northeast U.S. spiked during a lengthy period of cold weather, with daily prices reaching as high as $175 per million British thermal units as high demand for natural gas led to a record-high weekly withdrawal from U.S. storage.[54]

Although these record high natural gas prices were primarily the result of increased demand promulgated by the period of cold weather, the price spikes were exacerbated by two additional factors. First, the lack of pipeline capacity in the Permian Basin and the Northeast resulted in bottlenecks that raised prices during periods of high demand.[55] Additionally, Jones Act restrictions—which, as a practical matter prevents the transport of LNG from the United States' Gulf Coast to

Enacted in 1920, the Jones Act increases shipping costs by mandating that only vessels... in the U.S. can participate in maritime shipping ...limiting the supply of domestic shipping.

the Northeast—prevented the development of a U.S.-based LNG supply chain.[56] Enacted in 1920, the Jones Act increases shipping costs by mandating that only vessels that are built, owned, crewed, and flagged in the U.S. can participate in maritime shipping between domestic ports, thus limiting the supply of domestic shipping. The Jones Act affects where products are shipped because the costs of domestic transportation largely determine the pattern of energy trade. This being the case, in order to avoid the added costs caused by the Jones Act, some companies opt to hire foreign ships to export crude oil to Canada instead of shipping it to a domestic refinery.[57] This increases costs to energy consumers relative to what they would be absent the Jones Act and also diverts the economic activity away from the U.S. Both of these factors played a role in limiting the supply of natural gas in the Northeast during periods of high demand in 2018. Consequently, expanding U.S. energy infrastructure to keep up with increases in both the supply and demand of natural gas and Jones Act reform should be priority issues for policymakers going forward.

COAL



Coal

- The U.S. produced 756 million short tons of coal in 2018.
- Coal was responsible for about 13.1 percent of the total energy consumed in the U.S. in 2018.
- Coal generates about 28 percent of the total electricity in the U.S.
- In 2018, U.S. coal exports rose for the second consecutive year to 116 million short tons.

Overview of Coal in the United States

The U.S. produced 756 million short tons of coal in 2018, which was about 20 million short tons less than in 2017.[58] Coal consumption in the U.S. also dropped in 2018 to about 687 million short tons.[59] The electric power sector consumes over 90 percent of the coal in the U.S. and coal-fired power plants provide about 28 percent of our total electricity. There are five major coal-producing basins in the U.S. Two of them, the Central Appalachian and Illinois Basin, saw increases in production in 2018 by 4 percent and 2 percent respectively, according to the EIA.[60]

Opportunities for U.S. Coal Abroad

Although these numbers suggest a declining role for coal in the U.S., it would be a mistake to write off coal's future and understate the important role it will continue to play in the U.S. and emerging economies. In 2018, U.S. coal exports rose for the second consecutive year to 116 million short tons. Asian countries drove demand for exports, as India, Japan, and South Korea were the three largest importers of U.S. coal.[61]

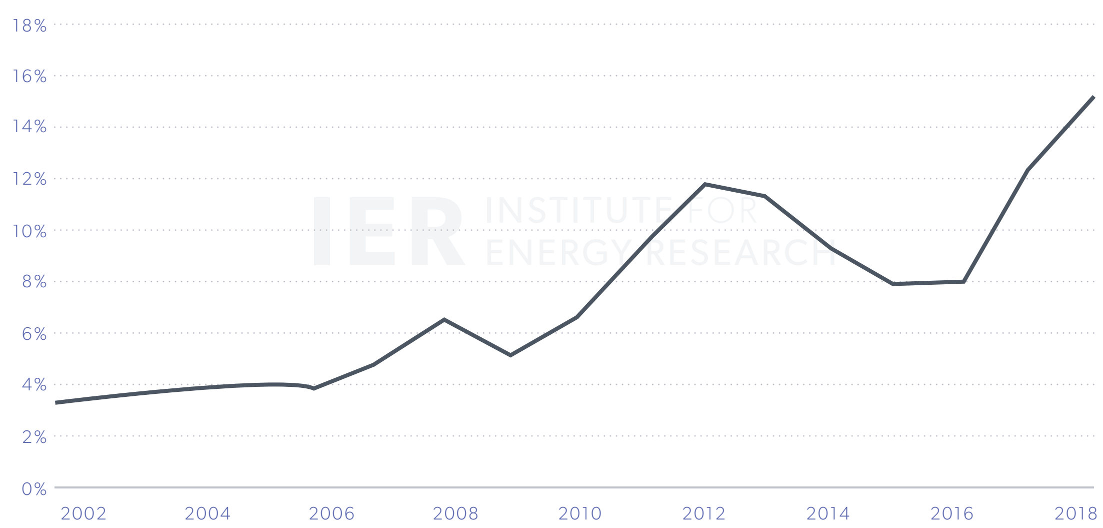
International demand for coal has helped support export prices in recent years, as the average price was $59 per ton for steam coal and $138 per ton for metallurgical coal in 2018.[62] Metallurgical coal maintains a higher price as it is used in the steel-making process. Asian countries account for about 75 percent of the global metallurgical coal trade, and high demand in China and India has helped increase prices for metallurgical coal in Asia.[63] In 2018, the U.S. exported 62 million short tons of metallurgical coal (up from 55 million short tons in 2017) and 54 million short tons of steam coal (up from 42 million short tons in 2017).[64] U.S. steam coal exports to Asia have increased dramatically in the past two years from 5 million short tons in 2016 to 20 million short tons in 2018.[65]

Coal demand in India and other emerging Asian economies has grown, and the expectation is that their demand for coal will continue to grow for the foreseeable future.[66] In its 2019 Energy Outlook, BP projects India to be the largest growth market for coal, with its share of world coal consumption more than doubling to around a quarter in 2040.[67] This is important for understanding the opportunities that exist for the U.S. coal industry abroad. Since 2002, the U.S. has been exporting an increasing percentage of its coal production. In 2018, the U.S. exported 15 percent of its coal production, up from about 13 percent in 2017.[68] This suggests that the U.S. coal industry recognizes the opportunities for coal in emerging economies and is making efforts to enter those markets. The growth of U.S. coal exports is demonstrated in the graph below.

However, coal exports have been limited by political restrictions on permitting new export terminals in the U.S. The most notable example of this took place in 2017 when a proposed export terminal along the Columbia River was

U.S. COAL EXPORT SHARE OF U.S. COAL DISPOSITION (2002-2018)

percent of total



Source: U.S. Energy Information Administration, *Annual Coal Report*, and the U.S. Department of Commerce, Census

More than 90 percent of U.S. coal consumption comes from the power sector, as coal power generation is about 28 percent of the total electricity generation in the U.S.

rejected by Washington state's Energy Facility Site Evaluation Council. The terminal would have been able to handle up to 44 million tons of coal from western mines.

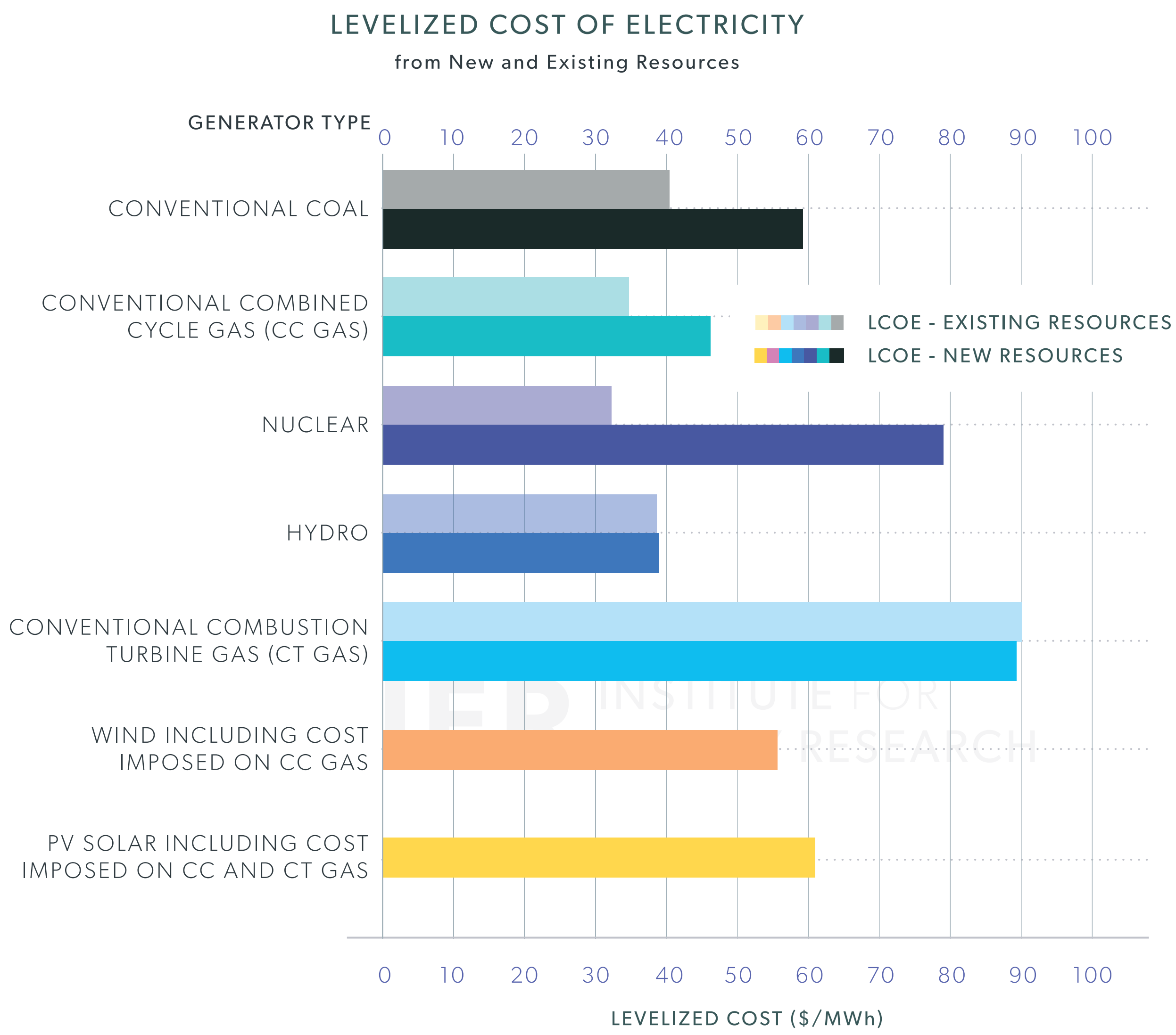
Coal's Role in the Power Sector

More than 90 percent of U.S. coal consumption comes from the power sector, as coal power generation is about 28 percent of the total electricity generation in the U.S.[69] Although coal's share has declined in recent years, coal will likely continue to play an important role in U.S. power generation as existing coal power plants continue to provide reliable baseload capacity for the grid.

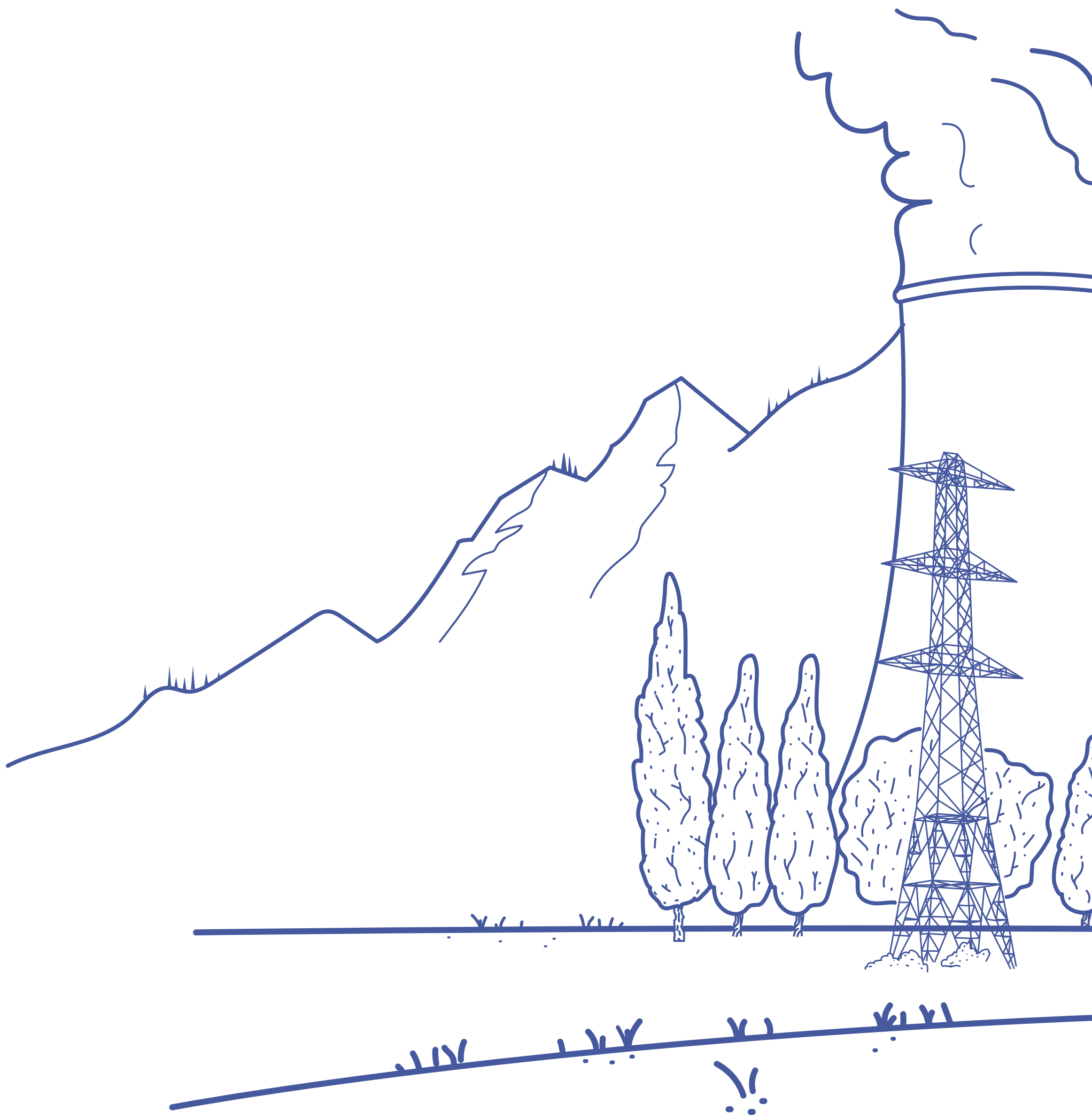
Some have claimed that new wind and solar generation could replace large portions of the existing coal fleet without increasing costs for ratepayers. However, these projections do not take into account important factors such as the cost of lost capital, retirement costs, or an analysis of reliability. In June of 2019, the Institute for Energy Research published a study that examines the levelized cost of new and existing power plants; the study also considers the imposed costs of wind and solar. Levelized cost of electricity (LCOE) represents the average revenue per unit of electricity generated that would be required to recover the costs of building and operating a generating plant during an assumed financial life and duty cycle. However, wind, solar, and other intermittent resources are not dispatched on the grid and do not necessarily follow a duty cycle based on load conditions. Imposed costs are the cost of keeping dispatchable plants available when wind or solar generation isn't producing electricity. The study found that, on average, new wind and solar plants cost about 65 percent more than existing coal-fired power plants before applying the imposed costs to wind and solar and twice as much when the imposed costs are applied.[70] The study's levelized cost findings are presented in the table to the right.

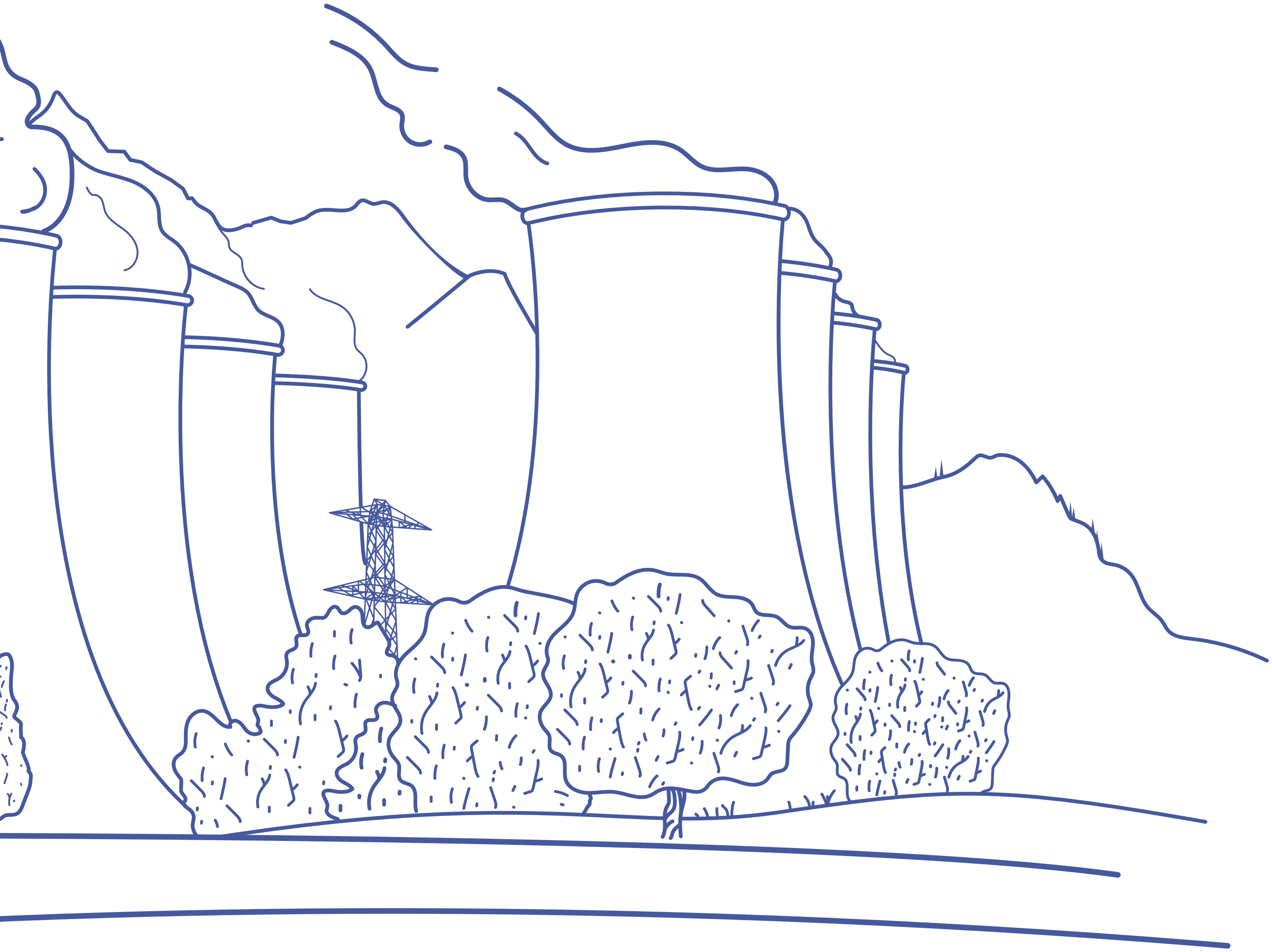
Opposition to Coal

Even though coal power plants continue to produce inexpensive and reliable baseload power necessary for operating a stable grid, coal power plants continue to be the target of attacks by environmental groups and other competitors in the electricity generation industry.[71] The Sierra Club, for example, received at least $17 million in grants for the explicit purpose of blocking the development of coal-fired power plants across the United States from 2008 to 2016. In one instance, the Sierra Club received a $1.08 million grant from the Energy Foundation specifically "to defeat new coal-fired power plants in Kentucky, Louisiana, Michigan, Pennsylvania, South Dakota, and Wyoming." Subsequently, in the period leading up to and directly following the receipt of the grant, the Sierra Club was directly involved in blocking the development of new coal-fired power plants in those states.[72]


LEVELIZED COST OF ELECTRICITY
from New and Existing Resources
GENERATOR TYPE
0 10 20 30 40 50 60 70 80 90 100
CONVENTIONAL COAL
CONVENTIONAL COMBINED CYCLE GAS (CC GAS)
NUCLEAR
HYDRO
CONVENTIONAL COMBUSTION TURBINE GAS (CT GAS)
WIND INCLUDING COST IMPOSED ON CC GAS
PV SOLAR INCLUDING COST IMPOSED ON CC AND CT GAS
LCOE - EXISTING RESOURCES
LCOE - NEW RESOURCES
INSTITUTE FOR RESEARCH
LEVELIZED COST ($/MWh)

NUCLEAR





Nuclear

- In 2018, nuclear electric power was responsible for 8.3 percent of the total energy consumed in the United States.
- Nuclear power generates 19.4 percent of the total electricity in the U.S.
- In 2018, the U.S. nuclear power fleet generated its highest capacity factor ever at 92.6 percent.

Overview of Nuclear Energy in the United States

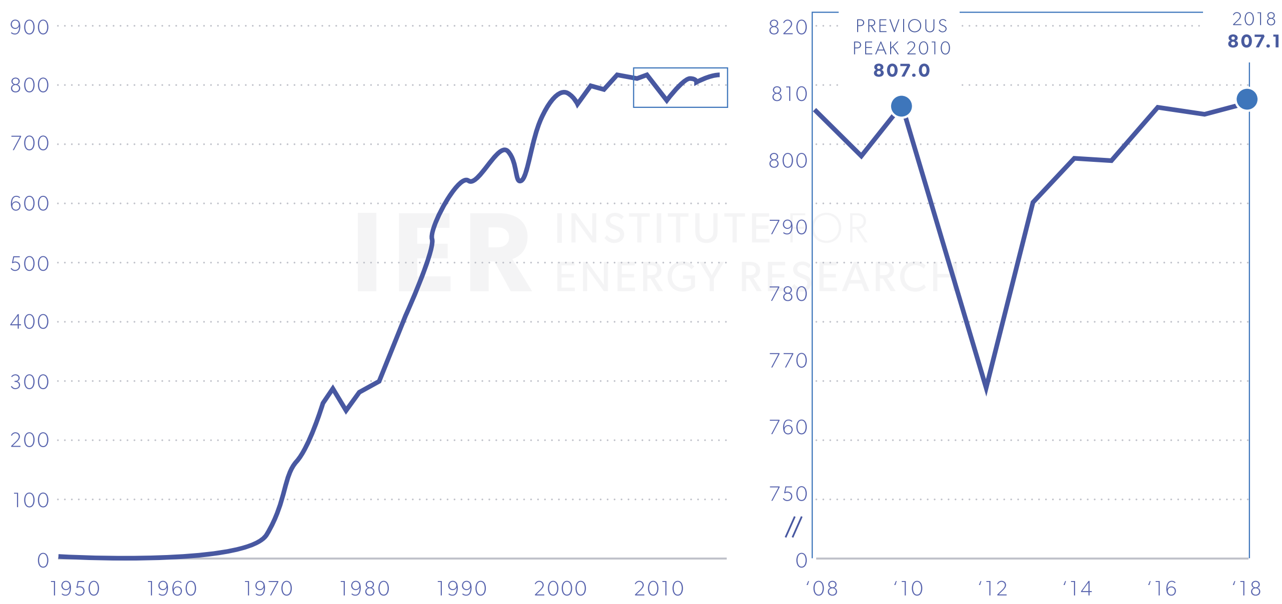
The U.S. is the world's largest producer of nuclear power, with 96 reactors operating in 30 different states, with a combined total electricity generating capacity of slightly more than 99 gigawatts.[73] In 2018, nuclear power plants produced over 19 percent of the total electricity in the U.S.[74]

Even though no new reactors were added in 2018 and several nuclear power plants have closed since 2010, nuclear power plants were able to increase their production of electricity in 2018.[75] Collectively, nuclear power plants generated 807.1 million megawatt hours in 2018; this was slightly higher than the previous high of 807.0 million megawatt hours in 2010.[76]

There are two factors that are contributing to this increase in nuclear energy production. First, existing power plants have added capacity in recent years due to uprates.[77] The U.S. Nuclear Regulatory Commission regulates the maximum power level commercial nuclear power plants may produce. The process of increasing this maximum level is called uprating.[78] The U.S. Energy Information Administration recorded 2.0 gigawatts of thermal power uprates between 2010 and 2018—this is almost equivalent to adding two new reactors to the grid. In addition to these recent uprates, nuclear power plants have also shortened the amount of operational downtime needed for refueling and maintenance. The combination of these factors allowed the U.S. nuclear power fleet to generate its highest capacity factor ever, at 92.6 percent in 2018.[79]

U.S. NUCLEAR ELECTRICITY GENERATION (1957-2018)

million megawatthours



Source: U.S. Energy Information Administration, *Monthly Energy Review*, and *Electric Power Monthly*

Challenges for Nuclear Energy in the United States

Despite these improvements in production, nuclear energy does face a number of challenges. Since 2010, the only new nuclear plant to be built in the U.S. was the Tennessee Valley Authority's Watts Bar Unit 2 nuclear power reactor, which started operations in 2016.[80] Additionally, since 2013, seven nuclear power plants with a combined capacity of 5.3 gigawatts were retired, with two more expected to retire in 2019.[81]

There are several factors that contribute to this decline. In recent years, relatively low natural gas prices have created an increasingly competitive market for power generation in the U.S., challenging nuclear energy's position in the market. Nearly 50 percent of the existing nuclear power plants operate in partially deregulated wholesale markets where natural gas-fired generators often set the marginal price for electricity.[82] In the past, monopoly providers could guarantee output requirements for long periods into the future; this mitigated some of the challenges presented by the high capital costs associated with constructing a nuclear plant. In competitive markets, private generating companies have to accept shorter output contracts, so, in general, they prefer shorter investment periods, steering them away from the high capital costs associated with nuclear power. Because of this, the price of natural gas will likely play a major role in determining the future of the U.S. nuclear power fleet. Under current economic and regulatory conditions, natural gas appears to have the upper hand as 62 percent of the 31.3 gigawatts of generating capacity that was added in 2018 came from natural gas.[83] In contrast, the EIA projects that net electricity generation from nuclear power plants will decline by 17 percent by 2025.[84]

In addition to competition from low-cost natural gas plants, high regulatory costs also present a challenge for nuclear power.

In addition to competition from low-cost natural gas plants, high regulatory costs also present a challenge for nuclear power.[85] A 2017 study by the American Action Forum (AAF) found that the average nuclear power plant is encumbered by close to $60 million in annual regulatory costs.[86] The nuclear industry also faces a permit and construction timeline that can take over 20 years, with even modest requests for uprates taking several years to gain approval.[87] Using the Mercatus Center's RegData tool, AAF demonstrated that the number of restrictions emanating from the Nuclear Regulatory Commission correlates almost directly with rising maintenance and operation costs.[88] In 2016, a paper published in Energy Policy provided additional insight into the regulatory costs and delays surrounding nuclear power by examining the overnight costs of nuclear power plants around the world.[89] The paper found that in the U.S., overnight costs have increased from $650 per kilowatt to nearly $11,000 per kilowatt.[90]

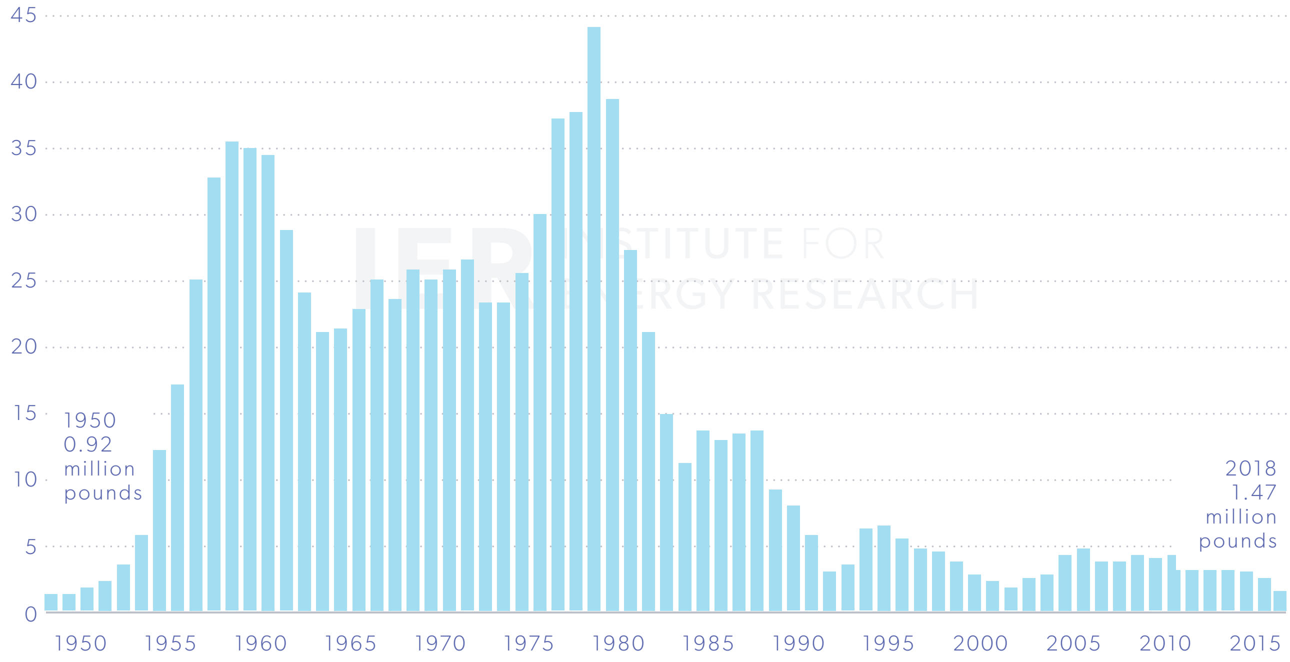
Despite its strong safety record, nuclear energy is also hindered to some degree by a public perception problem. People have offered numerous explanations for the public's mistrust in the safety of nuclear energy, and it's likely that a combination of these factors contribute to the problem.[91] Certainly, high profile incidents at Three Mile Island, Chernobyl, and Fukushima have played a role in how the public perceives nuclear energy. However, it's important to note that the Three Mile Island incident that occurred in the U.S. did not result in any loss of life. In the case of Chernobyl, the failure to maintain the public's safety can be reasonably attributed to the incentive problems that plagued the Soviet bureaucracy. There is also compelling evidence that suggests that the government's overreaction to these events has played a predominant role in increasing the public's fear of nuclear energy.[92] Additionally, research by Edward Calabrese suggests that the risks of exposure to nuclear radiation to human health have been exaggerated within the scientific community, which, if true, likely contributes to the public's misperception of nuclear energy's safety.[93]

Finally, declining uranium production in the U.S. potentially presents another challenge for nuclear energy. In 2018, the U.S. produced 1.47 million pounds of uranium concentrate, the lowest level since 1950.[94]

Over the years, as domestic production has declined, the U.S. has imported uranium from other countries such as Canada, Australia, Russia, and Kazakhstan. As the U.S. increasingly relies on foreign uranium sources, worsening geopolitical tensions as well as an unstable trade environment could potentially disrupt the supply of uranium, raising costs for nuclear power plants along the way. In 2018, owners and operators of U.S. civilian nuclear power reactors purchased a total of 40 million pounds of uranium from U.S. and foreign suppliers, at a weighted-average price of $38.81 per pound.[95] It is important to note that prices have nearly doubled since 2006, when the United States was producing about three times as much uranium.[96]

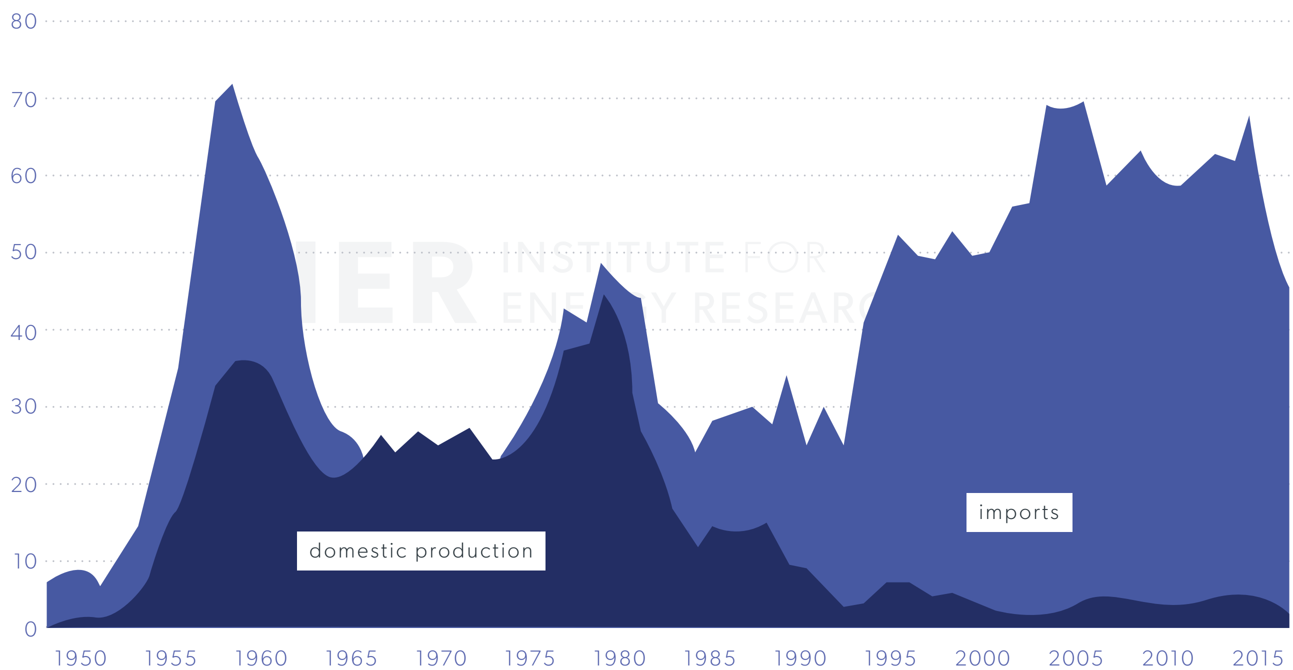
U.S. URANIUM CONCENTRATE PRODUCTION (1950-2018)

million pound U308



U.S. URANIUM SUPPLY TO COMMERCIAL NUCLEAR REACTORS

million pound U308



WIND AND SOLAR

Wind and Solar

- In 2018, wind generated 6.5 percent of the electricity in the United States, generating a slightly lower share than hydroelectric power, which generated 7 percent.
- In 2018, solar power generated 1.5 percent of the electricity in the United States, ranking third among the renewables in generating power.

Overview of Wind and Solar in the United States

Renewable energy is defined as energy from sources that are naturally replenishing but limited in the amount of energy that is available per unit of time. The major types of renewable energy sources are wind, solar, hydropower, geothermal, and biomass.[97]

Aided by government subsidies and mandates, renewable energy has seen strong year-over-year growth in recent years in the U.S. and around the world. However, in 2018, the renewable energy industry experienced an unexpected flattening of growth as renewables added about the same net capacity worldwide in 2018 as they did in 2017.[98] In 2018, total renewable energy, including from wind, solar, hydroelectric, geothermal, and biomass, produced a record 713 million megawatt-hours of electricity in the U.S., close to double the amount it produced a decade ago.[99] The vast majority of the growth in the renewable sector during this period (close to 90 percent) came from wind and solar.

In the U.S., wind produced almost 275 million megawatt-hours of electricity in 2018, which was 6.5 percent of the total electricity generation in the U.S.[100] Solar (rooftop, utility PV, and solar thermal combined) generated 67 million megawatt-hours of electricity in 2018, which was 1.5 percent of total generation.[101] Solar generation can be split into two categories: customer-sited rooftop solar installations and utility-scale generation (PV and solar thermal). Last year, about 69 percent of total solar generation came from utility-scale solar.

The renewable energy sector was responsible for 17 percent of the net electricity generated in the U.S. in 2018.[102] Renewable energy's share of the generation market in the U.S. is demonstrated in the chart to the right.

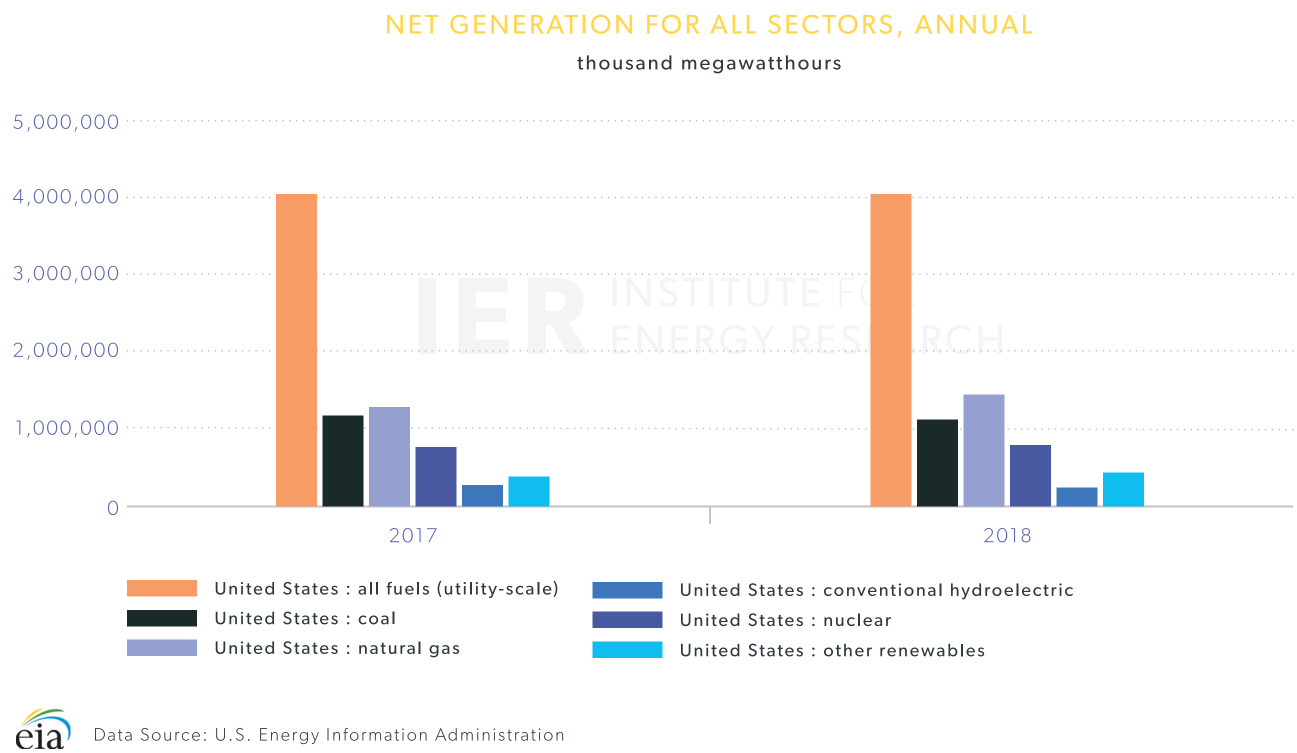
Wind and Solar Subsidies and Mandates

For several decades, the wind and solar industries have received lucrative federal tax subsidies in the form of the Production Tax Credit (PTC) for wind and the Investment Tax Credit (ITC) for solar. In 1992, Congress passed the Energy Policy Act that established the PTC for wind energy, providing a tax credit of 2.3 cents per kilowatt-hour of wind energy produced for the first 10 years of the facility's operation.[103] The ITC for solar energy was originally established by the Energy Policy Act of 2005; it provides a 30 percent tax credit on the investment in a qualifying solar facility.[104] These tax incentives were originally designed to get these industries off the ground, but after all these years taxpayers are still paying for them even though these industries now account for about 8 percent of the total electricity generated in the U.S. For a number of reasons, these subsidies have led to higher electricity costs for consumers. As a recent report on wind and solar tax credits released by the Institute for Energy Research explained:

"Not only are taxpayers subsidizing these industries, but American consumers are also paying more for electricity. While fossil fuel prices have been declining and electricity demand has been relatively flat, electricity prices have increased by 56 percent between 2000 and 2018, with the largest increases coming from many of the states that promoted the establishment of wind and solar energy through state subsidies and mandates for their production."[105]

What explains these rising prices? First, the PTC disrupts the economics of generation by causing wholesale generating prices to occasionally drop below zero. As the aforementioned report describes:

"For example, wholesale prices tend to range between $30 and $50 per megawatt-hour but can drop into the negative



range or spike well above $500 per megawatt-hour. Wind producers are paid the equivalent of $35 per megawatt-hour in Production Tax Credit subsidies (pre-tax income of the $23 per megawatt credit), so a wind producer can still profit while paying the grid to take its electricity, producing negative prices. When the price becomes negative, electric generators are actually paying the grid to take their electricity. Fundamentally, negative wholesale prices send a distress signal telling markets that the supply and demand balance on the grid is economically unsustainable and suppliers need to reduce their output. But, these market signals do not apply to wind since they are paid by taxpayers to produce electricity whether it is needed or not."[106]

Over time, these negative prices lead to higher costs for consumers as grid operators have to devote more resources to balancing the negative pricing, making the already difficult task of maintaining a stable grid even more complicated.

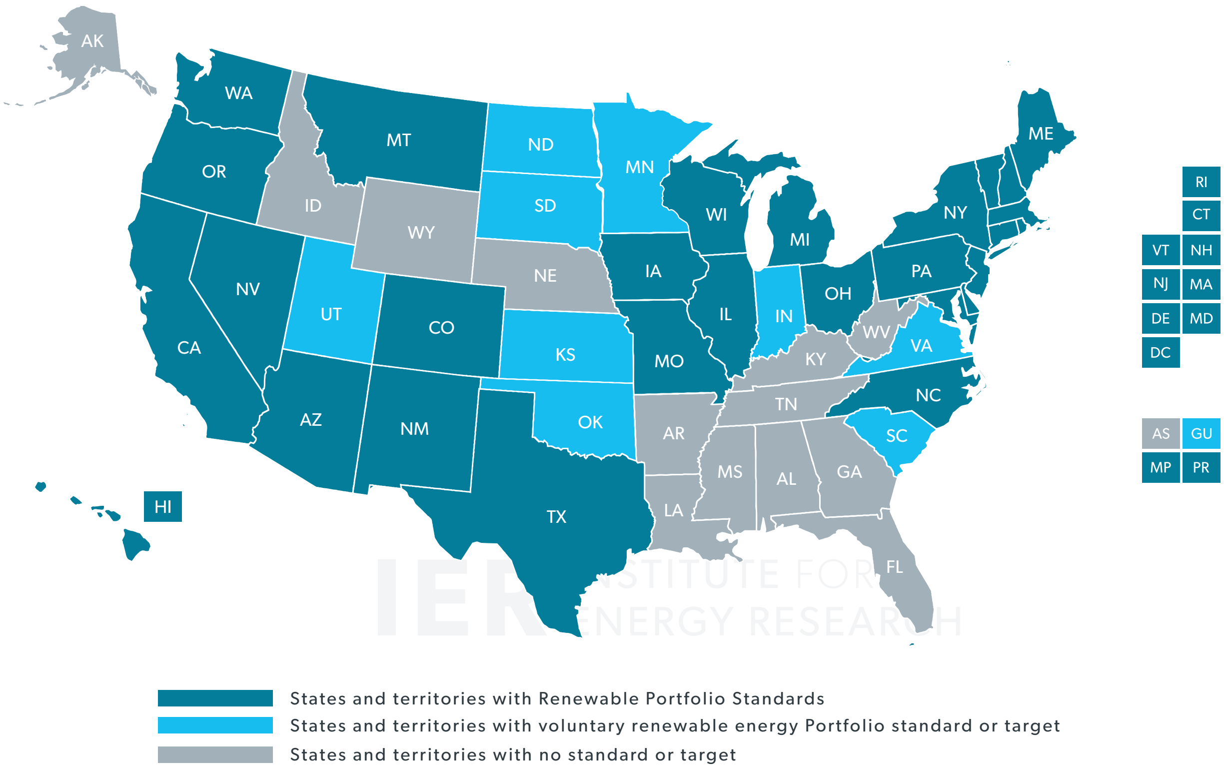
Wind and solar can only generate power when the wind is blowing and the sun is shining.

Wind and solar also require backup power to compensate for the fact that they are intermittent generating sources.[107] Wind and solar can only generate power when the wind is blowing and the sun is shining. As a result, they require backup generators to be installed in conjunction with them, raising the capital costs required to operate a fully functioning grid that is capable of providing electricity twenty-four hours a day, seven days a week. This backup power can come in many forms including natural gas power plants, batteries, and pump-storage hydroelectric generators. The additional costs imposed by requiring this backup generation are somewhat removed from the direct costs of producing wind and solar energy and are therefore not included in most levelized cost reports. For this reason, even though these costs show up on consumers' monthly electric bills, they are usually not attributed to wind or solar producers. Finally, there are also additional transmission costs associated with wind and solar as the optimal places for generating energy from these sources are frequently far-removed from where most electricity consumers are located.[108]

State Renewable Portfolio Mandates

In addition to direct subsidies for wind and solar, many states mandate the use of them through the implementation of renewable portfolio standards (RPS). These RPS mandates intentionally supplant economic processes in favor of a state-directed outcome. State renewable mandates require electricity suppliers to generate a certain portion of their electricity from renewable sources by a specified time period. States have offered different guidelines for what constitutes a renewable source, but the general focus is on prioritizing resources that do not directly produce carbon dioxide emissions.[109] Renewable portfolio standards are generally formulated in terms of a target percentage that must be reached by a certain year. However, it's important to note that renewable portfolio standards are often constructed in a way to exclude certain forms of renewable energy, particularly hydroelectric power. As a result, the state array of renewable portfolio standards consists mostly of policies that disincentivize one of the most reliable and versatile forms of renewable energy in favor of wind and solar.[110] At the start of 2019, twenty-nine states and the District of Columbia had RPS mandates; those states are displayed in the map to the right.

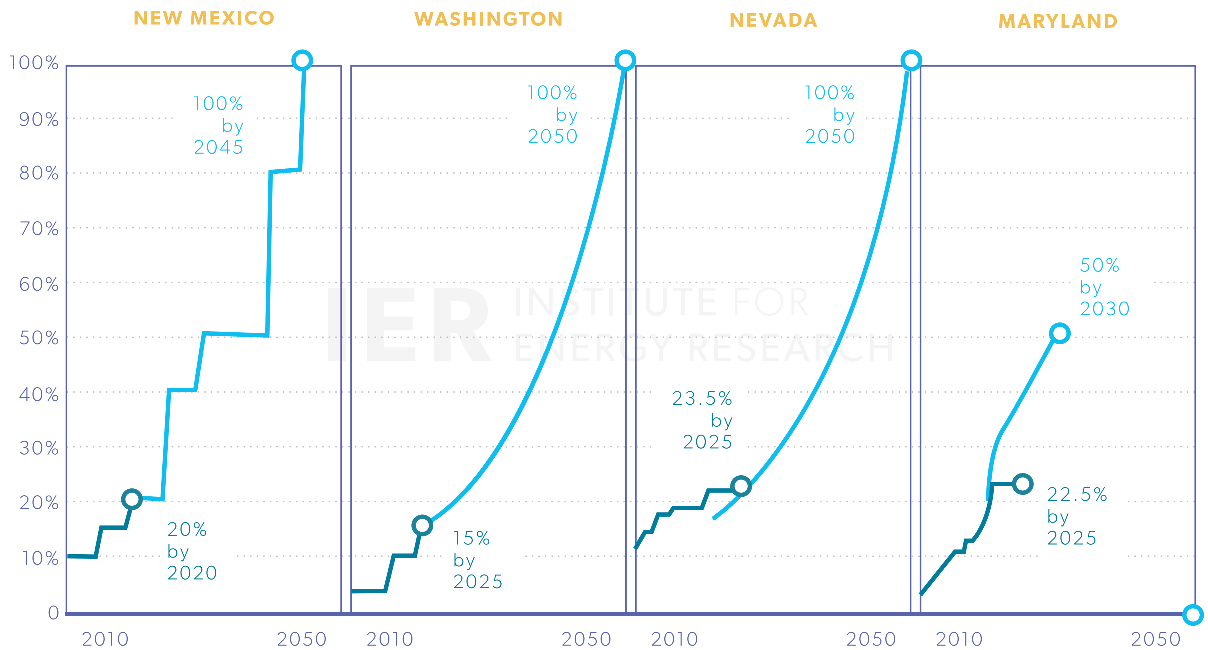
Through June of 2019, four states—New Mexico, Washington, Nevada, and Maryland—have increased their RPS mandates; those changes are reflected in the graph to the right.[112]



Source: National Conference of State Legislatures[111]

RENEWABLE PORTFOLIO STANDARDS TARGETS FOR SELECTED STATES (2010-2050)

percent of retail electricity sales



Source: U.S. Energy Information Administration, based on states' renewable portfolio standards

Additionally, in July of 2019, New York increased its RPS goal to 100 percent carbon-free electricity by 2040, and Ohio passed a bill to eliminate their RPS altogether.

Quantifying the Costs of Wind and Solar

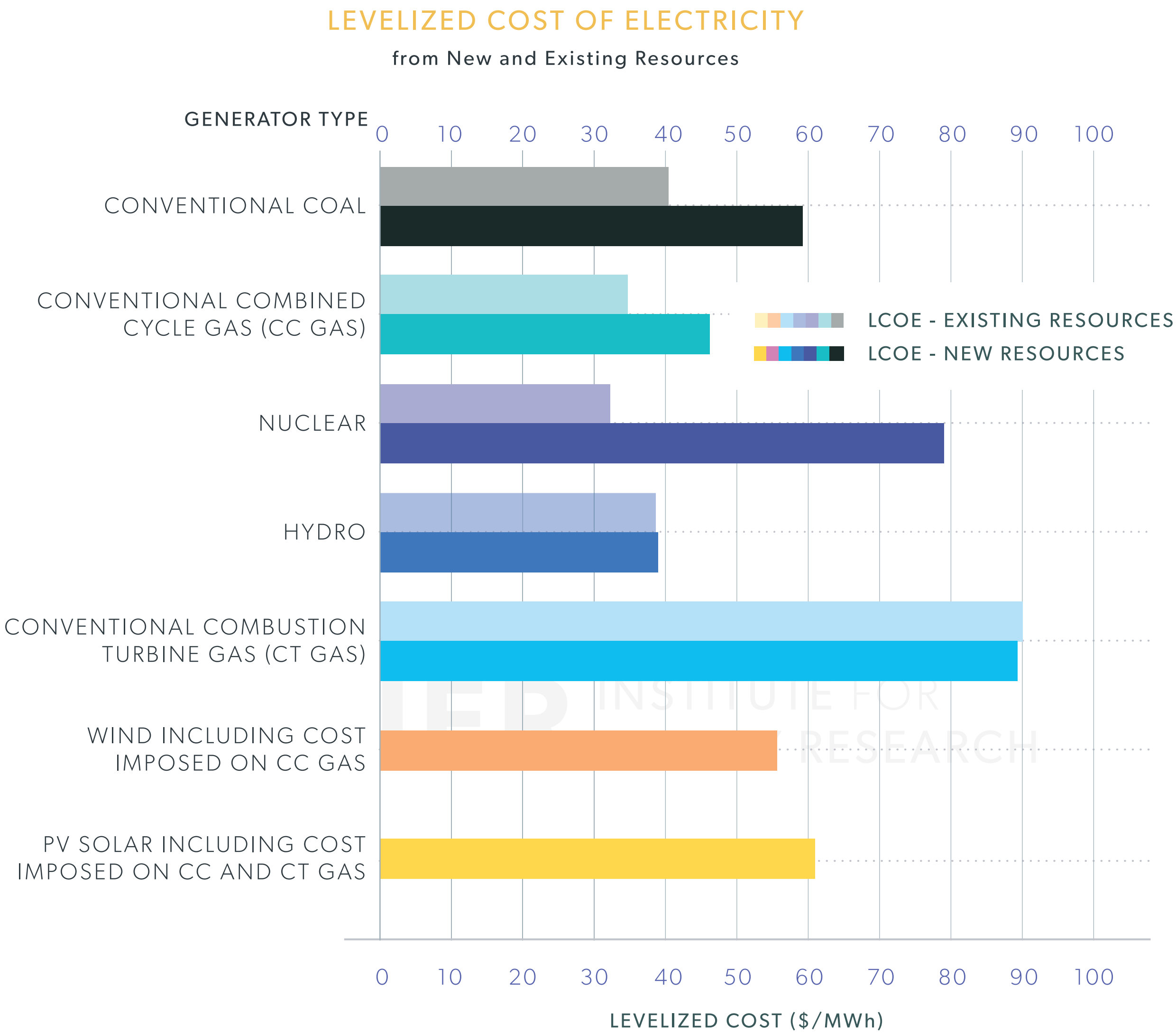
In June of 2019, the Institute for Energy Research released a report that looked at the costs associated with adding wind and solar energy to the grid.[113] The report calculated the levelized cost of electricity for existing generating units and compared those to the Energy Information Administration's most recent estimates of levelized costs for new plants, modified for todays' fuel prices and capacity factors. EIA defines the levelized cost of electricity as "the per-megawatt-hour cost (in real dollars) of building and operating a generating plant over an assumed financial life and duty cycle."

In a recent study, a group of researchers from the University of Chicago assessed the impacts of RPS policies on electricity prices, consumption, renewable penetration, carbon dioxide emissions, and economic activity.

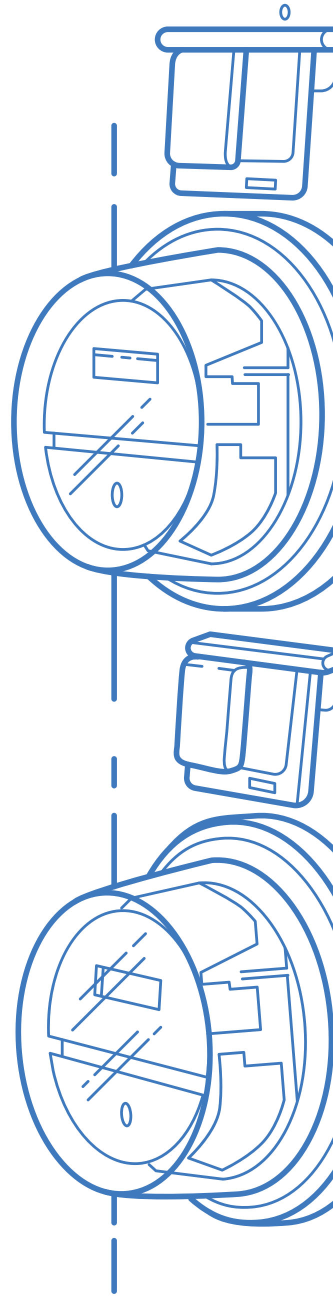
The report shows, on average, existing power plants have lower fixed costs, yet similar variable costs, compared to their most likely replacements.[114] The reason new plants have higher fixed costs is that they begin their operational lives with a full burden of construction cost to recover. Conversely, the ongoing fixed costs of existing power plants are lower because they have already paid for some or all of their original construction costs. In order to compare the levelized costs of wind and solar power with dispatchable resources, the report provides a calculation of "imposed costs" that are added to the levelized costs of wind and solar power. These "imposed costs" are the costs associated with having to account for the intermittent nature of wind and solar. The levelized cost findings from the report are displayed in the figures to the right.

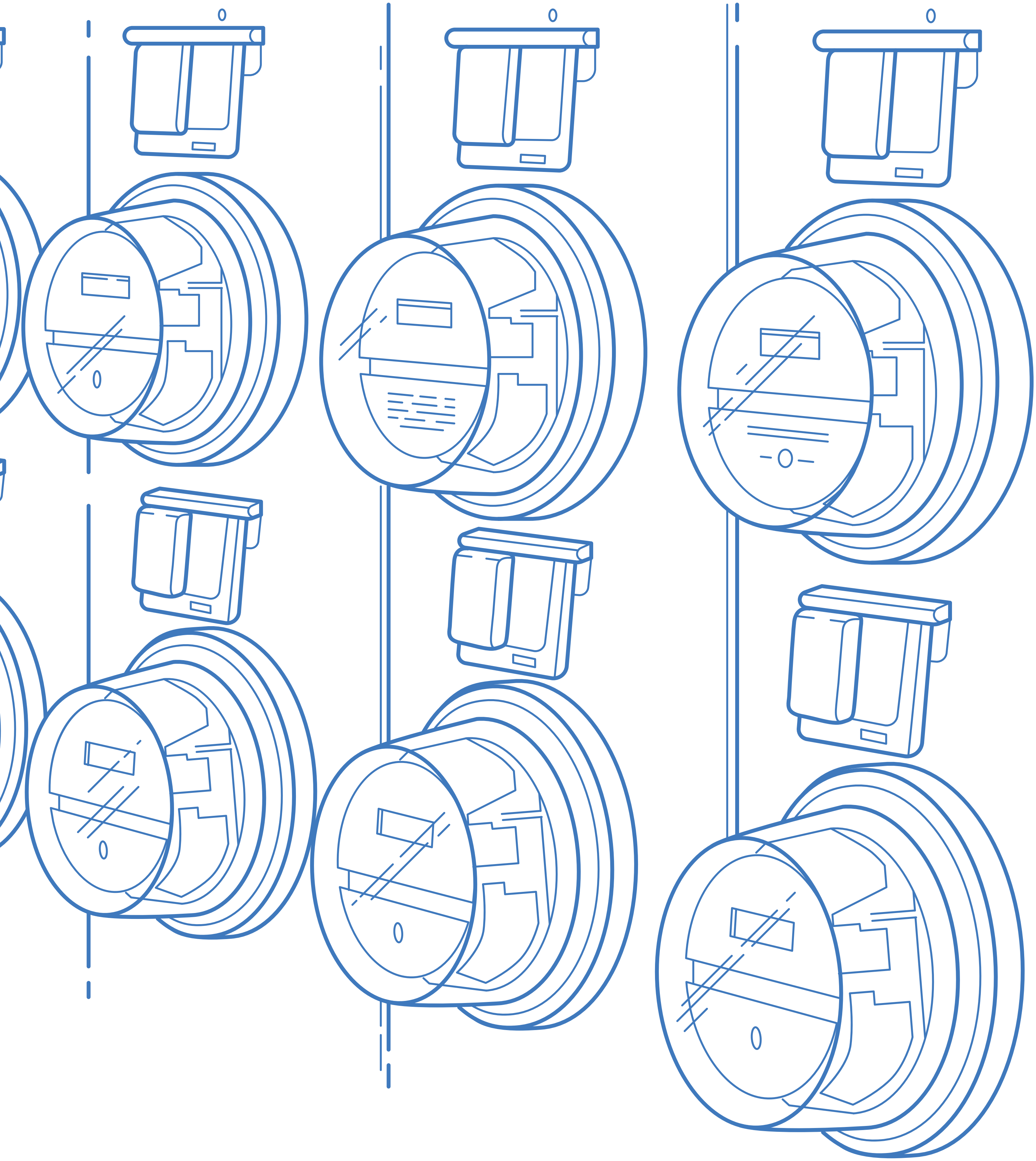
This report is part of a growing consensus about the impact of wind and solar on electricity prices.[115] In a recent study, a group of researchers from the University of Chicago assessed the impacts of RPS policies on electricity prices, consumption, renewable penetration, carbon dioxide emissions, and economic activity.[116] They found that RPS mandates have a rather predictable outcome in that they increased average retail electricity prices by 11 percent seven years after the policy was adopted and by 17 percent twelve years after the policy was adopted.[117] The study also found that consumers in the 29 RPS states paid $125.2 billion more for electricity than they would have without the implementation of RPS policies.[118]

Additionally, researchers discovered that seven years after the creation of an RPS mandate, the renewable share of generation is 1.8 percent higher and 4.2 percent higher twelve years after adoption. The report also showed that by increasing the share of renewable generation, states with RPS mandates prevented 95 to 175 million tons of carbon dioxide emissions seven years after the beginning of the programs.[119] Importantly, those reductions in carbon dioxide emissions came at a cost in the range of over $130 per metric ton of carbon dioxide to as high as $460 per metric ton of carbon dioxide. If reducing carbon dioxide emissions is the goal, these figures are significant because they provide context for just how inefficient RPS mandates are. For comparison, they are significantly higher than the estimates of the social cost of carbon that were used by the Obama administration, which in today's dollars would be close to $50 per ton.[120]


LEVELIZED COST OF ELECTRICITY
from New and Existing Resources
GENERATOR TYPE
0 10 20 30 40 50 60 70 80 90 100
CONVENTIONAL COAL
CONVENTIONAL COMBINED CYCLE GAS (CC GAS)
NUCLEAR
HYDRO
CONVENTIONAL COMBUSTION TURBINE GAS (CT GAS)
WIND INCLUDING COST IMPOSED ON CC GAS
PV SOLAR INCLUDING COST IMPOSED ON CC AND CT GAS
LCOE - EXISTING RESOURCES
LCOE - NEW RESOURCES
LEVELIZED COST ($/MWh)

HYDROELECTRIC, GEOTHERMAL, AND BIOMASS





Hydroelectric, Geothermal, and Biomass

- In 2018, hydroelectric power generated 7 percent of the electricity in the United States—more than any other type of renewable energy.
- In 2018, geothermal generated 0.4 percent of the electricity in the United States.
- In 2018, biomass generated 1.4 percent of the electricity in the nation.
- In 2018, 45 percent of biomass consumption was used in the production of biofuels.

Overview of Hydroelectric in the United States

Like all forms of energy, there are tradeoffs associated with hydroelectric dams. Their biggest limitation is that they must be constructed on suitable waterways, a problem that presents diminishing opportunities for hydroelectric energy as many of the ideal locations have already been developed.[121] On the other hand, one attractive feature of hydroelectric dams is their ability to serve multiple purposes by aiding in flood control efforts, irrigation, and the provision of drinking water. Currently, all of the hydroelectric energy generated in the U.S. is dedicated to generating electricity. In 2018, conventional hydroelectric generating facilities produced 292 million megawatt-hours of electricity in the U.S.—a slight decrease from 2017 where hydroelectric generating facilities produced 300 million megawatt-hours of electricity.[122]

Although construction of several new hydroelectric projects is unlikely due to regulations and political pressure from environmental groups, if the U.S. were to see an increase in demand for electricity, there would be some opportunity for expanding hydropower in the U.S. According to the Department of Energy, as recently as 2012, there were more than 80,000 non-powered dams in the United States.[123] Since these dams have already been built, most of the monetary and environmental costs have already been incurred; so adding power to them could potentially be a cost-effective source of new production.[124] Like other forms of energy, a costly permitting and licensing process hampers hydroelectric power; this is especially costly for small-scale hydroelectric projects like the retrofitting process described above.[125] Together, a maze of federal regulations and large subsidies for other sources like wind and solar have put hydroelectric energy at a disadvantage in the U.S.

According to the Department of Energy, as recently as 2012, there were more than 80,000 non-powered dams in the United States.

Overview of Geothermal in the United States

Geothermal energy is energy that is derived from the natural energy of the earth's core. In most cases, steam is extracted from underground in order to produce electricity. In 2018, geothermal energy produced only 17 million megawatt-hours of electricity.[126] Currently, geothermal energy is only responsible for a small portion of our energy mix as it faces three significant challenges.[127] First, barring significant improvements in technology, geothermal energy is severely limited by geographical constraints, as geothermal plants are only viable in a few places.[128] Second, current geothermal technology is a risky investment because developers face a higher degree of uncertainty as they can rarely tell if a given location will be viable or profitable until after they have drilled.[129] Finally, this problem is further compounded by the fact that geothermal power plants require large upfront capital investments.[130]

Like other renewable sources, geothermal energy has benefitted from federal subsidization dating back to the 1970s.[131] More recently, in 2004, the American Jobs Creation Act made geothermal power and other sources eligible for a federal production tax credit for the first five years of production; this was later extended to 10 years by subsequent legislation. In addition to subsidies, the federal government also provides the geothermal industry with the additional federal support through loan guarantees.[132] These federal incentive programs have likely done more harm than good as policymakers have ignored the problems associated with guaranteeing debt obligations.[133] Perhaps the best example of this was a company called Nevada Geothermal Power (NGP), which received millions of dollars in federal loan guarantees and enjoyed public support from former Senator Harry Reid.[134] Even with the government's backing, NGP failed to pay back its private loans as the company had underestimated the amount of energy its Blue Mountain Geothermal facility would be able to produce in its first year of operation.[135] Since then, NGP has been in danger of defaulting on its loan obligations several times, resulting in several changes in ownership.

Overview of Biomass and Ethanol in the United States

Biomass energy is a broad category of energy that includes energy derived from several different materials including wood, corn (which is converted into ethanol), as well as waste to energy sources. In the U.S., biomass produced 63 million megawatt-hours of electricity in 2018, which was 1.4 percent of the total.[136]

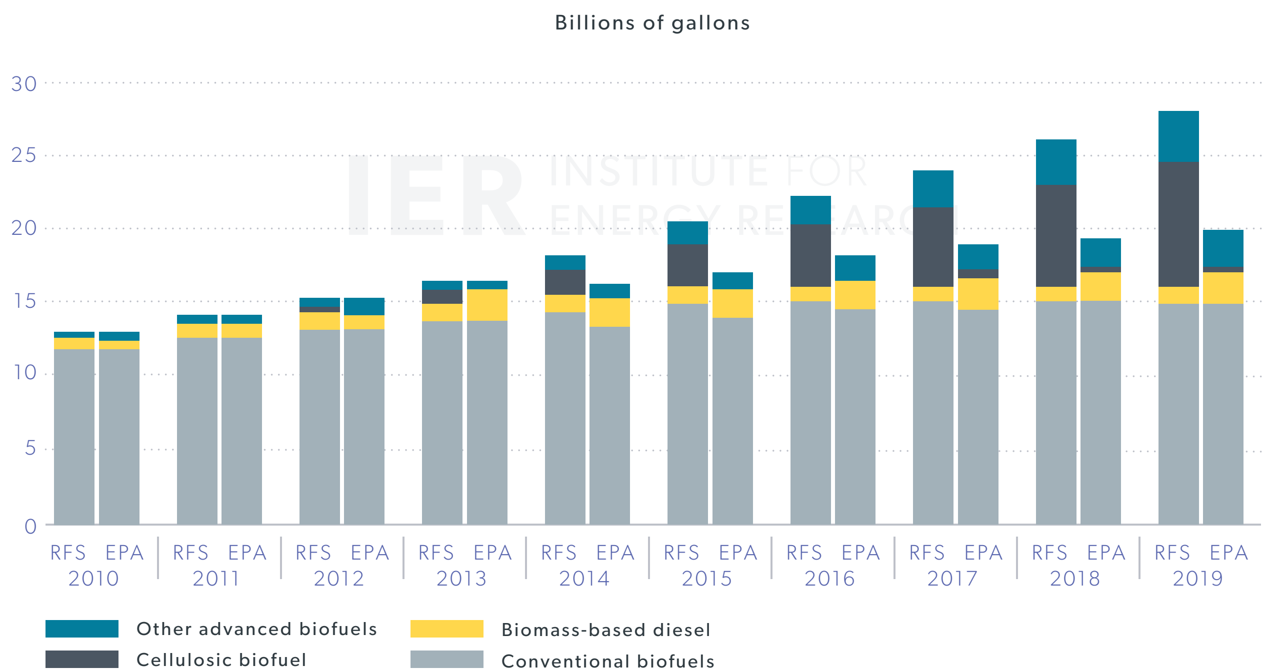
Biomass's most significant role in our energy mix comes in the form of biofuels, a role that has been supported in large part by public policies such as the Renewable Fuel Standard (RFS). Congress enacted the RFS as part of the Energy Policy Act of 2005 and expanded it in the Energy Independence and Security Act of 2007.[137] Originally, the purpose of the RFS was to decrease American dependence on foreign oil by mandating the addition of biofuel to gasoline and diesel sold in the U.S. In 2005, the RFS mandated a minimum of 4 billion gallons of biofuels be added to gasoline in 2006; it would then increase to 7.5 billion gallons by 2012.[138]

In 2007, the Energy Independence and Security Act required an additional increase from 9 billion gallons in 2008 to 36 billion gallons in 2022. The requirements were then divided between 15 billion gallons worth of corn-based ethanol (which is the most common biofuel currently produced in

Since its inception, it has become increasingly clear that the RFS has failed to deliver on any of its stated goals, and instead, it has produced a litany of unintended consequences.

the U.S.) and 21 billion gallons of advanced biofuels.[139] Not surprisingly, the high costs of producing advanced biofuels meant that this target was unrealistic, and the EPA reset the levels of advanced biofuel production to levels that were more practicable to achieve. Changes to the RFS over time are displayed in the graph below:[140]

FIGURE 1: VOLUMES OF ALL BIOFUELS TO BE BLENDED INTO DOMESTIC TRANSPORTATION FUEL, AS SET BY THE RENEWABLE FUEL STANDARD STATUTE AND BY EPA, 2010 THROUGH 2019



Source: Government Accountability Administration

One of the most important developments in the energy industry over the past decade has been the improvement in technology for developing our oil and natural gas resources, a development that has diminished the calls for public policy aimed at establishing American energy independence. With this, the arguments in favor of the RFS have changed, and the focus has shifted away from energy independence toward the role of biofuels in reducing greenhouse gas emissions and lowering gasoline prices. However, since its inception, it has become increasingly clear that the RFS has failed to deliver on any of its stated goals, and instead, it has produced a litany of unintended consequences.

According to state-level analysis conducted by the Government Accountability Office (GAO), the nationwide RFS produced moderate increases in the price of gasoline in areas outside of the Midwest because these areas lacked the necessary storage and transportation infrastructure that is associated with blending ethanol into gasoline. The costs of developing this infrastructure were then likely passed on to customers.[141] Although proponents of the RFS tout ethanol as a source of savings for fuel consumers based on periods of relatively lower prices for ethanol than gasoline, this direct comparison is misleading because it ignores the fact that one gallon of ethanol does not produce as much energy as a gallon of gasoline. On average, 1.5 gallons of ethanol are required to replace one gallon of gasoline, meaning that the RFS imposes costs on consumers by requiring them to purchase a less efficient fuel.[142] Furthermore, there are also compliance costs associated with the RFS as the biofuels blended into gasoline are sold with an artificial market-based mechanism known as a "renewable identification number" (RIN). These RINs are purchased along with biofuel and traded amongst refiners in order to track the compliance of the refiner's RFS obligations, and the compliance costs associated with the RIN market are then passed on to consumers.[143] A report released by American Action Forum in 2018 examined these imposed costs of the RFS and found that it cost fuel consumers $76 billion over the past ten years.[144]

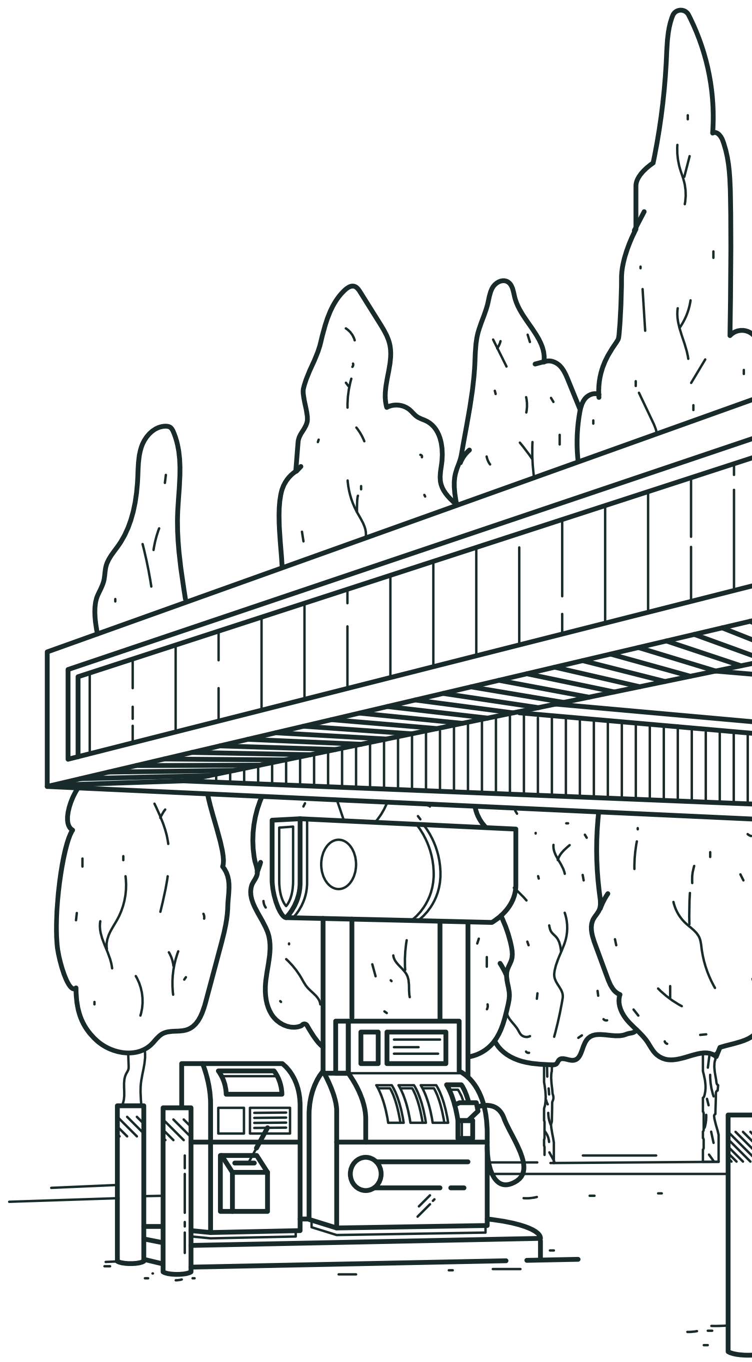
A study from the University of Minnesota found that corn-based ethanol creates more pollution than gasoline.

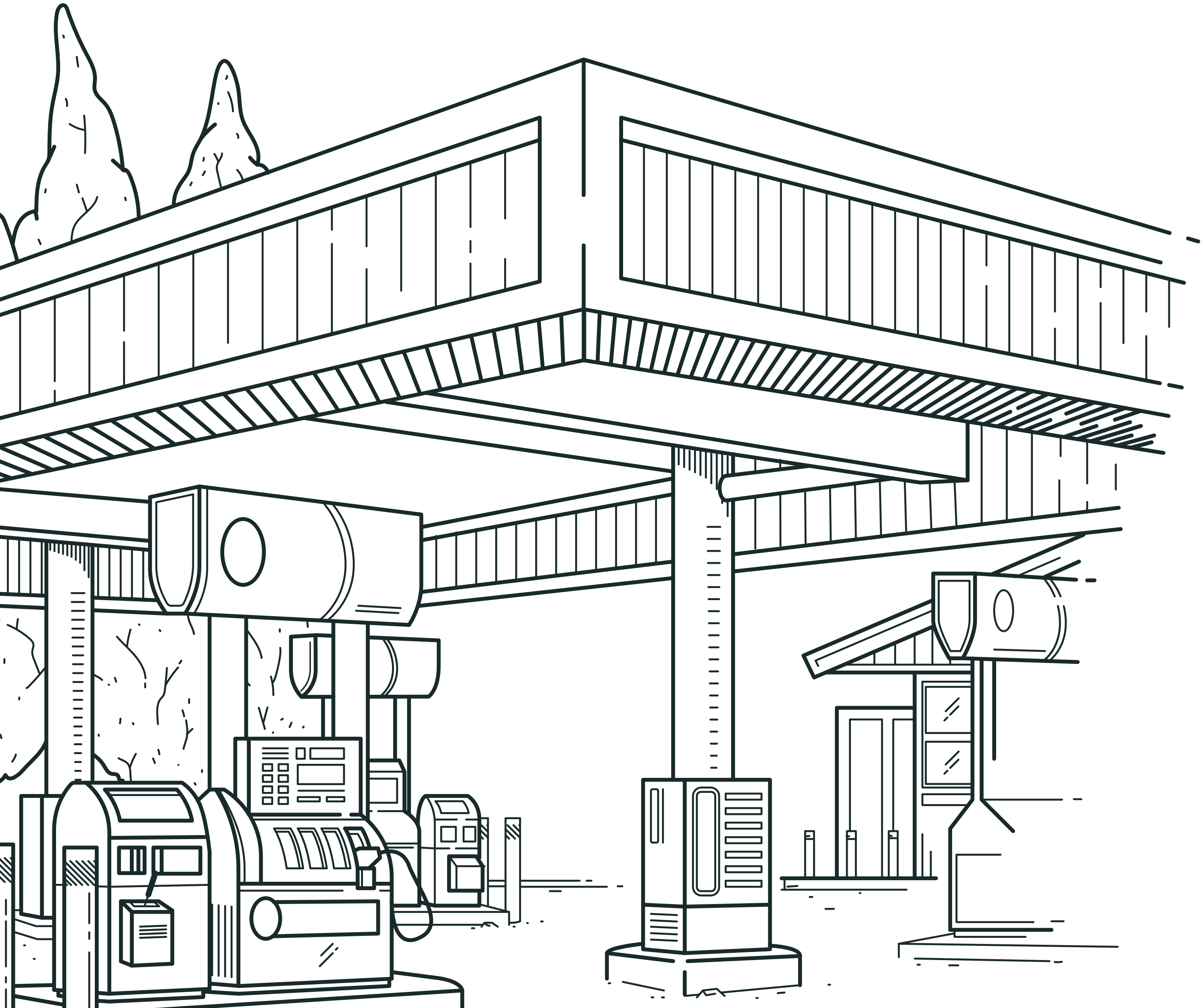
In addition to examining the impact of the RFS on gasoline prices, the aforementioned GAO report also included a discussion about the impacts of the RFS on greenhouse gas emissions. The report explains:

"Most of the experts GAO interviewed generally agreed that, to date, the RFS has likely had a limited effect, if any, on greenhouse gas emissions. According to the experts and GAO's prior work, the effect has likely been limited for reasons including: (1) the reliance of the RFS to date on conventional corn-starch ethanol, which has a smaller potential to reduce greenhouse gas emissions compared with advanced biofuels, and (2) that most corn-starch ethanol has been produced in plants exempt from emissions reduction requirements, likely limiting reductions early on when plants were less efficient than they are today. Further, the RFS is unlikely to meet the greenhouse gas emissions reduction goals envisioned for the program through 2022."[145]

The GAO's analysis comports with other studies that have shown the remarkable shortcomings of the RFS. For example, in 2014, a study from the University of Minnesota found that corn-based ethanol creates more pollution than gasoline.[146] Given the shifting narrative supporting the RFS and the overwhelming evidence of the policy's failure to deliver lower fuel prices and decreases in greenhouse gas emissions, it's clear that the purpose of the program is simply to serve as a wealth transfer from energy consumers to the ethanol industry; it should therefore be eliminated.

CONCLUSION & ACKNOWLEDGEMENTS





Conclusion

Reliable and affordable energy is the lifeblood of our economy as energy is an input into all economic activity. It makes our lives better by expanding creative human potential and allowing us to do more with the one resource for which there is no substitute—time. Yet for much of our recent history, American energy policy has focused on placing constraints on our energy industry through outdated regulatory processes and tax and subsidy schemes that allow unelected bureaucrats to determine winners and losers in the market. As a result, political processes often drive the energy industry and the costs are passed to all of us in the form of higher energy prices.

For too long, the federal government and Congress have stifled the American energy industry with a combination of onerous regulations and by restricting access to natural resources. The federal government needs to get out of the way of *all forms of energy*, and allow market competition to drive the future of energy production and innovation going forward. Given the increasing demand for energy around the world, policymakers should pursue policies that help unlock America's great energy potential, allowing us to unleash our creative abilities to solve our current and future energy challenges.

The federal government needs to get out of the way of all forms of energy and allow market competition to drive the future.

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To my mother and father for giving me the freedom to think for myself and for allowing me to find my own way, and to Emma for her constant love and support.

Glossary of Terms[147]

Barrel of oil: A unit of volume equal to 42 U.S. gallons. One barrel weighs 306 pounds or 5.80 million Btu of crude oil.

Base load: The minimum amount of electric power delivered or required over a given period of time at a steady rate.

Base load capacity: The generating equipment normally operated to serve loads on an around-the-clock basis.

Base load plant: A plant, usually housing high-efficiency steam-electric units, which is normally operated to take all or part of the minimum load of a system, and which consequently produces electricity at an essentially constant rate and runs continuously. These units are operated to maximize system mechanical and thermal efficiency and minimize system operating costs.

Biofuels: Liquid fuels and blending components produced from biomass, usually corn.

Biomass: Energy source that uses any organic (plant or animal) material including agricultural crops and agricultural wastes and residues, wood and wood wastes and residues, animal wastes, municipal wastes, and aquatic plants.

Bituminous coal: A dense coal, usually black, sometimes dark brown, often with well-defined bands of bright and dull material, used primarily as fuel in steam-electric power generation, with substantial quantities also used for heat and power applications in manufacturing and to make coke. Bituminous coal is the most abundant coal in active U.S. mining regions. Its moisture content usually is less than 20 percent. The heat content of bituminous coal ranges from 21 to 30 million Btu per ton on a moist, mineral-matter-free basis. The heat content of bituminous coal consumed in the United States averages 24 million Btu per ton, on the as-received basis (i.e., containing both inherent moisture and mineral matter).

Coal: A fuel formed by the breakdown of vegetable material trapped underground without access to air.

Coal-Producing States: The States where mined and/or purchased coal originates are defined as follows: Alabama, Alaska, Arizona, Arkansas, Colorado, Illinois, Indiana, Kansas, Kentucky Eastern, Kentucky Western, Louisiana, Maryland, Mississippi, Missouri, Montana, New Mexico, North Dakota, Ohio, Oklahoma, Pennsylvania anthracite, Pennsylvania bituminous, Tennessee, Texas, Utah, Virginia, Washington, West Virginia Northern, West Virginia Southern, and Wyoming.

Crude oil: A mixture of hydrocarbons that exists in liquid phase in natural underground reservoirs and remains liquid at atmospheric pressure after passing through surface separating facilities. Depending upon the characteristics of the crude stream, it may also include 1. Small amounts of hydrocarbons that exist in gaseous phase in natural underground reservoirs but are liquid at atmospheric pressure after being recovered from oil well (casing head) gas in lease separators and are subsequently comingled with the crude stream without being separately measured. Lease condensate recovered as a liquid from natural gas wells in lease or field separation facilities and later mixed into the crude stream is also included; 2. Small amounts of nonhydrocarbons produced with the oil, such as sulfur and various metals; 3. Drip gases, and liquid hydrocarbons produced from tar sands, oil sands, gilsonite, and oil shale.

Domestic crude oil: Crude oil produced in the United States including the Outer Continental Shelf (OCS).

Electricity: A form of energy characterized by the presence and motion of elementary charged particles generated by friction, induction, or chemical change.

Electricity Generation: The process of producing electric energy or the amount of electric energy produced by transforming other forms of energy, commonly expressed in kilowatthours (kWh) or megawatthours (MWh).

Energy: The ability to do work or the ability to move an object.

Energy Consumption: The use of energy as a source of heat or power or as an input to a manufacturing process.

Ethanol: A liquid fuel that burns to produce water vapor and carbon dioxide. The vapor forms an explosive mixture with air that can be used as a fuel in internal combustion engines.

Fuel: Any material that can be burned to make energy.

Gasoline: A complex mixture of hydrocarbons with or without small quantities of additives, blended to form a fuel suitable for use in spark-ignition engines.

Geothermal energy: Hot water or steam extracted from geothermal reservoirs in the earth's crust. Water or steam extracted from geothermal reservoirs can be used for geothermal heat pumps, water heating, or electricity generation.

Generating Capacity: The amount of electrical power a power plant can produce.

Gigawatt (GW): One billion watts or one thousand megawatts.

Grid: The layout of an electrical distribution system.

Gross domestic product (GDP): The total value of goods and services produced by labor and property located in the United States. As long as the labor and property are located in the United States, the supplier (that is, the workers and, for property, the owners) may be either U.S. residents or residents of foreign countries.

Hydraulic fracturing: Fracturing of rock at depth with fluid pressure. Hydraulic fracturing at depth may be accomplished by pumping water into a well at very high pressures. Under natural conditions, vapor pressure may rise high enough to cause fracturing in a process known as hydrothermal brecciation.

Hydropower: Energy that comes from moving water.

Kilowatt: A unit of power, usually used for electric power or to energy consumption (use). A kilowatt equals 1000 watts.

Kilowatthour (kWh): A measure of electricity defined as a unit of work or energy, measured as 1 kilowatt (1,000 watts) of power expended for 1 hour. One kWh is equivalent to 3,412 Btu or 3.6 million joules.

Levelized cost: The present value of the total cost of building and operating a generating plant over its economic life, converted to equal annual payments. Costs are levelized in real dollars (i.e., adjusted to remove the impact of inflation).

Liquefied natural gas (LNG): Natural gas (primarily methane) that has been liquefied by reducing its temperature to -260 degrees Fahrenheit at atmospheric pressure.

Megawatt: A unit of electrical power equal to 1000 kilowatts or one million watts.

Metallurgical coal: Coking coal and pulverized coal consumed in making steel.

Natural gas: Natural gas is an energy sourced that is generally formed beneath the earth's surface. The largest component of natural gas is methane, a compound with one carbon atom and four hydrogen atoms (CH4). Natural gas also contains smaller amounts of natural gas liquids (NGL; which are also hydrocarbon gas liquids), and nonhydrocarbon gases, such as carbon dioxide and water vapor. We use natural gas as a fuel and to make materials and chemicals.

Oil: The raw material that petroleum products are made from.

Outer Continental Shelf: Offshore Federal domain.

Petroleum - Generally refers to crude oil or the refined products obtained from the processing of crude oil (gasoline, diesel fuel, heating oil, etc.) Petroleum also includes lease condensate, unfinished oils, and natural gas plant liquids.

Pipeline (natural gas): A continuous pipe conduit, complete with such equipment as valves, compressor stations, communications systems, and meters for transporting natural and/or supplemental gas from one point to another, usually from a point in or beyond the producing field or processing plant to another pipeline or to points of utilization. Also refers to a company operating such facilities.

Pipeline (petroleum): Crude oil and product pipelines used to transport crude oil and petroleum products, respectively (including interstate, intrastate, and intracompany pipelines), within the 50 states and the District of Columbia.

Power (electrical): An electric measurement unit of power called a voltampere is equal to the product of 1 volt and 1 ampere. This is equivalent to 1 watt for a direct current system, and a unit of apparent power is separated into real and reactive power. Real power is the work-producing part of apparent power that measures the rate of supply of energy and is denoted as kilowatts (kW). Reactive power is the portion of apparent power that does no work and is referred to as kilovars; this type of power must be supplied to most types of magnetic equipment, such as motors, and is supplied by generator or by electrostatic equipment. Voltamperes are usually divided by 1,000 and called kilovoltamperes (kVA). Energy is denoted by the product of real power and the length of time utilized; this product is expressed as kilowatthours.

Production, crude oil: The volumes of crude oil that are extracted from oil reservoirs. These volumes are determined through measurement of the volumes delivered from lease storage tanks or at the point of custody transfer, with adjustment for (1) net differences between opening and closing lease inventories and (2) basic sediment and water. Crude oil used on the lease is considered production.

Production, lease condensate: The volume of lease condensate produced. Lease condensate volumes include only those volumes recovered from lease or field separation facilities.

Production, natural gas: The volume of natural gas withdrawn from reservoirs less (1) the volume returned to such reservoirs in cycling, repressuring of oil reservoirs, and conservation operations; less (2) shrinkage resulting from the removal of lease condensate; and less (3) nonhydrocarbon gases where they occur in sufficient quantity to render the gas unmarketable. Volumes of gas withdrawn from gas storage reservoirs and native gas, which has been transferred to the storage category, are not considered production. Flared and vented gas is also considered production. (This differs from “Marketed Production” which excludes flared and vented gas.)

Production, natural gas liquids: Production of natural gas liquids is classified as follows:

- Contract Production. Natural gas liquids accruing to a company because of its ownership of liquids extraction facilities that it uses to extract liquids from gas belonging to others, thereby earning a portion of the r esultant liquids.
- Leasehold Production. Natural gas liquids produced, extracted, and credited to a company’s interest.
- Contract Reserves. Natural gas liquid reserves corresponding to the contract production defined above.
- Leasehold Reserves. Natural gas liquid reserves corresponding to leasehold production defined above.

Production, natural gas, dry: The volume of natural gas withdrawn from reservoirs during the report year less:

1. the volume returned to such reservoirs in cycling, repressuring of oil reservoirs, and conservation operations; less
2. shrinkage resulting from the removal of lease condensate and plant liquids; and less
3. nonhydrocarbon gases where they occur insufficient quantity to render the gas unmarketable.

Volumes of gas withdrawn from gas storage reservoirs and native gas, which has been transferred to the storage category, are not considered production. This is not the same as marketed production, because the latter also excludes vented and flared gas, but contains plant liquids.

Production, natural gas, wet after lease separation: The volume of natural gas withdrawn from reservoirs less (1) the volume returned to such reservoirs in cycling, repressuring of oil reservoirs, and conservation operations; less (2) shrinkage resulting from the removal of lease condensate; and less (3) nonhydrocarbon gases where they occur in sufficient quantity to render the gas unmarketable. Note: Volumes of gas withdrawn from gas storage reservoirs and native gas that has been transferred to the storage category are not considered part of production. This production concept is not the same as marketed production, which excludes vented and flared gas.

Production, oil and gas: The lifting of oil and gas to the surface and gathering, treating, field processing (as in the case of processing gas to extract liquid hydrocarbons), and field storage. The production function shall normally be regarded as terminating at the outlet valve on the lease or field production storage tank. If unusual physical or operational circumstances exist, it may be more appropriate to regard the production function as terminating at the first point at which oil, gas, or gas liquids are delivered to a main pipeline, a common carrier, a refinery, or a marine terminal.

Proved energy reserves: Estimated quantities of energy sources that analysis of geologic and engineering data demonstrates with reasonable certainty are recoverable under existing economic and operating conditions. The location, quantity, and grade of the energy source are usually considered to be well established in such reserves. Note: This term is equivalent to "Measured Reserves" as defined in the resource/reserve classification contained in the U.S. Geological Survey Circular 831, 1980. Measured and indicated reserves, when combined, constitute demonstrated reserves.

Refinery: An industrial plant that heats crude oil (petroleum) so that is separates into chemical components, which are then made into more useful substances.

Shale Gas: Natural gas produced from wells that are open to shale formations. Shale is a fine-grained, sedimentary rock composed of mud from flakes of clay minerals and tiny fragments (silt-sized particles) of other materials. The shale acts as both the source and the reservoir for the natural gas.

Short ton (st): A unit of weight equal to 2,000 pounds.

Solar Energy: The radiant energy of the sun, which can be converted into other forms of energy, such as heat or electricity.

Steam coal: Coal used in boilers to generate steam to produce electricity or for other purposes.

Uranium: A heavy, naturally-occurring, radioactive element.

Utility Generation: Generation by electric systems engaged in selling electric energy to the public.

Well: A hole drilled in the earth for the purpose of (1) finding or producing crude oil or natural gas; or (2) producing services related to the production of crude or natural gas.

Wellhead: The point at which the crude (and/or natural gas) exits the ground.

Wind: The term given to any natural movement of air in the atmosphere. A source of energy used to turn turbines to generate electricity.

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