U.S. DEPARTMENT OF ENERGY

Economic and National Security Impacts under a Hydraulic Fracturing Ban

Report to the President

January 2021

United States Department of Energy

Washington, DC 20585

Message from the Secretary

As directed by the President in an October 31, 2020 Presidential Memoranda titled: "Memorandum on Protecting Jobs, Economic Opportunities, and National Security for All Americans," the Department of Energy is submitting the following report on the economic and national security outcomes of a domestic ban on hydraulic fracturing technologies. This report addresses Section 4 (Domestic and Economic Impacts of Undermining Hydraulic Fracturing and Other Technologies) and Section 5 (National Security Impacts of Undermining Hydraulic Fracturing and Other Technologies) of the Presidential Memoranda.

I am proud to present this report to the Assistant to the President for Economic Policy and the Assistant to the President for National Security Affairs, as it is technologies like hydraulic fracturing that unleashed America's natural resources and made the United States the world's largest natural gas and oil producer, while also creating high-paying jobs and delivering meaningful consumer savings. As this report concludes, a ban on hydraulic fracturing — a practice that has been used for over 50 years in the United States and other countries — would result in the loss of millions of jobs, price spikes at the gasoline pump and higher electricity costs for all Americans. Such a ban would eliminate the United States' status as the top oil and gas producing country and return us to being a net importer of oil and gas by 2025. It would weaken America's geopolitical standing and negatively impact our national security.

If you have any questions or need additional information, please contact me or Ms. Melissa Burnison, Assistant Secretary for Congressional and Intergovernmental Affairs, at (202) 586-5450.

Sincerely,

Dan Brouillette

Executive Summary

Abundant American oil and natural gas reserves are a strategic asset in driving sustained, long-term economic growth, achieving environmental goals, and enhancing the national security interests of the United States. Over the past two decades, due to technological advancements in the combination of horizontal drilling and hydraulic fracturing technology,[1] the United States is now firmly the world's largest producer of both natural gas and crude oil.

This emergence of American energy leadership, tied directly to increasing production from shale gas, tight gas, and tight oil formations, supports high-paying jobs across multiple sectors of the economy, delivers meaningful home energy savings, and gives American manufacturers a competitive advantage. Production from these formations also dramatically enhances American energy security by reducing dependence on foreign sources of oil and natural gas and drives progress in meeting clean air goals.

Domestically produced oil and natural gas is an essential component of modern life and all sectors of the United States economy realize the benefits of sustained domestic production, as an October 2020 U.S. Department of Energy report[2] concluded.

American energy leadership rests in the private-sector's operational freedom to innovate and deploy a range of modern technologies that safely, responsibly, and efficiently extract natural gas and oil hydrocarbons from public and private lands. Hydraulic fracturing and horizontal drilling technology are the most commonly used techniques for oil and natural gas extraction, which, as noted in the October 31 Presidential Memorandum,[3] "are vital not just to our domestic prosperity but also to our national security."

Since the domestic "shale revolution" began in earnest in 2008, the use of horizontal drilling with high-volume hydraulic fracturing has become highly prevalent – 75 percent of the domestic natural gas and 63 percent of the domestic crude oil produced in 2019 relied on this combination of technologies.[4] Commonly referred to as "unconventional" production,[5] the use of horizontal drilling and hydraulic fracturing technology has enabled oil and natural gas to be economically produced from reservoirs once seen as too unprofitable to develop, resulting in exponential production increases in the nation's top 10 energy-producing states: Texas, Pennsylvania, Wyoming, Oklahoma, West Virginia, North Dakota, Colorado, Louisiana, New Mexico and Ohio (listed in order of total energy production in British Thermal Units).[6]

Future policies will dictate the direction and extent of American natural gas and oil production, export, and use. The economic and national security consequences of one such potential policy, a United States ban on high-volume hydraulic fracturing technology on any new or existing onshore wells starting in 2021, was assessed at the President's direction. Such a ban would render the development of unconventional onshore oil and natural gas resources uneconomic, and the drilling of new wells for these resources would effectively cease.

A hydraulic fracturing ban would reverse United States oil and natural gas production growth and return the country to a net-importer of oil and natural gas by 2025. With declining domestic production, the analysis suggests natural gas price implications under a hydraulic fracturing ban would be considerable, with an estimated 244 percent increase from the 2019 level, reaching $8.80 per million British Thermal Units (MMBtu) by 2025.

These price hikes would have a crippling economic effect through increased household energy bills, higher fuel costs for industrial and commercial customers, higher and more frequent electricity price spikes, and deteriorating competitiveness of the United States energy supply in the global market.

The broader economic impact of the hydraulic fracturing ban would be substantial. Compared to a world with hydraulic fracturing, in 2025, the United States economy would have 7.7 million fewer jobs, $1.1 trillion less in gross domestic product (GDP), and $950 billion less in labor income. A hydraulic fracturing ban would result in increases in energy costs for electricity, motor fuels, and natural gas; would burden American families, small businesses, hospitals, manufacturers; would have negative impacts on virtually all other sectors of the economy; and would inevitably stunt the post-pandemic economic recovery.

Furthermore, America's environment would be worse off without hydraulic fracturing because less natural gas would be available for electricity generation. The U.S. Energy Information Administration (EIA) concluded in a November 2020 note, "*U.S. electric power sector emissions have fallen 33 percent from their peak in 2007 because less electricity has been generated from coal and more electricity has been generated from natural gas and non-carbon sources.*"[7] Natural gas serves as an important enabler for integrating, low-carbon intermittent renewables like wind and solar.

In the first year of a ban, the country would see a year-over-year increase in carbon dioxide (CO_2), nitrogen oxides (NO_x), and sulfur dioxide (SO_2) emissions with these emissions rising 16 percent, 17 percent, and 62 percent respectively. This outcome undermines the considerable progress the United States power generation sector has made in cutting emissions by 30 percent, 76 percent, and 91 percent respectively for CO_2, NO_x, and SO_2 during the 2005 to 2019 time period.

Finally, from a national security and foreign policy perspective, significantly curtailing American natural gas and oil production removes an important tool for American diplomacy while increasing global energy dependence on Russia and the Organization of the Petroleum Exporting Countries (OPEC) nations.

Eliminating the primary technology responsible for the growth in United States oil and natural gas production would increase natural gas, transportation fuel and electricity prices initiating a ripple effect of severe consequences to the Nation's economy, environment, and geopolitical standing.

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I. Introduction

A. *Presidential Request for an Economic and National Security Study*

America's natural resource abundance has been a primary driver of economic growth and societal progress for generations. While the United States has a diverse mix of energy sources essential to providing reliable and affordable electricity, transportation fuel, and manufacturing feedstocks, enhanced production from hydrocarbon-rich shale reservoirs in the early 2000s kicked off a domestic energy revolution with global reverberations.

With its roots in a combination of market-driven entrepreneurism and early research by the U.S. Department of Energy (DOE), this energy revolution has turned energy markets upside down. It has unlocked abundant domestic crude oil and natural gas from subsurface rock formations once largely considered uneconomic to produce – shales and other "tight" (low permeability) formations – using a combination of hydraulic fracturing and horizontal drilling. For the purposes of this report, hydraulic fracturing is defined as "the process of directing pressurized fluids containing any combination of water, proppant, and any added chemicals to penetrate tight formations, such as shale or coal formations, that subsequently require high rate, extended flowback to expel fracture fluids and solids during completions."[8]

Throughout this report, the combination of hydraulic fracturing and horizontal drilling is defined as "unconventional" production, which is typically oil and natural gas production from onshore, low permeability formations, such as shales and tight sandstones, that require horizontal drilling and high-volume hydraulic fracturing for economic production.[9] "Conventional" production is defined in this report as oil and gas from high permeability reservoirs that may be produced using vertical or horizontal wells, but that do not require the use high-volume hydraulic fracturing.

For the first time in half-a-century, the United States is a net energy exporter and has surpassed Saudi Arabia and Russia as the world's leading oil and natural gas producer. This accomplishment, in which the United States has broken free from dependence on foreign nations to meet growing energy needs, is owed primarily to the innovation, based on the industry and DOE's research, that combined horizontal drilling and high-volume hydraulic fracturing technologies. These drilling technologies have made oil and natural gas resources found in deep shale reservoirs in the Appalachian Basin, Permian Basin, Mid-Continent, Williston Basin, Eagle Ford, and Denver-Julesburg Basin, to name a few, technically recoverable and commercially viable.

These shale producing assets across public and private lands have proven to be prolific resources with long-term development horizons. For example, technically recoverable gas resources in the Appalachian Basin rose from 2 trillion cubic feet (Tcf) in 2002 to 214 Tcf in 2019, according to the U.S. Geological Survey.[10] This increase in recoverable resources – attributable to technological and geological knowledge advancements – occurred as production gains from the Marcellus Shale and Utica-Point Pleasant Shale plays made the Appalachian Basin the country's most prolific natural gas producing basin.

DOE produced this report in response to a Presidential directive issued October 31, 2020 titled, *"Memorandum on Protecting Jobs, Economic Opportunities, and National Security for All Americans."* This Presidential Memoranda specifically instructed federal agencies to assess the domestic economic impacts and national security impacts of policies prohibiting hydraulic fracturing.

As the directive states:

> Sec. 4. Assessing the Domestic and Economic Impacts of Undermining Hydraulic Fracturing and Other Technologies. (a) Within 70 days of the date of this memorandum, the Secretary of Energy, in consultation with the United States Trade Representative, shall submit a report to the President, through the Assistant to the President for Economic Policy (who shall act in coordination with the Assistant to the President for National Security Affairs), assessing:
>
> (i) the economic impacts of prohibiting, or sharply restricting, the use of hydraulic fracturing and other technologies, including the following:
>
> (A) any loss of jobs, wages, benefits, and other economic opportunities by Americans who work in or are indirectly benefited by the energy industry and other industries (including mining for sand and other minerals);
>
> (B) any increases in energy prices (including the prices of gasoline, electricity, heating, and air conditioning) for Americans (including senior citizens and other persons on fixed incomes) and businesses;
>
> (C) any decreases in property values and in the royalties and other revenues that are currently available to private property owners; and
>
> (D) any decreases in tax revenues, impact fees, royalties, and other revenues currently available to the Federal Government, to State and local governments, and to civic institutions (including public schools, trade and vocational schools, community colleges, and other educational and training institutions; hospitals; and medical clinics);
>
> (ii) the trade impacts of prohibiting, or sharply restricting, the use of hydraulic fracturing and other technologies, including impacts on United States exports of liquefied natural gas (LNG) and other energy products, as well as exports of other commodities that may be affected by increases in transportation costs; and
>
> (iii) such other domestic or economic impacts as the Secretary of Energy deems appropriate.
>
> (b) In preparing the report described in subsection (a) of this section, the Secretary of Energy and the United States Trade Representative shall consult with the Secretary of the Treasury, the Secretary of the Interior, the Secretary of Agriculture, the Secretary of Commerce, the Secretary of Labor, the Secretary of Transportation, the Administrator of the Environmental Protection Agency, the Chairman of CEA, the Chairman of the Council on Environmental Quality, and such other officials as the Secretary of Energy and the United States Trade Representative deem appropriate.

> Sec. 5. Assessing the National Security Impacts of Undermining Hydraulic Fracturing and Other Technologies. Within 70 days of the date of this memorandum, the Secretary of Energy shall submit a report to the President, through the Assistant to the President for National Security Affairs (who shall act in coordination with the Assistant to the President for Economic Policy), assessing the national security impacts of prohibiting, or sharply restricting, the use of hydraulic fracturing and other technologies. This report shall include an assessment of potential impacts on Russian and Chinese energy production, consumption, and trade activities, and on the energy security of United States allies, that may be attributable to changes in United States exports of LNG and other energy products. In preparing this report, the Secretary of Energy shall consult with the Secretary of State, the Secretary of Defense, the United States Trade Representative, and such other officials as the Secretary of Energy deems appropriate. This report may be combined, as appropriate, with the report required by section 4 of this memorandum, in which case the combined report shall be submitted to the President through the Assistant to the President for National Security Affairs and the Assistant to the President for Economic Policy.

Today, the United States is a global energy leader, with benefits enjoyed by hard-working families, manufacturers, and small businesses both home and abroad. Policies that encourage domestic energy development have brought about these broadly shared economic benefits and, as this report details, severely curtailing production or banning extractive technologies would have a massive impact on the domestic economy and national security.

B. Report Overview and Findings

The main content of the report is divided into the following five sections. Each of the following sections provides insights and analysis in support of the following findings:

Section II: Evolution of the United States Energy Markets since 2005

- In 2019, the United States produced 4.5 billion barrels of crude oil and 34.0 Tcf of natural gas, which represented increases of 137 percent and 88 percent, respectively, from 2005 levels.
- The use of horizontal drilling coupled with hydraulic fracturing to develop low permeability oil and natural gas reservoirs has allowed the United States to reverse its dependence on imports. For the first time in history, the United States became a net exporter of natural gas in 2017. In 2019, natural gas exports reached a record high of 4.66 Tcf exported to 38 countries. Net imports of petroleum products, like gasoline and diesel, reversed direction from 2005 to 2019 with the United States becoming a net exporter of petroleum products in 2011 and increasing net exports to more than 1.1 billion barrels in 2019.
- Increased domestic oil and natural gas supply has put downward pressure on consumer prices for gasoline and natural gas. In 2019, gasoline and diesel prices were 40 percent and 38.3 percent lower, respectively, compared to 2012, and average end-user prices for natural gas fell 24.3 percent in 2019 from 2008 levels.
- The electric power generation sector has been the principal driver of domestic natural gas consumption growth, accounting for 59.3 percent of the total natural gas demand increase in 2019 from 2005 levels.

- A considerable shift has taken place in electric power generation, with natural gas generating 38 percent of the nation's power in 2019 compared to 19 percent in 2005. This shift in power generation fuel mix has resulted in significant reductions in NO_x, SO_2, and CO_2 emissions, with emissions of these compounds tied to the electric power sector falling 76, 91, and 30 percent, respectively, below 2005 levels.

Section III: Energy Market Impacts of a Hydraulic Fracturing Ban, 2021–2025

- If a ban on high-volume hydraulic fracturing were to occur starting in 2021, natural gas production would decline, and the United States would reverse the trajectory that has led to its becoming a major global liquefied natural gas (LNG) exporter and once again become a net importer of natural gas by 2025.
- Crude oil imports would also rise by 2025, as United States crude oil production would be removed from international markets and the United States would return to reliance on imports from foreign nations for the crude oil inputs to domestic refineries.
- Oil and natural gas price increases under a hydraulic fracturing ban scenario would be considerable. As of December 24, 2020, current prices are $48.23 per barrel for West Texas Intermediate (WTI) crude oil and $2.68 per MMBtu for Henry hub natural gas.[11] With a ban on high-volume hydraulic fracturing, WTI crude oil prices would peak at $130.20 per barrel in 2023 before stabilizing at $93.2 per barrel in 2025. By 2022, the national benchmark Henry Hub price would rise to $6.17 per MMBtu – a level not reached since 2008 – and further to $8.80 per MMBtu in 2025.
- Under a hydraulic fracturing ban, the high price of natural gas would significantly shift overall power generation and patterns of new builds by 2025. Power generation fueled by natural gas would fall from nearly 40 percent of United States electric power generation in the business-as-usual Base Case for 2021 to only 14 percent in 2025 under the hydraulic fracturing ban scenario.
- Changes to the power generation fleet and fuel prices would increase average wholesale power prices across all markets – from a low of $16.07 per megawatt-hour (MWh) in the Southwest Power Pool (SPP) to a high of $33.34 per MWh in the Electric Reliability Council of Texas (ERCOT).
- Emissions of NO_x, SO_2, and CO_2 rise in the first year of a hydraulic fracturing ban, and would increase 17, 62, and 16 percent, respectively, due to fuel generation mix changes where coal replaces natural gas.
- Consumers across all segments of the economy would bear the impacts of a hydraulic fracturing ban through higher electricity and natural gas costs. Retail electricity costs would increase by more than $480 billion between 2021 and 2025, and retail natural gas costs would increase by more than $400 billion between 2021 and 2025.
- Consumers would face higher gasoline and diesel costs if hydraulic fracturing were banned. Annual average gasoline prices would increase over 100 percent to over $4.20 per gallon in 2022 and 2023, and annual average diesel prices would increase 95 percent to $4.56 per gallon in 2022. Higher prices for gasoline, diesel, and petroleum products would amount to $1.9 trillion in additional, cumulative costs from 2021 to 2025 across all sectors.

Section IV: Macroeconomic Impacts of a Hydraulic Fracturing Ban, 2021–2025

- The economy would experience a significant upset due to a hydraulic fracturing ban, derailing the recovery from pandemic-driven economic disruptions and increasing the risk of another recession in the early 2020s. Job losses, reductions in GDP, and lost wages and reduced labor income would significantly increase economic hardship for millions of Americans.
- With a high-volume hydraulic fracturing ban, the United States would see 7.7 million fewer jobs and a $1.1 trillion reduction to GDP by 2025 as decreased energy production has a direct impact on oil and natural gas sector employment and increased energy costs negatively impact the economy more broadly as industries deal with the higher energy costs.
- Domestic job losses and GDP reductions would be immediate and significant in 2021 relative to the Base Case, with 3.2 million fewer jobs (1.6 percent lower) and a $400 billion contraction to GDP (2.0 percent lower than otherwise projected).
- A hydraulic fracturing ban would have a contractionary effect on the wages and other compensation paid to American workers. By 2024, Americans would experience $667 billion in lost wages, $105 billion in lost fringe benefits (mostly health insurance and their employers' contributions to private savings), $49 billion in lost employer-paid contributions to Social Security and Medicare, and $188 billion in proprietors' income.

Section V: National Security Impacts of a Hydraulic Fracturing Ban

- Amid falling domestic crude oil and natural gas supply, the analysis forecasts diminished U.S. energy security due to increased reliance on Middle Eastern and Russian energy supplies.
- A decrease in LNG and crude oil exports would weaken geopolitical standing globally and take away an important diplomacy tool.
- Countries in Europe, Asia, and Latin America would be unable to source oil and natural gas from the United States and would turn to alternative producers. Further, if options in the United States are limited, oil and gas companies would likely be keen to invest in oil and gas production in foreign countries.

Section VI: Further Potential Impacts

- The cost of products that are essential elements of everyday, modern American life and rely on domestic production of oil and natural gas, such as fertilizers that increase crop yields, advanced, light-weight plastics to improve vehicle fuel efficiency and safety, and life-saving medical products, would be impacted.
- Banning high-volume hydraulic fracturing, and thereby dramatically reducing domestic oil and natural gas production, would have adverse impacts on renewable technology development – both in terms of manufacturing costs and ensuring a reliable electricity grid.
- Many university endowments, education funding, and state and local budgets are tied directly to oil and natural gas production severance taxes, fees, lease royalties, and state income taxes. Dramatically reducing production volumes will decrease these taxes, fees, and royalty revenues and create significant budget gaps to be filled, likely through increases in other taxes.

II. EVOLUTION OF THE U.S. ENERGY MARKETS SINCE 2005

The U.S. energy landscape has undergone a dramatic transformation since 2005, as new exploration and production technologies and approaches – from advances in seismic detection to horizontal drilling and hydraulic fracturing – have unleashed the energy, economic, and national security potential of resources residing within America's shale formations.

This energy revolution, which came at a time of rising domestic prices and increasing reliance on foreign energy sources, fundamentally changed America's energy outlook and upended global energy flows, enabling the country to achieve long-sought energy security goals, while driving domestic economic growth.

For decades, shales and other tight formations were a mystery, known to hold enormous quantities of oil and natural gas, yet considered too expensive to develop. Innovations in the late 1990s and early 2000s transformed these tight rocks from impenetrable fortresses into some of the world's largest oil and natural gas fields.

It was the combination of hydraulic fracturing and horizontal drilling technology that unlocked America's energy abundance. Hydraulic fracturing is a technique in which fluids under high pressure create fissures in rock formations to stimulate oil and natural gas flow. The technique is not new and was first tested seven decades ago in 1947 and first applied in the industry around 1949.[12] Later, in 1968, industry began applying high-volume hydraulic fracturing, which is a technique that uses volumes that are an order of magnitude or greater than conventional hydraulic fracturing methods.[13]

Horizontal drilling, a technique used for nearly a century,[14] began to supplement hydraulic fracturing in the late 1980s.[15] The combination of these two well-understood, environmentally safe techniques are responsible for the dramatic increase in U.S. oil and natural gas production. By 2016, hydraulically fractured horizontal wells accounted for 69 percent of all oil and natural gas wells drilled in the U.S. and 83 percent of the total linear footage drilled.[16]

In short time, domestic production has reached unprecedented levels and established the U.S. as the world's leading oil and natural gas producer--surpassing Russia in 2011 to become the world's largest producer of natural gas and surpassing Saudi Arabia in 2018 to become the world's largest producer of petroleum.[17] The oil and natural gas sectors' achievements through hydraulic fracturing has strengthened the domestic energy security and diversified the U.S. and the world's energy supply.

As with any commodity, there is a cyclical nature to the oil and natural gas market, largely driven by supply and demand market forces. The COVID-19 pandemic and resulting lockdown orders have dramatically impacted economic activity and lowered oil and natural gas demand. Unlike state-owned companies where governments control supply flow, domestic producers have largely responded to market forces with rapid curtailments in drilling activity.

While the U.S. economy may be temporarily down, the abundance of its energy resources, the resilience of its citizens and businesses, and its future economic opportunity, persist. A cornerstone of the U.S. economic recovery will be the abundance of reliable and affordable energy to enable U.S. manufacturing and other sectors of the economy to reignite the pre-pandemic boom.

A. U.S. OIL AND NATURAL GAS MARKETS

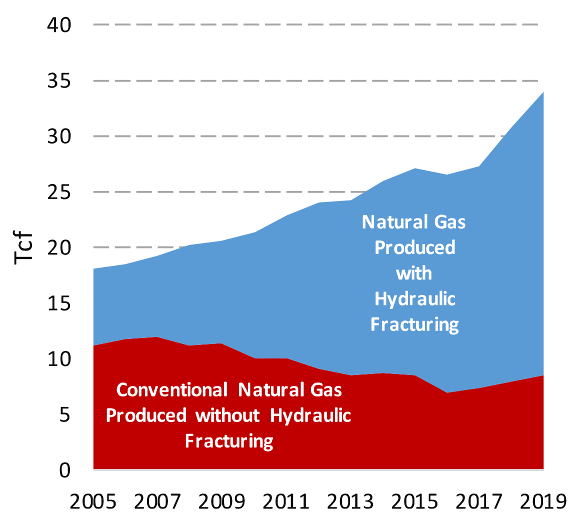
1. U.S. OIL AND NATURAL GAS PRODUCTION

In 2005, U.S. crude oil and natural gas production were 1.9 billion barrels and 18.1 Tcf.[18] By 2019, U.S. oil and natural gas production grew significantly to 4.5 billion barrels and 34.0 Tcf, respectively, which amounted to a 137 percent increase in oil production and an 88 percent increase in natural gas production during that period.[19]

Hydraulic fracturing, in combination with horizontal drilling, drove these increases. As shown in Figure 1, conventional natural gas production without hydraulic fracturing declined from 2005 to 2019 while gas production via hydraulic fracturing grew from 6.8 Tcf in 2005 to 25.5 Tcf in 2019, an increase of 275 percent.[20] In 2019, hydraulically fractured gas contributed 75 percent of U.S. natural gas supply, growing from 38 percent of gas supply in 2005.

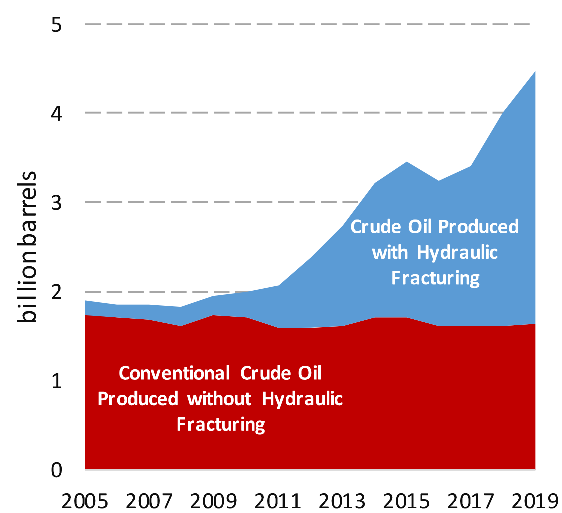
Similarly, Figure 2 shows hydraulic fracturing accounting for the entire increase in U.S. crude oil production from 2005 to 2019 as conventional crude oil production remained stagnant. In 2005, only eight percent of U.S. crude oil was developed from wells that underwent fracture treatments. By 2019, the amount grew to more than 63 percent.

Figure 1: U.S. Dry Gas Production (2005–2019)



Source: U.S. Energy Information Administration

Figure 2: U.S. Oil Production (2005–2019)



Source: U.S. Energy Information Administration

2. U.S. Oil and Natural Gas Imports and Exports

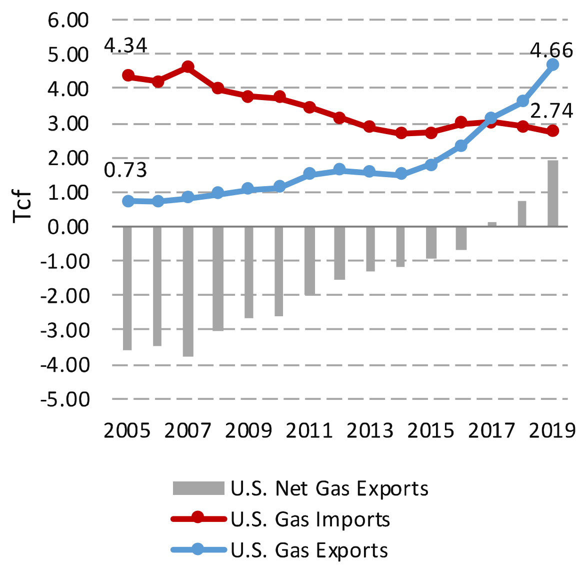
In 2005, the U.S. was a net importer of crude oil, petroleum products, and natural gas. Net imports of crude oil amounted to 3.7 billion barrels and net imports of petroleum product amounted to 0.9 billion barrels. U.S. net imports of natural gas were 3.6 Tcf in 2005, with net import volumes coming from Canadian pipeline imports (3.3 Tcf) and LNG imports (0.6 Tcf) and net export volumes coming from Mexico (0.3 Tcf). Trinidad & Tobago supplied 70 percent of U.S. LNG imports, while the remaining 30 percent came from Algeria, Egypt, Malaysia, Nigeria, Oman, and Qatar.

The effective combination of hydraulic fracturing and horizontal drilling has allowed the U.S. to reverse its dependence on imports. As shown in Figure 3, the U.S. became a net exporter of natural gas in 2017 for the first time in history and has steadily increased net exports of natural gas since then. In 2019, the U.S. achieved a record high of 4.66 Tcf in natural gas exports to 38 countries and decreased imports to a low level of 2.74 Tcf. The difference resulted in net exports of natural gas of 1.9 Tcf.

Before the U.S. energy revolution, the U.S. was expected to become a growing LNG importer, likely dependent on Russian, Middle East and North African supplies,[21] just as it had depended primarily on foreign crude supply for decades. From 2000 to 2008, the U.S. added 3.7 billion cubic feet per day (Bcfd) of LNG regasification capacity in anticipation of being reliant on LNG imports, amounting to a total of 6.0 Bcfd in total LNG import capacity.[22] Not only was the U.S. anticipating greater dependence on imports, but U.S. companies were increasingly looking abroad for places they could produce oil and gas.

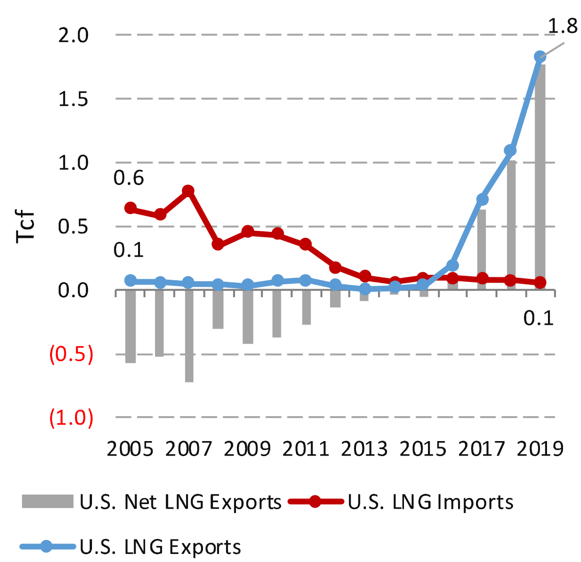
However, between 2016 and 2019, the U.S. added 8.4 Bcfd in liquefaction capacity to export gas. In 2019, the U.S. became the world's third-largest LNG exporter after Qatar and Australia. Figure 4 shows the trajectory of U.S.

Figure 3: U.S. Natural Gas Imports and Exports (2005–2019)



Source: U.S. Energy Information Administration

Figure 4: U.S. LNG Imports and Exports (2005-2019)



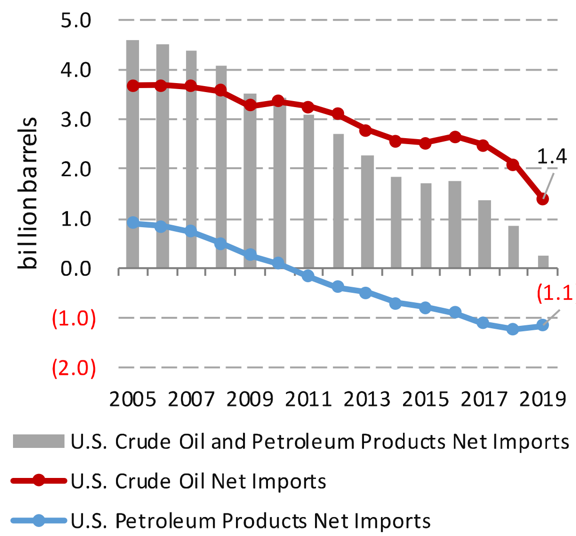
Source: U.S. Energy Information Administration

LNG imports and exports enabled with hydraulic fracturing. Natural gas from shales and other tight formations contributed to lower natural gas prices domestically and allowed U.S. natural gas to compete in international markets.

In addition to the benefits provided to the natural gas industry and its downstream sectors, hydraulic fracturing also has enabled the U.S. to increase its domestic crude oil production, thereby reducing its dependence on foreign crude oil imports, as shown in Figure 5. In 2005, the U.S. imported 3.7 billion barrels of crude oil. By 2019, the U.S. decreased its net imports of crude oil by 2.3 billion barrels to 1.4 billion barrels of crude oil, a reduction of 62 percent.

Net imports of petroleum products, such as gasoline and diesel, reversed direction from 2005 to 2019. In 2005, the U.S. was a net importer of 0.9 billion barrels of petroleum products as shown in Figure 5. By 2011, the U.S. became a net exporter of petroleum products and then increased its net exports to over 1.1 billion barrels by 2019.

Figure 5: U.S. Net Imports of Crude Oil and Petroleum Products (2005-2019)



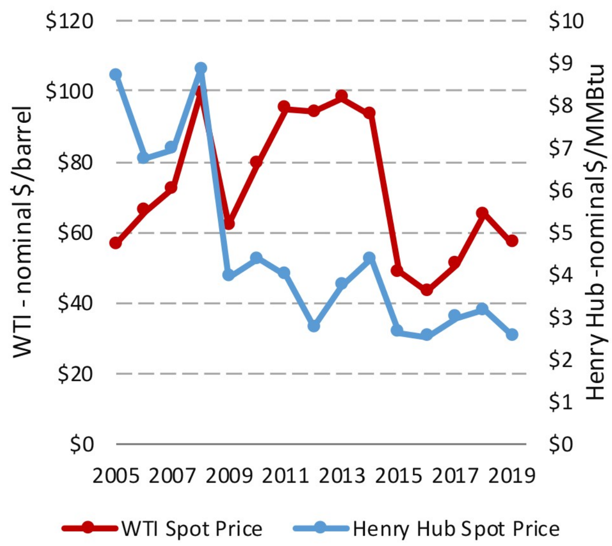
Source: U.S. Energy Information Administration

3. U.S. Oil and Natural Gas Consumption and Prices

Deployment of hydraulic fracturing has allowed U.S. oil and natural gas developers to produce more crude oil and natural gas at increasingly lower prices. As shown in Figure 6, traded oil and natural gas prices have declined from their peaks in 2008 of $99.67 per barrel and $8.86 per MMBtu, respectively, to $57.00 per barrel and $2.56 per MMBtu in 2019.[23]

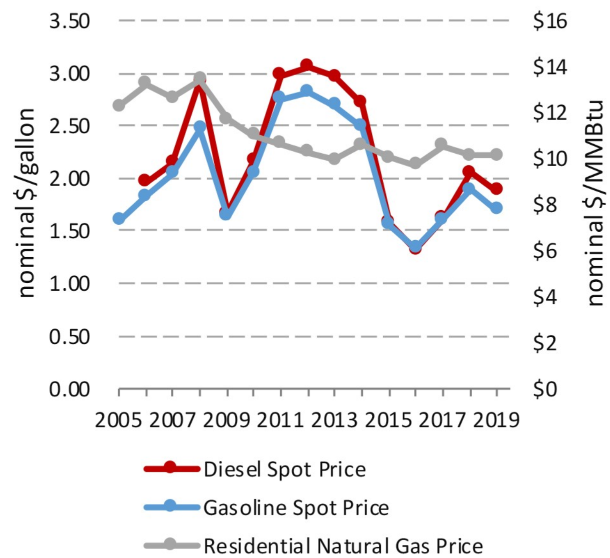
Similarly, as shown in Figure 7, end-user prices for refined oil products and natural gas have also declined significantly since 2012. In 2019, gasoline and diesel prices were 40.0 percent and 38.3 percent lower than in 2012. Average end-user prices for natural gas fell by 24.3 percent, to $10.14 per MMBtu, from 2008 to 2019.

Figure 6: Traded Oil and Natural Gas Prices (2005–2019)



Source: U.S. Energy Information Administration

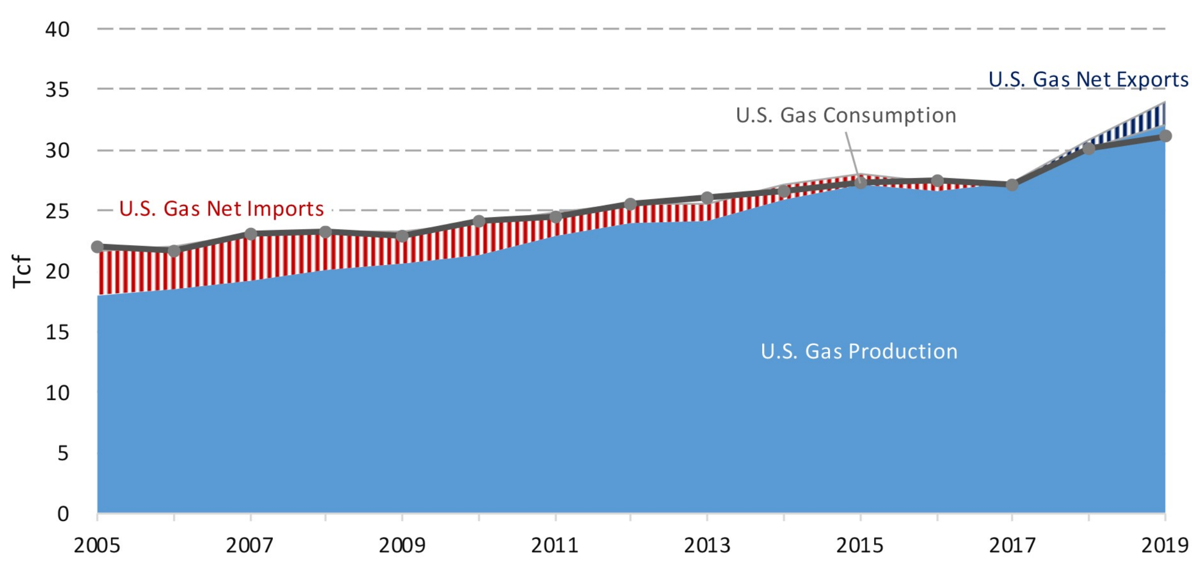
Figure 7: End-User Prices for Refined Oil Products and Natural Gas (2005–2019)



Source: U.S. Energy Information Administration

With lower natural gas prices, consumption has increased considerably, rising from 22.0 Tcf in 2005 to 31.1 Tcf in 2019, an increase of 9.1 Tcf or 41.3 percent. As shown in Figure 8, production has begun to outpace consumption, leading to net exports of natural gas, as previously discussed.

Figure 8: Natural Gas Production, Consumption, Net Imports and Exports (2005-2019)

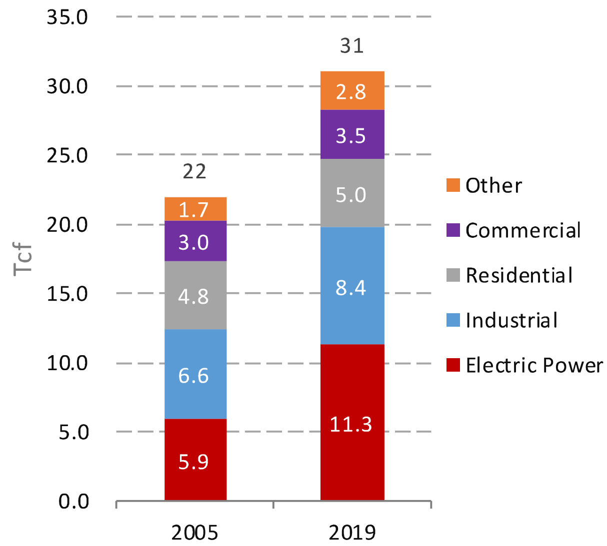


Source: U.S. Energy Information Administration

As shown in Figure 9, the electric power sector has been the principal driver of U.S. gas consumption growth, representing 5.4 Tcf or 59.3 percent of the total U.S. natural gas increase. The electric power sector's natural gas consumption grew from 5.9 Tcf in 2005 to 11.3 Tcf in 2019. As shown in the next section, natural gas prices have been a significant contributor to declining wholesale electricity prices and lower consumer costs.

The U.S. industrial sector has also benefited from hydraulic fracturing delivering more natural gas supply at lower prices. As shown in Figure 9, the industrial sector has increased its gas consumption from 6.6 Tcf to 8.4 Tcf from 2005 to 2019, an increase of 1.8 Tcf or 27.3 percent. Residential and commercial consumption of natural gas have increased as well during this period, rising slightly from 7.8 Tcf to 8.5 Tcf as more residences and commercial entities switched to natural gas heating due to lower gas prices.

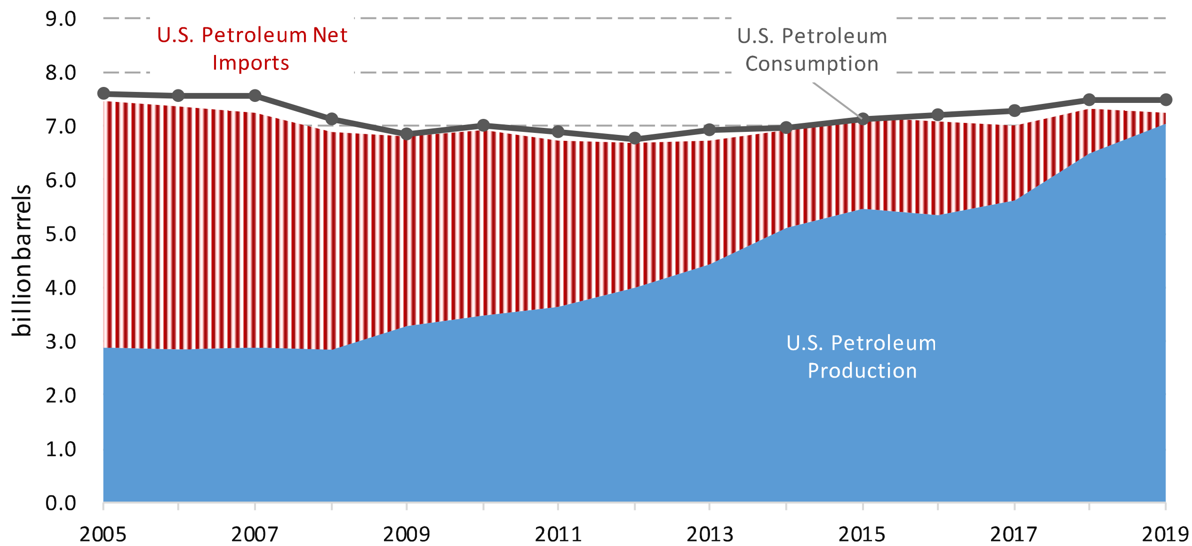
Figure 9: Natural Gas Consumption by Sector (2005 vs. 2019)



Source: U.S. Energy Information Administration

While U.S. gas consumption has increased considerably since 2005, U.S. crude oil consumption has remained relatively flat, as shown in Figure 10 below. This may seem counterintuitive given declining fuel prices at the pump and a growing economy but is explained by improving vehicle efficiencies (i.e., miles per gallon or "mpg"). Vehicle mpg improvements have allowed consumers to increase their vehicles miles traveled while keeping overall consumption from rising proportionally.

Figure 10: Petroleum Production, Consumption, Net Imports and Exports (2005–2019)



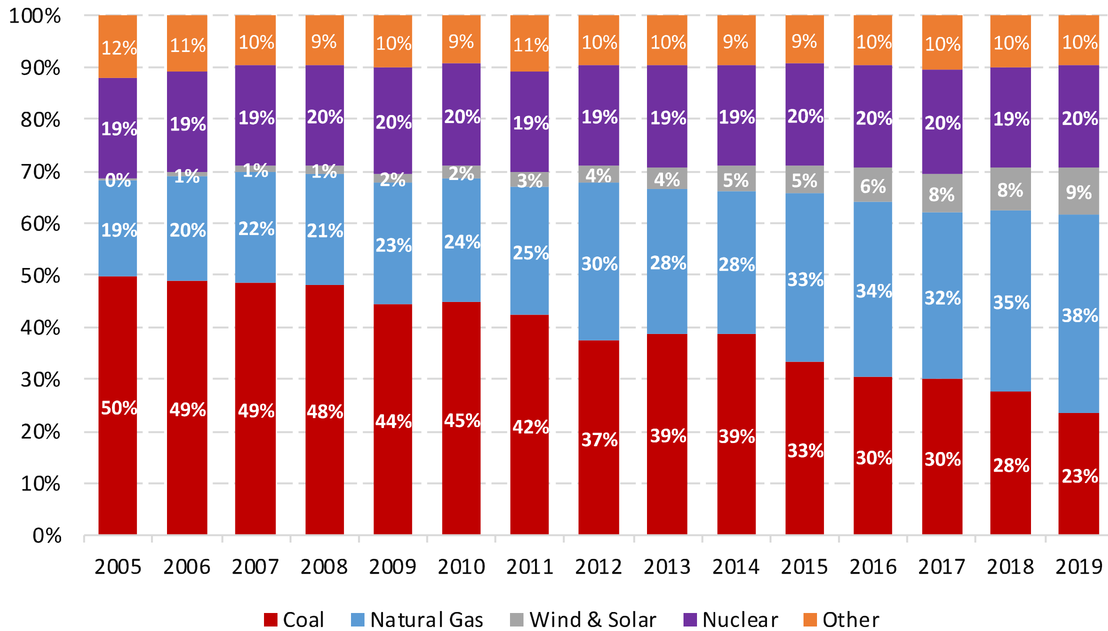
Source: U.S. Energy Information Administration

As shown in Figure 10, the U.S. total gross and net petroleum imports peaked in 2005, with net petroleum imports accounting for 60 percent of the total U.S. consumption.[24] Due to the contribution from shale production with hydraulic fracturing, U.S. net petroleum imports have declined from the peak with increasing exports and decreasing imports each year. In 2019, U.S. petroleum net imports reached the lowest level since 1954, accounting for approximately three percent of total U.S. petroleum consumption, a remarkable paradigm shift from the nation's historically high dependence on imports. The U.S. energy revolution also propelled the crude oil export ban implemented in 1975 to be lifted in December 2015,[25] allowing the U.S. to export crude oil to the global market.

B. Electric Power Sector Reductions in CO_2, SO_2, and NO_x Emissions

Figure 11 below shows that the electric power sector has experienced a considerable shift between generation types since 2005. In 2005, 70 percent of total electric power generation came from coal (50 percent), natural gas (19 percent), and wind and solar (1 percent). By 2019, these three generating sources provided 70 percent of total electric power generation; however, their shares changed significantly for natural gas (38 percent), coal (23 percent), and wind and solar (9 percent).

Figure 11: U.S. Generation Mix (2005-2019)



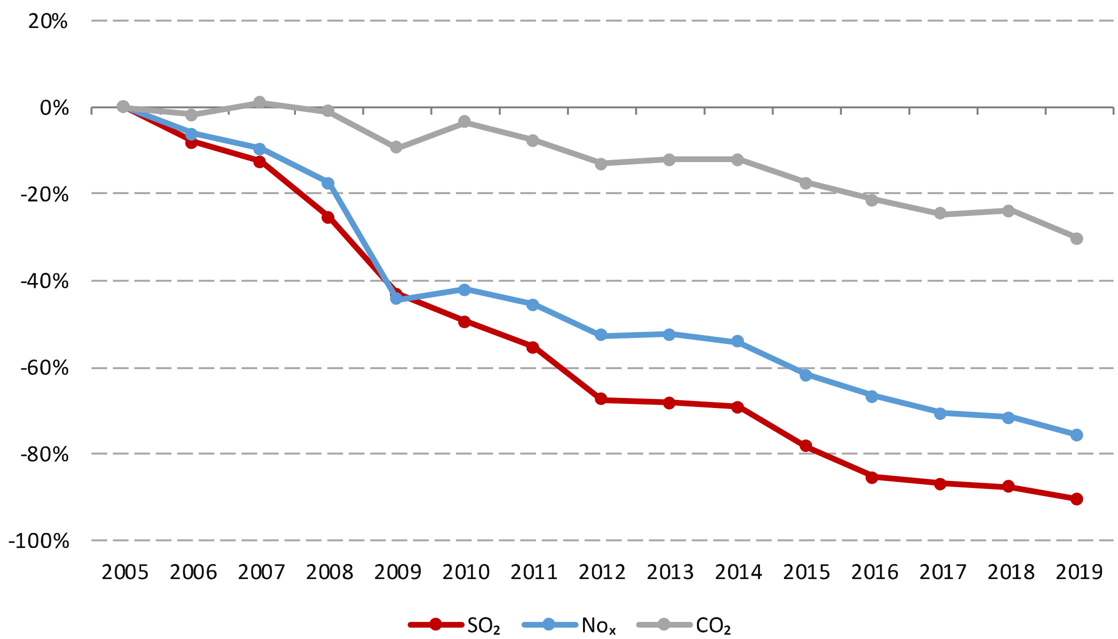
Source: U.S. Energy Information Administration

In their "U.S. Energy-Related Carbon Dioxide Emissions, 2019" report the Energy Information Administration (EIA) stated:

> "A major factor in recent reductions in the carbon intensity of electric generation in the United States is the reduced generation of electricity using coal. At the same time, generation has increased from natural gas (which emits less CO_2 for the same amount of electricity generated) and from non-carbon generation (including renewables), which emit no direct CO_2."[26]

NO_x and SO_2 emissions have also fallen significantly from 2005 to 2019 in large part due to this generation mix shift. By 2019, the electric power sector's CO_2 emissions fell 30 percent below 2005 levels, while NO_x and SO_2 emissions fell 76 percent and 91 percent below 2005 levels, respectively, as shown in Figure 12 below.

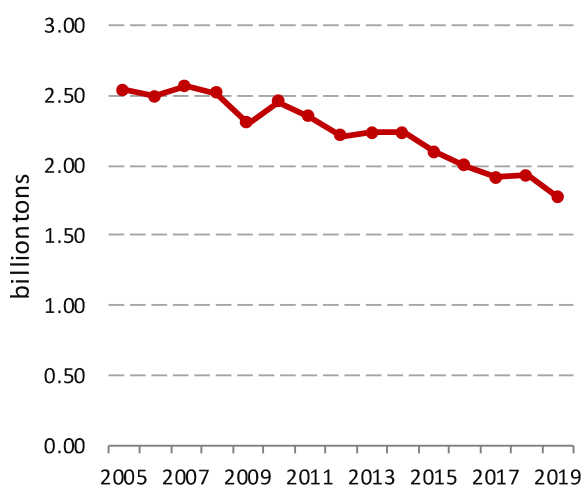
Figure 12: Electric Power Sector Emissions Indexed to 2005 Level



Source: U.S. Environmental Protection Agency

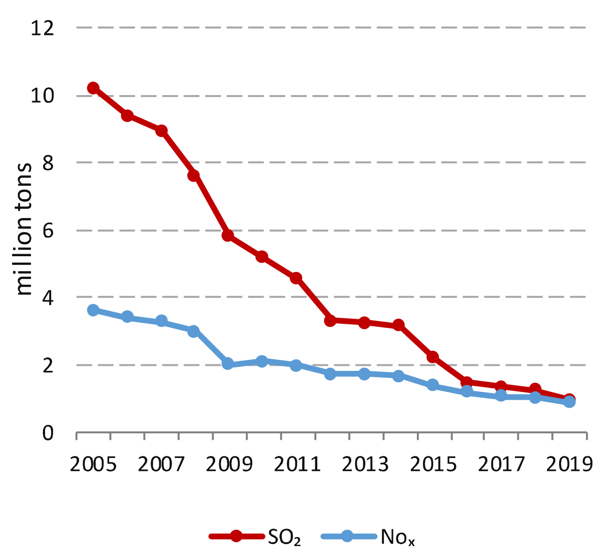
Figure 13 shows the decline in U.S. CO_2 emissions from 2.5 billion tons in 2005 to 1.8 billion tons in 2019. Figure 14 shows the same for SO_2 emissions, which have declined from 10.2 million tons in 2005 to 1.0 million tons in 2019, and NO_x emissions, which have decreased from 3.6 million tons in 2005 to 0.9 million tons in 2019.[27]

Figure 13: CO_2 Emissions from the Power Sector (2005-2019)



Source: U.S. Environmental Protection Agency

Figure 14: SO_2 and NO_x Emissions from the Power Sector (2005-2019)



Source: U.S. Environmental Protection Agency

III. Energy Market Impacts of a Hydraulic Fracturing Ban, 2021-2025

A. *Overview*

This section describes the energy market impacts – supply, demand, and prices – if a scenario were to exist where fracturing was banned starting in 2021 (HF Ban). This scenario was developed using a combination of key inputs such as oil and natural gas field decline rates in combination with energy models to forecast its impacts. The results shown in this section are compared to a business-as-usual scenario or "Base Case" through 2025. A forecast beyond 2025 was not conducted as the long-term technology and economic responsiveness to the high energy prices induced by a HF Ban scenario would be too uncertain.

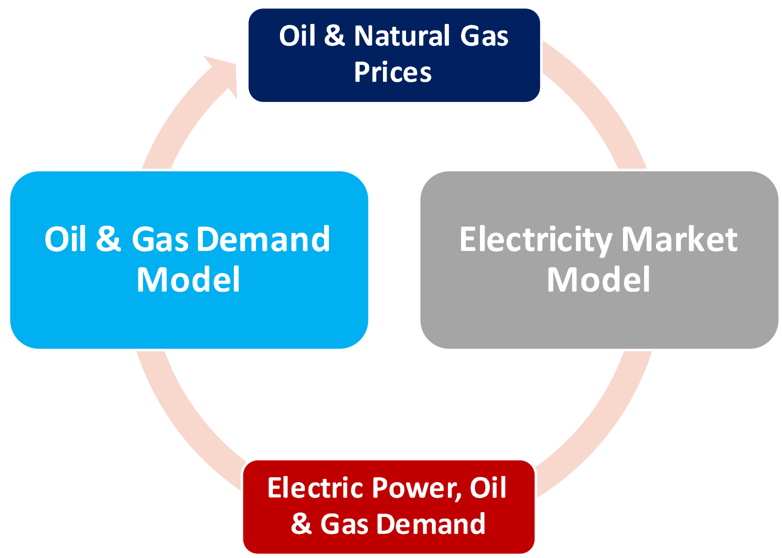
The Base Case relies principally on the EIA's Annual Energy Outlook (AEO) 2020 and was adjusted for COVID-19 energy market impacts as described further below. The EIA expects to release its AEO 2021 sometime in January 2021 after the release of this report, and, as such, cannot be incorporated.[28]

B. *Modeling Approach*

Two energy models were applied to assess the HF Ban scenario – an Oil & Gas Demand Model and an Electricity Market Model as shown in Figure 15. These models were solved iteratively to determine the oil and natural gas supply, demand, and prices that would occur under a HF Ban scenario. The Oil & Gas Demand Model forecasts non-electric U.S. domestic demand and prices of oil and natural gas by sector along with conventional production.

The Electricity Market Model is a licensed third-party mixed-integer linear programming model of the North American electrical grid. It solves for the least cost solution given cost and performance characteristics of all existing and new U.S. power plants, regional transmission and reserve margin constraints, and pertinent federal and state policies affecting regional electricity markets. In the short-term, the model changes how power plants dispatch due to changes in fuel prices. In the long-term, the model adds and retires plants.

Figure 15: Oil & Gas Demand Model and Electricity Market Model Iteration Process



The following sections describe these two models in further detail.

1. Oil & Gas Demand Model

The Oil & Gas Demand Model's objective function was to solve for the least cost solution for oil and natural gas prices under the HF Ban scenario. To solve for U.S. oil and natural gas supply, demand, and prices, the Oil & Gas Demand Model used the following key inputs:

- Demand Inputs
  - AEO 2020's implied elasticity of demand for natural gas in each of the following sectors: residential, commercial, industrial, and transportation.
  - Exogenous assumptions for Canadian and Mexican gas imports and exports based on the U.S. EIA and Mexico Ministry of Energy (SENER) forecasts.
  - An exogenous assumption for U.S. LNG exports and imports based on the results of the Global LNG Model, which tracks all operational and proposed liquefaction projects, regasification capacities, demand growth from major demand centers, LNG value chain costs, and prices formulation of key destination markets.
  - The response from the Electricity Market Model for the electric power sector's natural gas demand.
- Supply Inputs
  - A national decline curve forecast for existing oil and natural gas wells was developed; Appendix A describes the process for developing these decline curves.
  - AEO 2020's price elasticity of supply for oil and natural gas fields that are not hydraulically fractured. For gas, these include coal-bed methane wells and offshore oil and natural gas wells. For crude oil, these include vertical wells and offshore oil wells.

- In the HF Ban scenario, no new wells using hydraulic fracturing would come online. Existing wells would see their output decrease over time and some new conventional production would increase, induced by the higher oil and natural gas prices in the HF Ban scenario.

- WTI to Henry Hub Prices Relationships
    - In a HF Ban scenario, it was assumed that the WTI to Henry Hub price would return to the tight relationship experienced from 2006 to 2008, before the U.S. energy revolution.

2. ELECTRICITY MARKET MODEL

The Electricity Market Model was used to forecast natural gas demand for the power sector under a HF Ban scenario. The electric power sector can more readily respond to shocks than other sectors given its diverse set of technologies and fuel supply along with mandated minimum reserve margins in most markets. Additionally, the sector can delay retirements and build new, incremental capacity after a couple of years in response. Regardless, natural gas will remain an important fuel source for the U.S. electricity market even under a higher price scenario because natural gas-fired power generation resources are efficient, have a lower carbon footprint than other fossil fuels, and typically are capable of ramping up quickly during peak hours and ramping down quickly during off-peak hours.

The Electricity Market Model applied was a production cost model that uses a detailed representation of power markets to dispatch generation needed to meet zonal load while minimizing total system costs and respecting transmission constraints. This model provides both the short-term dispatch of generating plants and the long-term net capacity expansion (new builds and retirements) that would occur under the Base Case and HF Ban scenarios.

In the short term, the bulk power system has demonstrated an ability to switch between substitute fuels, such as gas and coal, on an economic basis to a significant extent during the past decade. [29] In the long-term, markets can move away from high-cost generation sources by building new power plants using alternative technologies or fuel types.

The Henry Hub natural gas price forecast from the Oil & Gas Demand Model was used to forecast regional gas prices given current basis differentials. The Electricity Market Model was then run from 2021 to 2025 with the regional gas price forecasts. The Electricity Market Model then dispatched units, built new units, and retired existing units in a manner that minimized overall system costs and respected operating constraints along with reasonable new build timelines and limits.

The Electricity Market Model provided the total electric power sector's annual gas consumption, which was inputted back into the Oil & Gas Demand Model. This model was then run again to obtain a revised set of natural gas prices. This iterative process led to the convergence of a stable price solution between the Oil & Gas Demand Model and the Electricity Market Model.

C. *KEY ASSUMPTIONS*

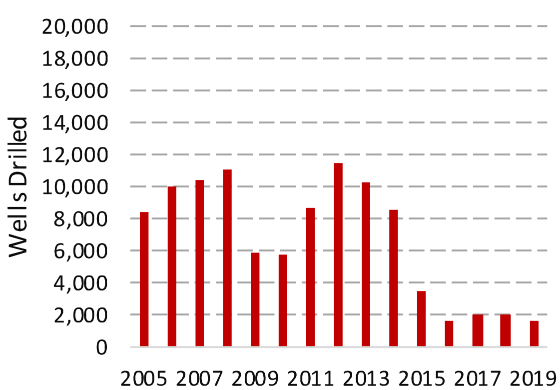
1. OIL AND NATURAL GAS FIELD DECLINE RATES

The Oil & Gas Demand Model forecasts oil and natural gas production in two stages. As described in the previous section, the first stage aims to forecast production from conventional wells drilled in the future, incentivized by market prices based on implied price elasticities of supply. Conventional wells defined here and previously are those wells that readily allow oil and gas to flow to the wellbore, therefore not requiring hydraulic fracturing. The second stage forecasts production from currently operating conventional and unconventional wells, as described further below.

Figure 16 below shows the number of conventional wells drilled in the U.S. per year from 2005 through 2019. Two noticeable periods of decline in the drilling of conventional wells are apparent, one following the financial crisis of 2008, and another following the crash in commodity prices near the end of 2014.

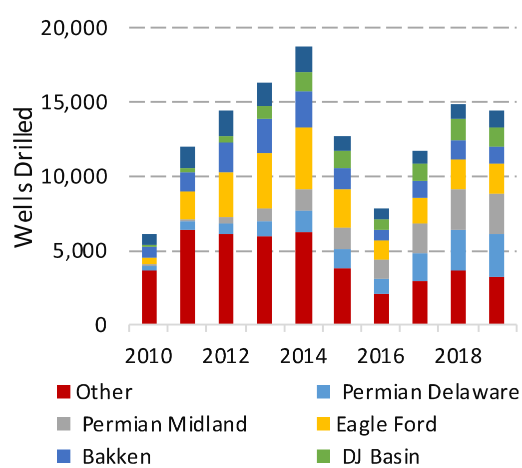
Unlike after the first decline in 2008, conventional well drilling has not recovered after the 2014 commodity price crash. Figure 17 shows unconventional wells drilled by play, by year, from 2010 through 2019. Unconventional wells did see an uptick in drilling after the 2014 commodity price collapse. However, new drilling has been consolidated more to core plays, as seen by the declining drilling activity in the "other" category.

Figure 16: Conventional Wells Drilled by Year (2005-2019)



Source: Rystad Energy

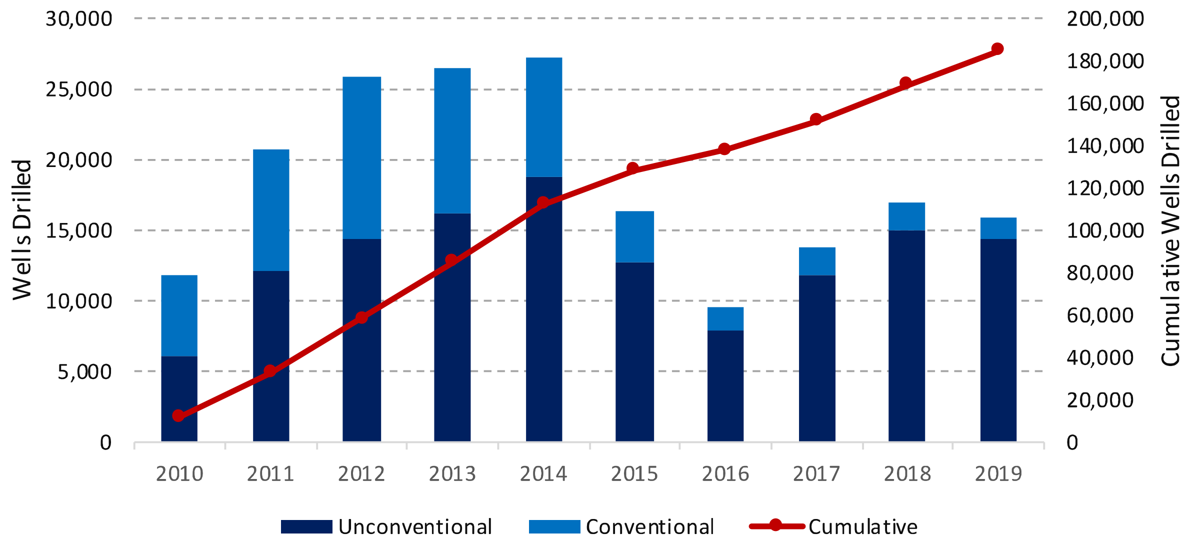
Figure 17: Unconventional Wells Drilled by Play (2010-2019)



Source: Rystad Energy

Finally, Figure 18 shows the total unconventional and conventional well drilling activity combined from 2010 through 2019. Unconventional drilling activity has clearly outpaced conventional drilling activity, accounting for 70 percent of the more than 184,000 cumulative wells drilled since 2010.

Figure 18: Total Wells Drilled by Type (2010-2019)



Source: Rystad Energy

Most of the existing wells drilled and completed since 2010 are still producing oil and natural gas and will continue to produce for many more months or years. Decline curve analysis allows for future production projections for these wells based on past production and the tendency of well-level production to follow one of several functional forms.

Historical monthly production for the more than 184,000 wells drilled since 2010 was collected from WellDatabase.[30] Each well's historical production was fitted to a decline curve type as described in further detail in Appendix A: Oil and Natural Gas Decline Curve Analysis. Once a well was fitted to a decline curve type, a production forecast for existing wells was created based on the cumulative set of fitted decline curves.

Figure 19 below shows the projected decline in natural gas production from existing wells, and Figure 20 shows the projected decline in oil production from existing wells. Due to the projections representing operating wells of many different vintages, production, in general, does not decline as quickly as production from any single newly producing well.

Gas production from existing wells is projected to decline approximately 23 percent from 2020 to 2021, with 2025 production dropping to only 46 percent of 2020 levels. Oil production from existing wells is expected to decline even further from 2020 to 2021 to 28 percent, with 2025 production falling to 43 percent of 2020 levels.

Figure 19: Existing Gas Well Production Forecast by State (2020-2025)

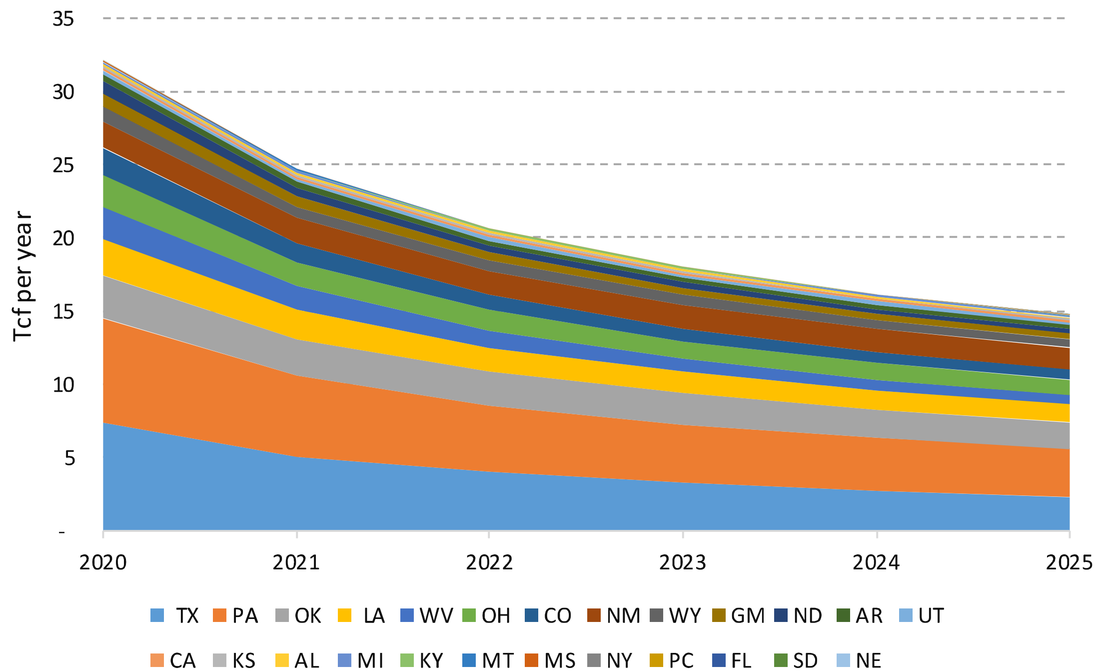
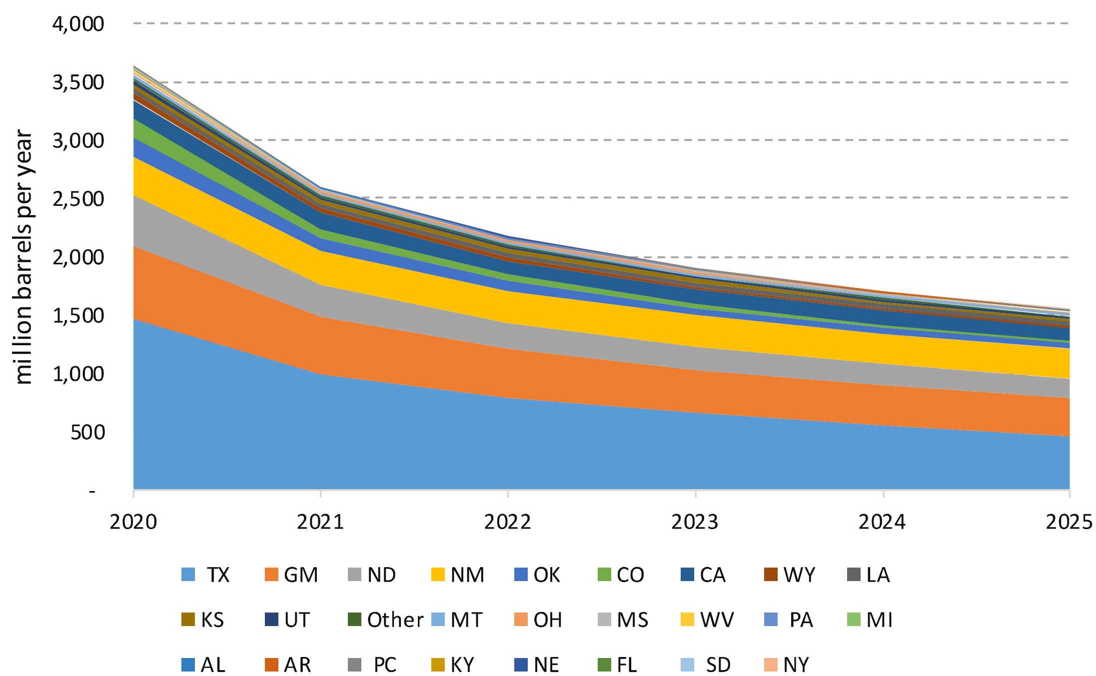


Figure 20: Existing Oil Well Production Forecast by State (2020-2025)



2. OIL AND NATURAL GAS PRICE ELASTICITIES OF DEMAND

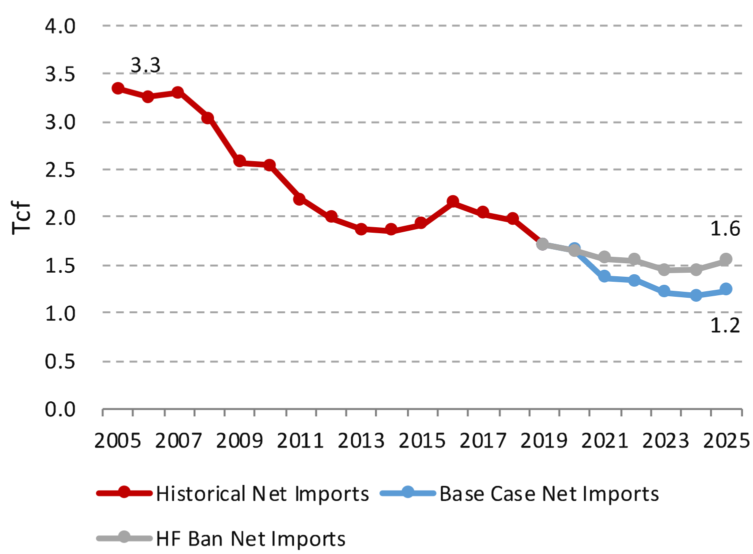
The AEO 2020 cases were used to develop the implied price elasticity of demand for the residential, commercial, industrial, and transportation sectors.[31]

Natural gas demand response for the electricity sector was endogenously determined from the Electricity Market Model. As depicted in Figure 15, the Oil & Gas Demand model and the Electricity Market Model were run iteratively until oil and natural gas prices converged.

3. Exogenous Natural Gas Import and Exports

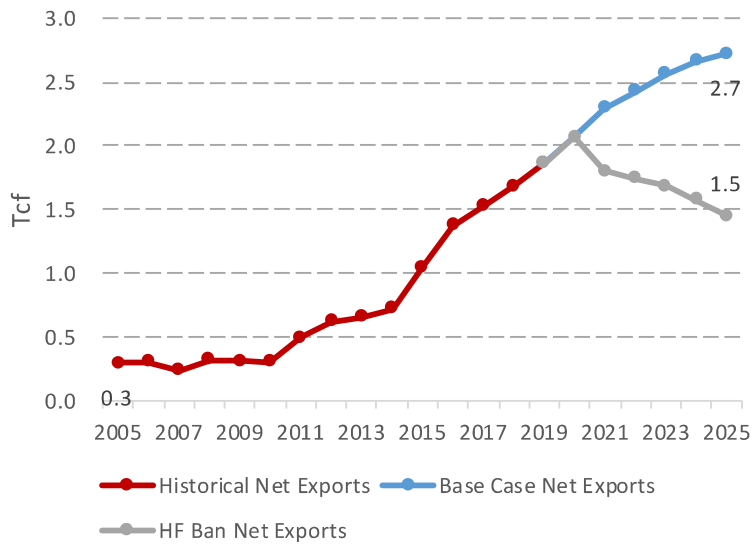
In a HF Ban scenario, the U.S. is expected to increase net natural gas imports from Canada and decrease net exports to Mexico. As shown in Figure 21, due to increased U.S. gas production, U.S. net natural gas imports from Canada has decreased from 3.3 Tcf in 2005 to 1.7 Tcf in 2019, and is expected to further decrease to 1.2 Tcf by 2025 in the Base Case. However, with a HF Ban scenario, the net imports are expected to remain flat.

Figure 21: U.S. Natural Gas Pipeline Net Imports from Canada (2005-2025)



Under a HF Ban scenario, the implications to Mexico's pipeline natural gas trade would be significant. In 2019, the U.S. exported 1.9 Tcf of natural gas to Mexico, which is 1.6 Tcf greater than 2005 export levels of 0.3 Tcf. Under a HF Ban scenario, this trend would reverse as U.S. exports are anticipated to decline to 1.5 Tcf by 2025, a decrease of 21 percent. Without a HF Ban, U.S. natural gas pipeline exports are anticipated to continue to increase from 1.9 Tcf in 2019, to 2.7 Tcf in 2025.

Figure 22: U.S. Natural Gas Pipeline Exports to Mexico (2005-2025)

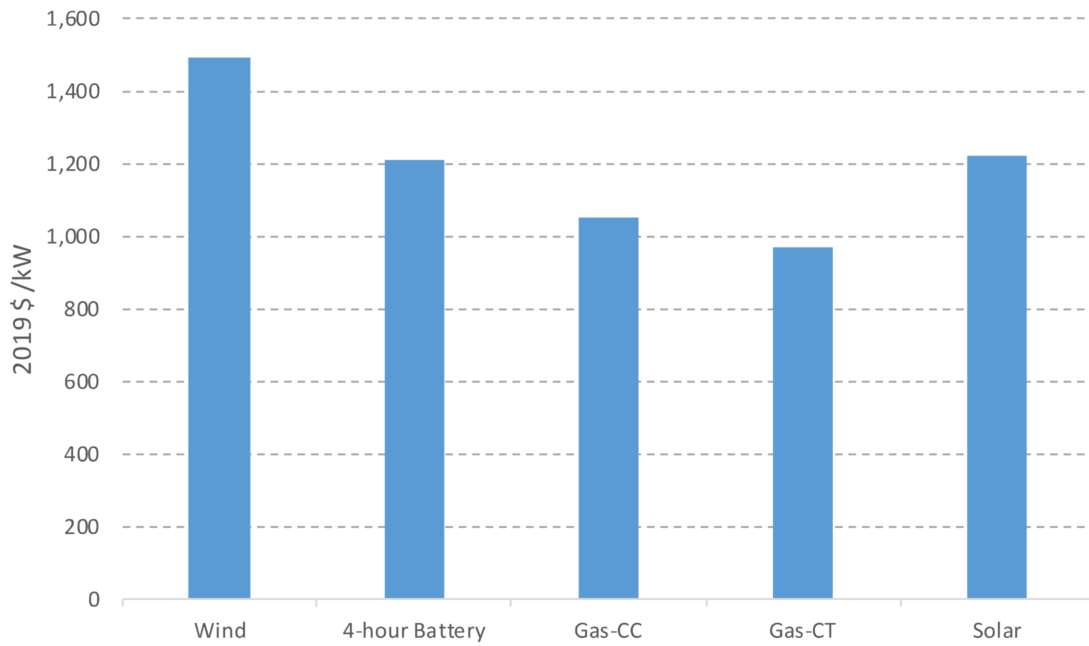


4. Electricity Market Model Assumptions

The Electricity Market Model solves for the least cost solution for new builds, retirements, generation, and prices given generating unit, regulatory, and market operating assumptions and constraints. Key assumptions include the cost and performance for new and existing units, regional load growth, and emissions factors. Regulatory constraints include state-level mandates such as the Renewable Portfolio Standards (RPS). Market operating constraints include regional-specific reserve margins and region-to-region transmission limits. The Electricity Market Model's main assumptions and constraints are detailed further below:

- **Capacity Expansion Build Costs:** Build costs are assigned to capacity expansion candidates within the Electricity Market Model on a zonal basis, with regional cost differentiation[32] and changing costs over time.[33] The Electricity Market Model chooses to build generation resources from among the various candidate options to meet load growth and reserve margin requirements in a least-cost fashion, subject to various physical and policy constraints. Figure 23 below shows the average build costs in real 2019 dollar per kilowatt (kW) of nameplate capacity for the primary expansion candidates available.

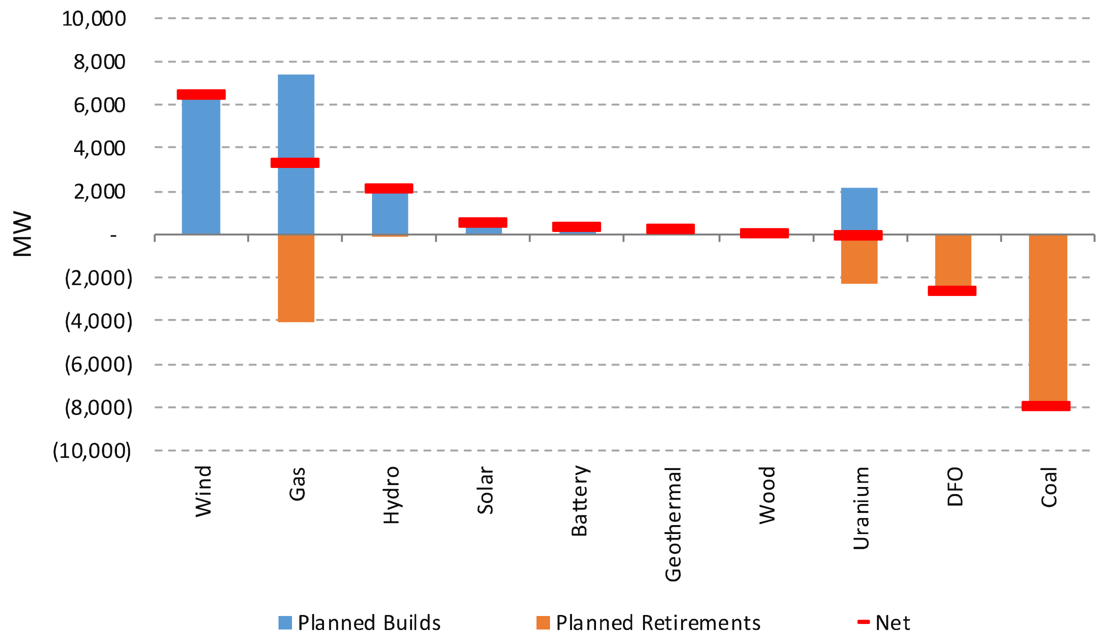
Figure 23: Average Build Cost for New Capacity (2021 -2025)



Note: The capital expenditure estimates for solar and battery storage are before applying the Investment Tax Credits (ITC).

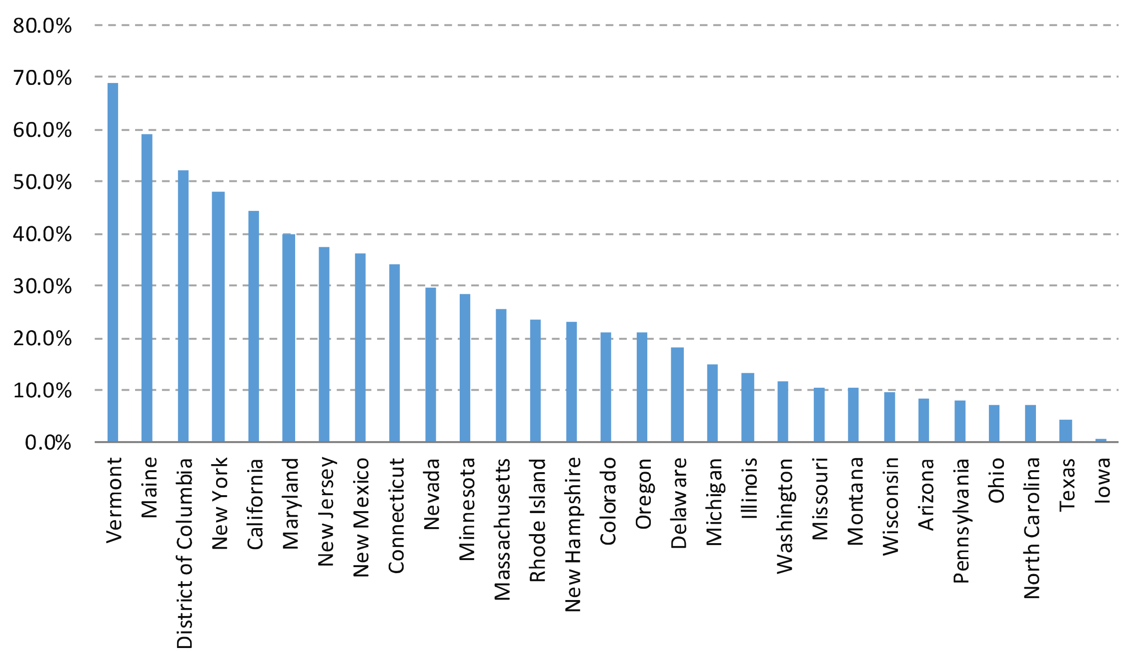
- **Planned Builds and Retirements:** The Electricity Market Model includes planned projects in advanced development stages and announced generator retirements as available through ABB Velocity Suite. [34] Figure 24 below shows the cumulative planned builds and retirements by generation type through 2025. The red bars show the net planned builds and retirements by type.

Figure 24: Cumulative Planned Builds & Retirements (2021-2025)



- **State Renewable Portfolio Standards:** The Electricity Market Model accounts for existing RPS as compiled from EPA's Integrated Planning Model (IPM) version 6.[35] For states that have RPS mandates, the RPS requirements are detailed for 2025 in Figure 25 below.

Figure 25: Renewable Portfolio Standards Target by State (2025)



- **Coal Prices:** Coal prices in the Electricity Market Model are solved simultaneously in the model given assumptions for coal basin-level supply curves and coal transportation costs.

- **Load:** The load forecasts used in the Electricity Market Model are based on Independent System Operator (ISO) official forecasts, adjusted downwards based on observed and forecasted impacts from COVID-19.

D. Natural Gas Market Outlook

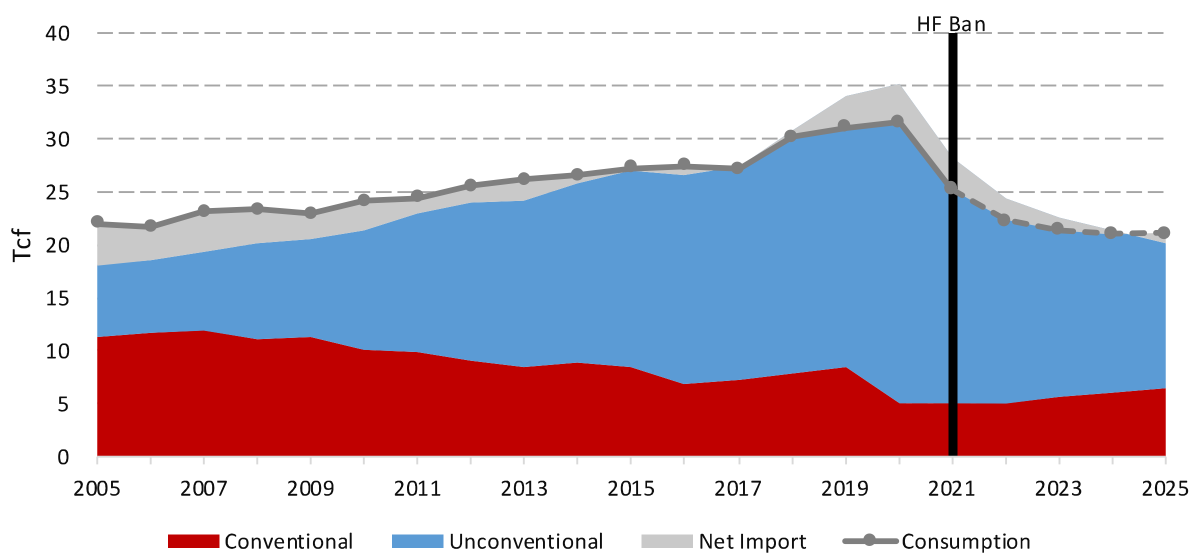
This section provides an outlook for natural gas production, consumption, and net exports under a HF Ban scenario. Under such a scenario, gas production from shale, tight gas, and tight oil would decline as previously shown in Figure 19 and Figure 20, meaning the U.S. would reverse its trajectory of becoming a major global LNG exporter and once again become a net importer of natural gas.

The rise of U.S. natural gas production has led to reduced domestic and international prices for natural gas. U.S. natural gas exports have helped to sever the long-time, global linkage between crude oil and natural gas prices that kept international gas prices artificially high.

1. Domestic Gas Production, Consumption, and Prices

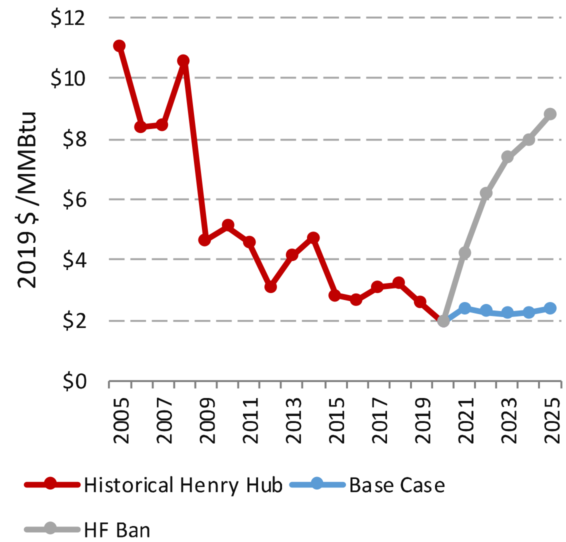
Currently, shale production is about 56.0 Bcfd or 60 percent of U.S. total dry gas production. Under a HF Ban scenario, production from unconventional (i.e., shale and tight gas formations that are horizontally drilled and hydraulically fractured) would rapidly decline, as shown in Figure 26. This is because the production from existing wells declines sharply over time, and new drilling is needed to sustain production levels. Due to the higher prices with a HF Ban, domestic gas consumption would decline from 31 Tcf in 2019 to 21 Tcf in 2025, and total U.S. dry gas production would decline from 34 Tcf in 2019 to 20 Tcf in 2025.

Figure 26: U.S. Natural Gas Production and Consumption under HF Ban (2005-2025)



The natural gas price implications under a HF Ban scenario would be considerable. Figure 27 shows that under the HF Ban scenario, Henry Hub natural gas prices rise to $6.17 per MMBtu by 2022, levels not experienced since 2008. Prices rise further from there, to $8.80 per MMBtu in 2025. Higher natural gas prices impact the power generation sector in terms of higher electricity prices because gas-fired generation is the marginal resource in many U.S. regional markets. In addition, a reduced gas-fired generation jeopardizes the trajectory of the emissions reductions achieved in recent years through the displacement of coal-fired generation. In addition, the residential, commercial, and industrial sectors are impacted with a steady upward pressure on prices due to supply curtailments.

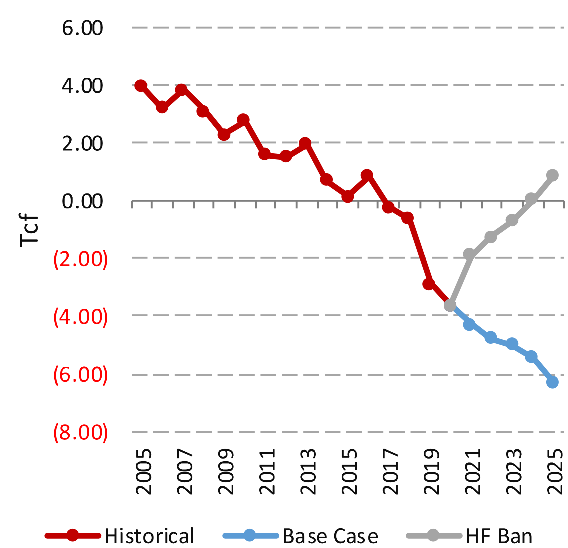
Figure 27: Historical and Forecasted Henry Hub Natural Gas Prices (2005-2025)



2. Natural Gas Imports and Exports

As previously mentioned, the U.S. became a net natural gas exporter for the first time in 2017. Figure 28 shows that in 2019, the U.S. had net exports of 2.9 Tcf, which is 2.7 Tcf more than in 2017. Under the HF Ban scenario, the U.S. is expected to, once again, be a net importer of natural gas starting in 2025 given the reduced supply. Under the HF Ban scenario, net imports of natural gas are expected to reach 0.9 Tcf in 2025, levels not experienced since 2016. In comparison, under the Base Case scenario, the U.S. is expected to maintain and strengthen its position as a net exporter of natural gas through 2025. In 2021, the Base Case scenario predicts that the U.S. will be a net exporter of 4.3 Tcf which is expected to increase to 6.3 Tcf in 2025.

Figure 28: Historical and Projected Natural Gas Net Imports (2005-2025)

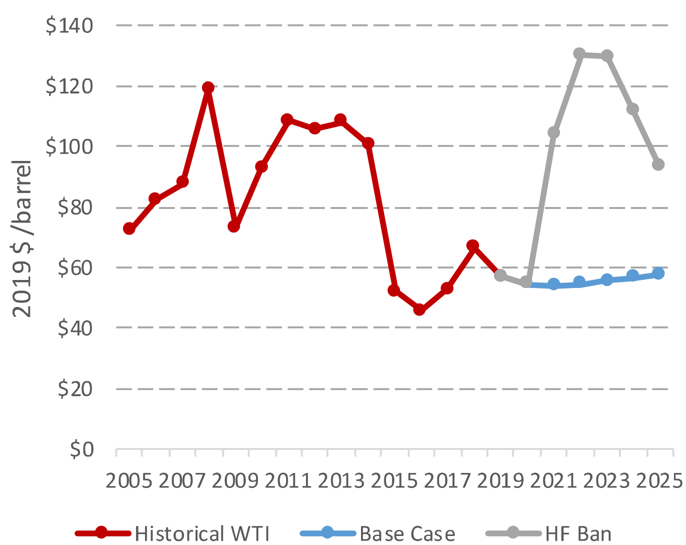


E. *Crude Oil Market Outlook*

While domestic crude oil production began to rapidly increase in 2005, U.S. law prohibited crude oil exports. Congress lifted that 40-year ban on exporting crude oil in December 2015 and, in the years since, U.S. crude oil has gained market share in domestic and foreign markets. The global crude market has been in an oversupply situation since 2014, when the growth in U.S. shale production became fully appreciated by the marketplace and when signs of decreasing global demand growth, particularly in China, became apparent.

As demonstrated with natural gas exports, under a hydraulic fracturing ban scenario, domestic crude oil production would fall, removing U.S. crude from international supply and increasing U.S. reliance on foreign nations for oil imports. With a global supply shortage, this analysis forecasts crude prices to rise rapidly, reaching $130.20 per barrel in 2023, and stabilize at $93.2 per barrel in 2025 after foreign supply catches up, as shown in Figure 29. Crude oil demand has shown to be inelastic, especially in the short term.

Figure 29: Historical and Forecasted WTI Prices (2005-2025)



Under a HF Ban scenario, WTI prices likely will return to a premium to Brent crude prices as they were before 2009. Since 2009, the U.S. has emerged as the world's leading producer of crude oil and WTI prices have been at a $7 per barrel discount to Brent prices.

Figure 30 shows the expected consumption and production under the HF Ban scenario. Unconventional production is expected to decline from 2.83 billion barrels in 2019 to 1.50 billion barrels in 2025, reverting the U.S. to higher reliance on imported crude oil to meet demand, as shown in Figure 31.

Figure 30: Historical and Projected U.S. Crude Production under HF Ban (2005-2025)

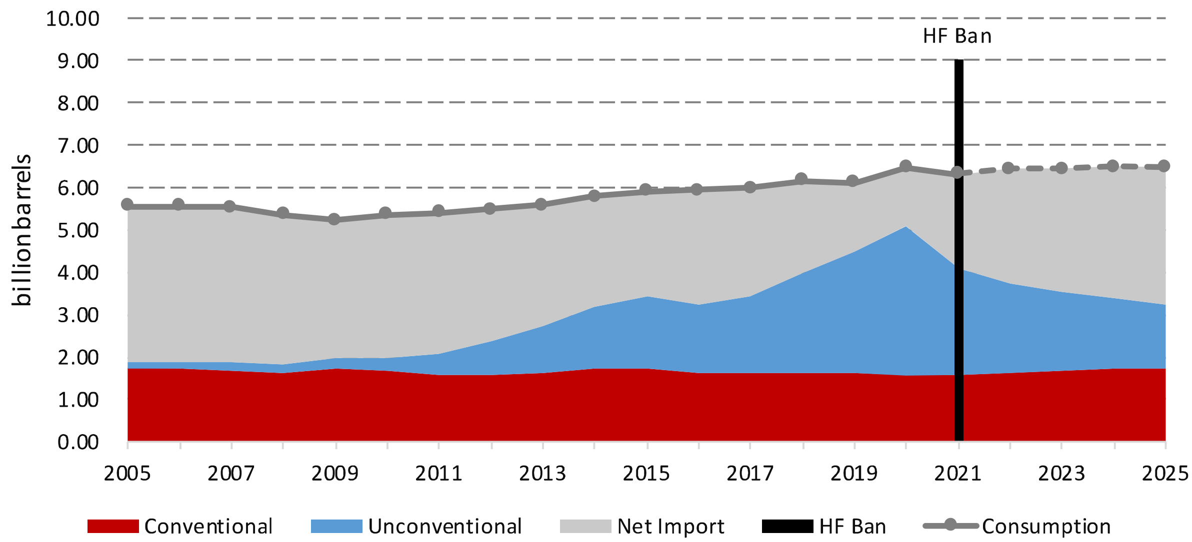
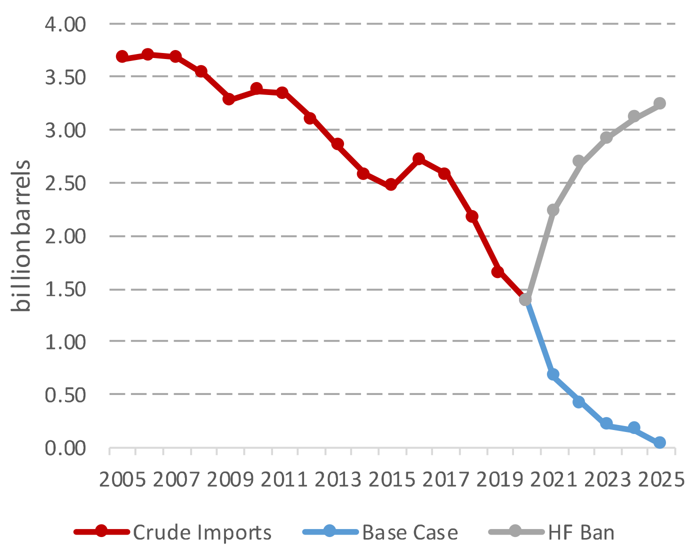


Figure 31: Historical and Projected Net Crude Imports under Base Case and HF Ban (2005-2025)



F. ELECTRICITY MARKET OUTLOOK

The AEO is perhaps the most widely disseminated long-term energy forecast for the U.S. The EIA publishes this report annually in the first quarter of each year, drawing on their modeling of the U.S. economy and energy markets in the integrated National Energy Modeling System (NEMS). The EIA released the AEO 2020 on January 29, 2020.

Given the timing of its release, the AEO 2020 does not reflect the impacts that COVID-19 has had on the economy and energy markets. The AEO 2020 envisioned a significantly more "normal" economic trajectory without COVID-19, which resulted in overly optimistic load forecasts of energy production, consumption, and prices. The Base Case electricity market projections include the impacts of COVID-19 on energy markets by incorporating updated fuel pricing informed by traded futures contracts along with reduced load growth assumptions.

The Base Case forecast shows a significant build-out of renewables, natural gas, and battery energy storage over the next five years, adding a cumulative solar capacity of 53 GW and a cumulative wind capacity of 63 gigawatts (GW). A 5-GW build-out of battery energy storage systems complement these large renewable builds. A 24-GW build-out of natural gas-fired capacity shores up baseload generation capacity and ramping capabilities and replaces some older, less efficient gas capacity.

A significant amount of coal and gas retirements at 36 GW and 53 GW, respectively, significantly reduce the coal and gas fleet's overall capacity when netted with the capacity additions. The net result of capacity additions and retirements from 2021 through 2025 is shown below in Figure 32. The difference between Figure 24 and Figure 32 is that Figure 24 shows only planned builds and retirements, while Figure 32 shows both planned and unplanned, or economic, builds and retirements.

Figure 32: Projected Base Case Net Capacity Additions (2021-2025)

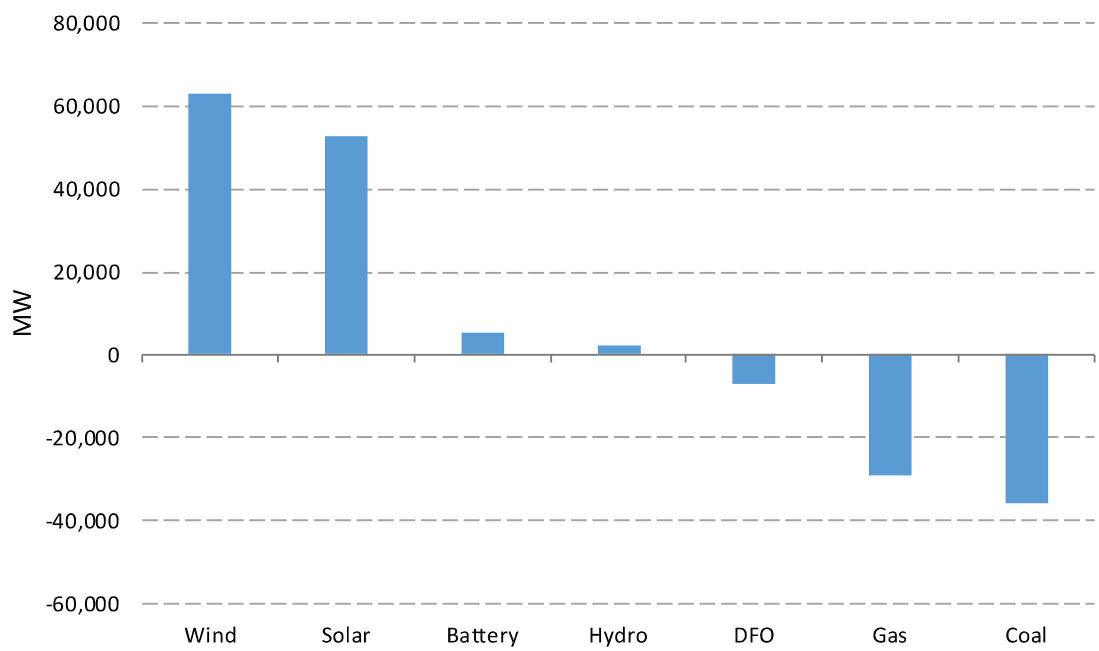
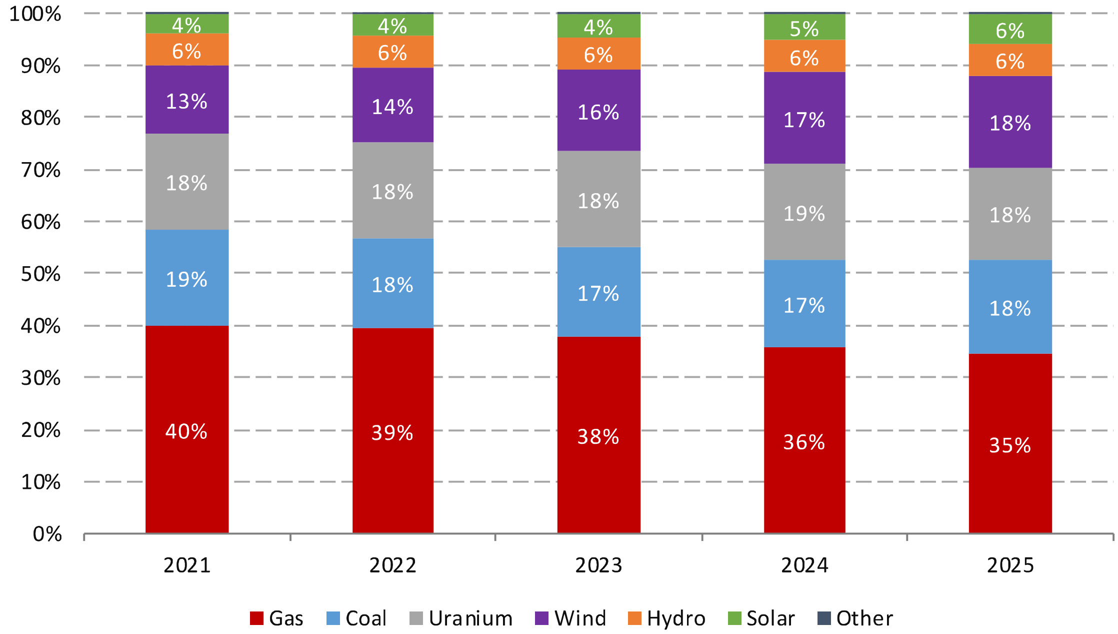


Figure 33 shows the resulting impact on the U.S. generation mix. Wind and solar's share of the generation mix increases significantly from a combined 17 percent in 2021 to 24 percent in 2025. Meanwhile, coal, nuclear, and hydro shares remain relatively stable, and gas sees a market share decline from 40 percent in 2021 to 35 percent in 2025.

Figure 33: Projected Base Case U.S. Generation Mix (2021-2025)



Under the HF Ban scenario, the high fuel prices lead to a significant shift in overall build and retirement patterns. Substitute generation sources such as wind and solar see much larger builds than under Base Case conditions, adding a cumulative 91 GW and 124 GW respectively, or about 28 GW and 71 GW respectively over the Base Case scenario. On the other hand, new gas-fired builds total only 15 GW compared to 24 GW under the Base Case conditions.

Coal retirements are much lower under the HF Ban scenario at only 13 GW compared to 36 GW under the Base Case conditions. However, natural gas retirements rise to 111 GW under the HF Ban scenario, compared to only 53 GW of gas retirements under the Base Case. Figure 34 below shows the net capacity additions under the no hydraulic fracturing conditions. Figure 35 shows the change in net capacity additions under the HF Ban scenario compared to the Base Case. Figure 35 also notably shows that changes in wood, battery, hydro, and distillate fuel oil (DFO) capacity are immaterial between the scenarios.

Figure 34: Projected HF Ban Net Capacity Additions (2021-2025)

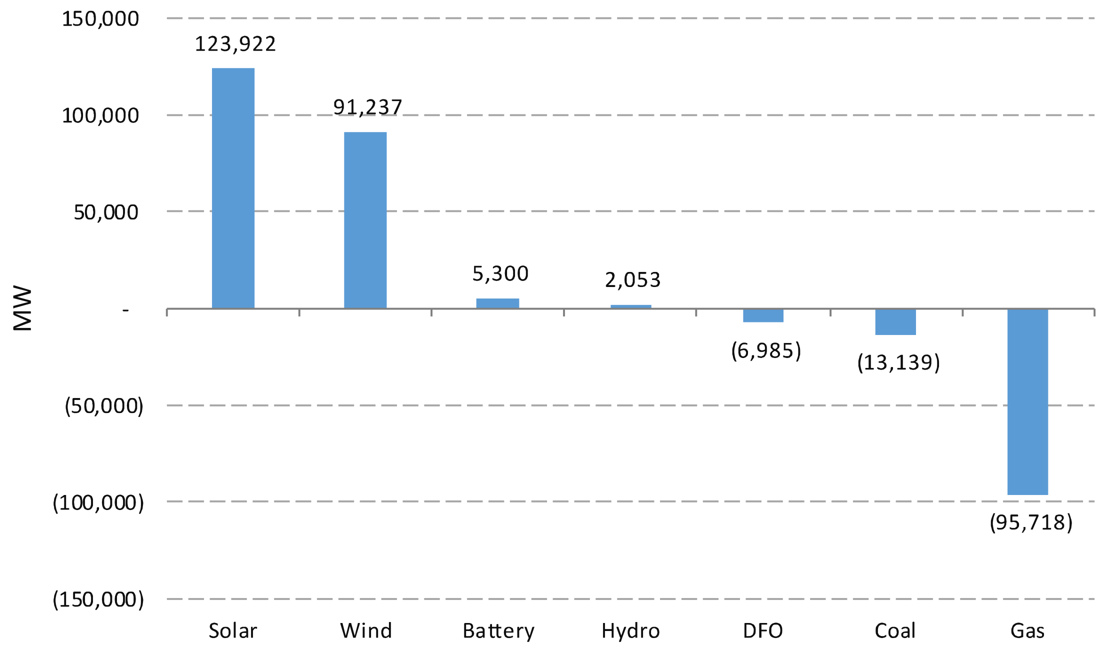
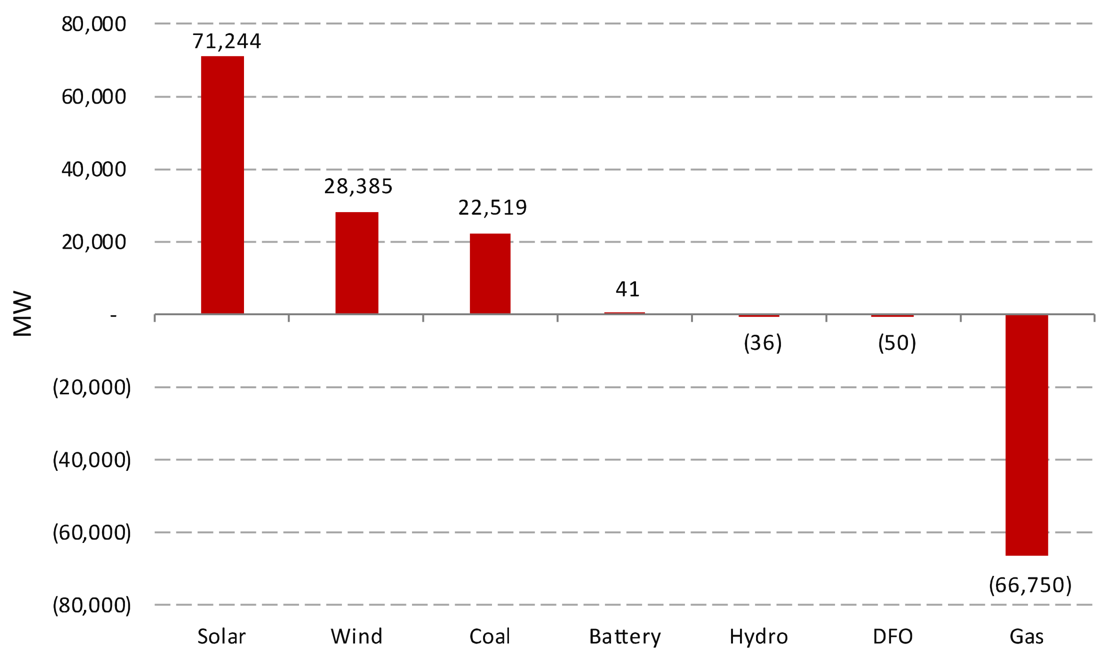


Figure 35: Change in Net Capacity Additions, HF Ban vs. Base Case (2021-2025)



The change in the generation fleet leads to a significantly different generation mix over the years in the HF Ban scenario compared to the Base Case, as Figure 36 shows. Gas market share immediately falls in 2021 from 40 percent in the Base Case to 25 percent in the HF Ban scenario, while coal market share increases from 19 percent to 33 percent. By the end of the forecast period, in 2025, gas market share falls as low as 14 percent in the HF Ban scenario, compared to 35 percent in the Base Case.

Figure 36: Projected HF Ban U.S. Generation Mix (2021-2025)

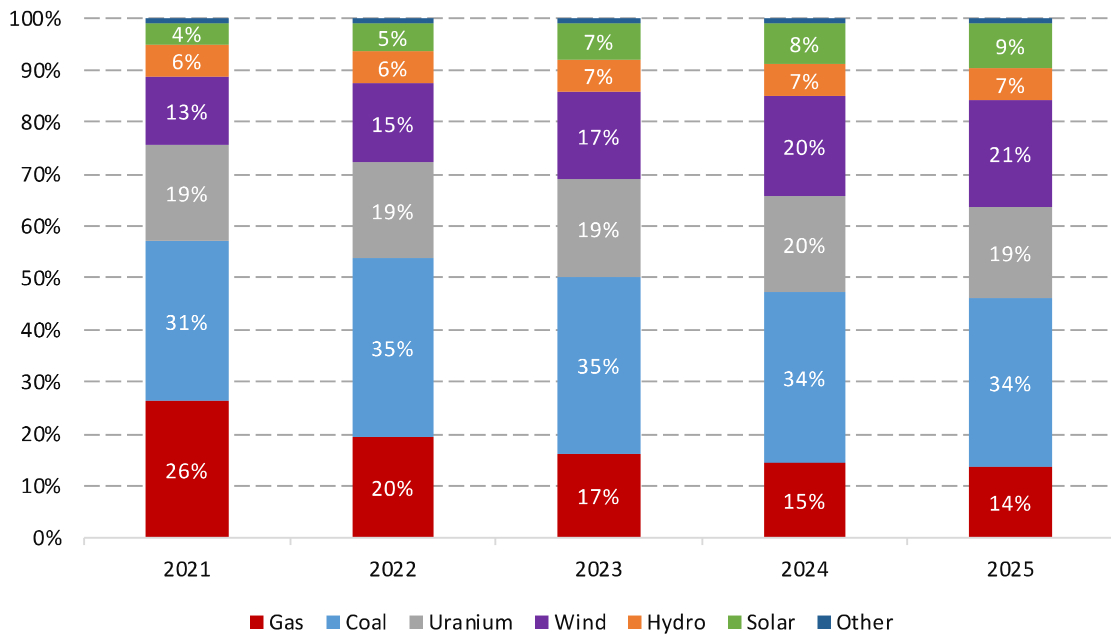
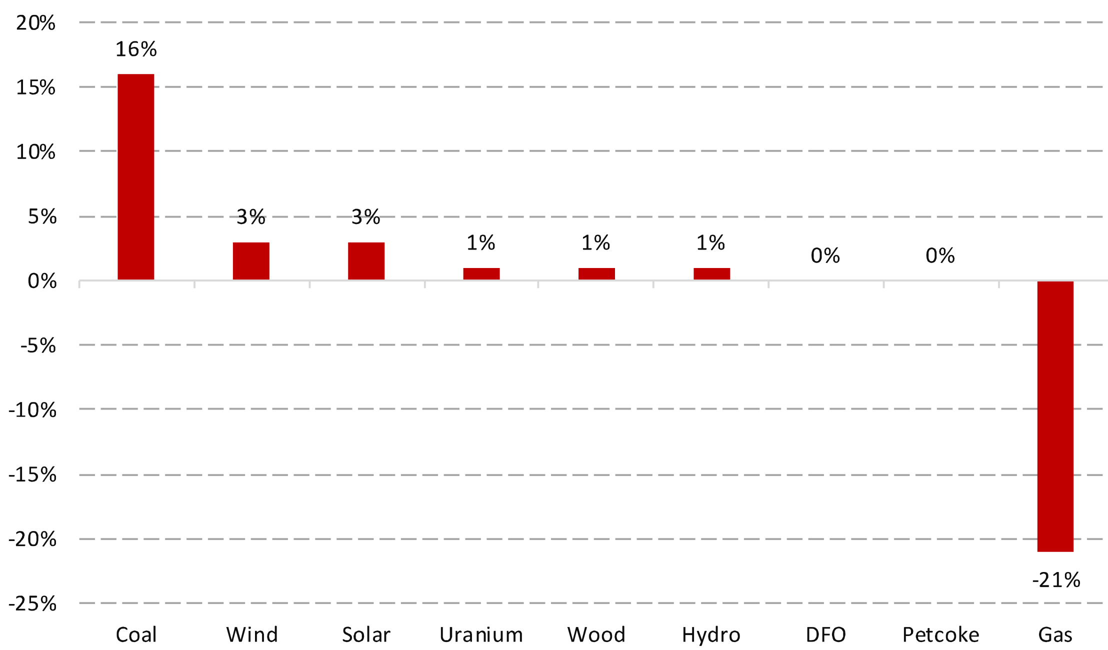


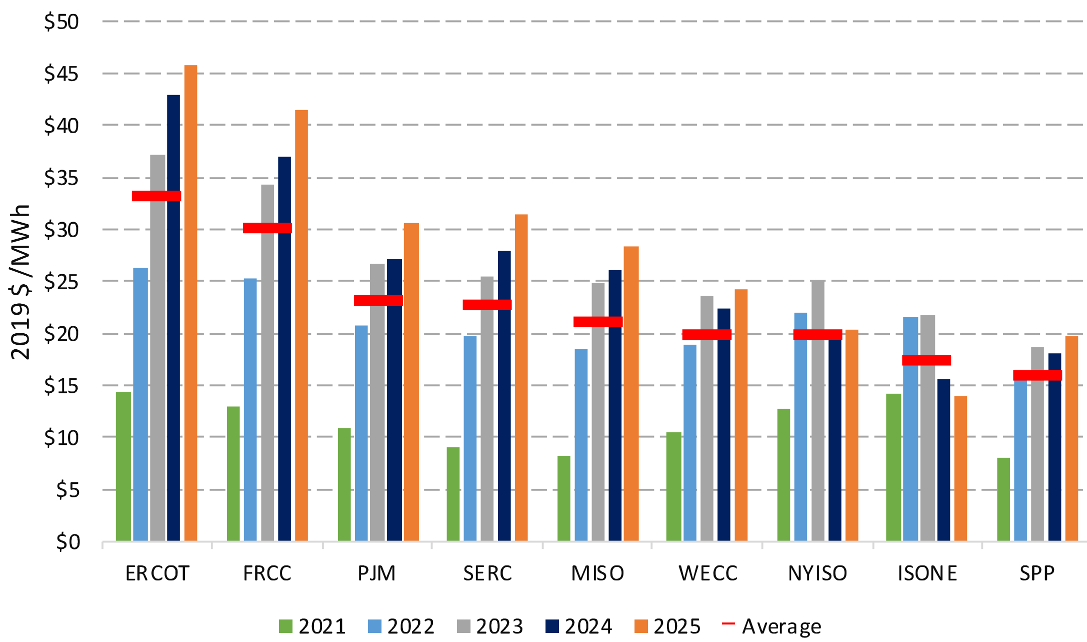
Figure 37 shows the overall change in the generation mix under the HF Ban scenario compared to the Base Case in 2025. Coal generation increases the most, backstopping lost generation from natural gas. While wind and solar have the largest capacity additions from 2021 to 2025, their changes in generation mix are only three percent each as they do not have the same installed base as coal and operate at lower capacity factors than coal. Changes in uranium, wood, hydro, DFO, and petcoke are negligible.

Figure 37: Percent Point Change in Generation Mix, HF Ban vs. Base Case (2025)



The changes to the generation fleet, fuel prices, and ultimately generator bid prices lead to a significant increase in wholesale power prices throughout the country. Figure 38 shows that the average wholesale market price increase from 2021 through 2025 ranges from a low of $16.07 per MWh in SPP to a high of $33.34 per MWh in ERCOT.

Figure 38: Increase in Wholesale Power Prices, HF Ban vs. Base Case (2021-2025)



Emissions in the Base Case scenario continue the decline seen since 2005 for CO_2, NO_x, and SO_2, albeit at a somewhat slower rate. Under the HF Ban scenario, the first year the ban is in effect shows a year over year increase for all three emissions, with CO_2 emissions rising 16 percent, NO_x emissions 17 percent, and SO_2 emissions 62 percent. In relative terms, this puts CO_2 and NO_x emissions back to near 2019 levels, and SO_2 back to somewhere in between 2018 and 2019 levels in 2021. For each emission type, the year over year increase between 2020 and 2021 would be the largest seen over the timeframe presented.

Figure 39 below shows historical, Base Case, and HF Ban CO_2 emissions from 2005 through 2025, while Figure 40 and Figure 41 show the same for NO_x and SO_2, respectively.

Figure 39: Historical and Projected CO_2 Emissions (2005-2025)

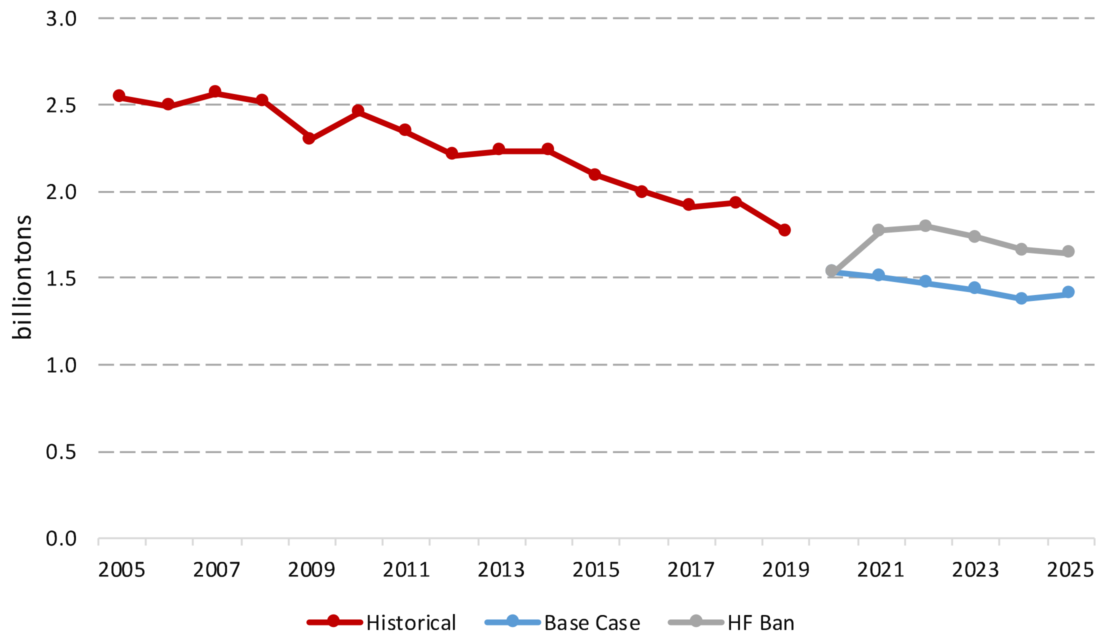


Figure 40: Historical and Projected NO_x Emissions (2005-2025)

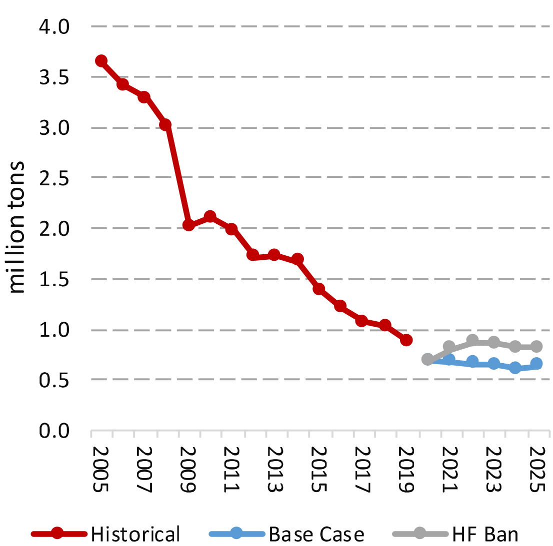
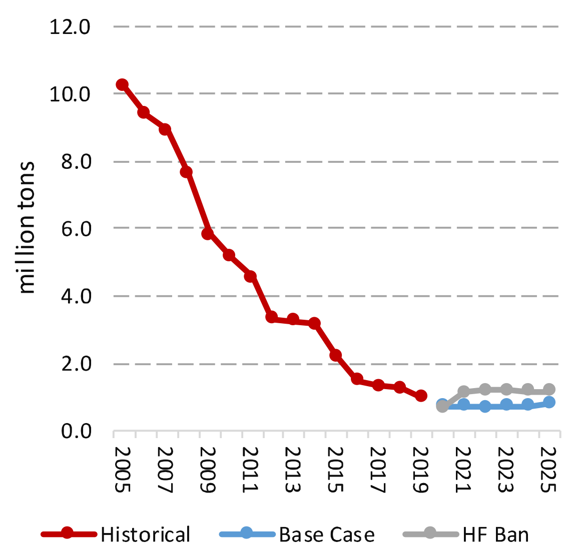


Figure 41: Historical and Projected SO_2 Emissions (2005-2025)



G. *END-USER ENERGY PRICE AND HOUSEHOLD COST IMPACTS*

This subsection summarizes the increase in energy costs for end-use customers in the residential, commercial, industrial, and transportation sectors. The residential sector end-use energy costs include electricity for lighting and air conditioning and natural gas and fuel oil for heating. The transportation sector costs incorporate gasoline and diesel costs for vehicles. The higher end-user costs for commercial and industrial users would be for many of the same items and for their operations and production, which would increase their cost of production significantly.

The end-use energy cost impacts derive from the Oil and Gas Model and the Electricity Market Model. Changes in prices were multiplied by consumption in the residential, commercial, industrial, and the transportation sectors to determine the total cost increase for each. For electricity costs, the results were derived from the Electricity Market Model's forecasted increase in the costs to serve load, given higher input prices for natural gas and fuel oil. These higher electricity costs were allocated across the different sectors based on their historical share of electricity demand according to federal data.

Table 1 shows the cost increases to end-use consumers of petroleum products, such as for gasoline, diesel, and distillate heating fuels. By far the largest user of petroleum products in the U.S. is the transportation sector, which includes transportation fuel consumption from the residential, commercial, and industrial sectors through personal vehicles, various types of medium- and heavy-duty trucks, specialized industrial vehicles, locomotives, and aircraft. Industrial users are the second largest because they need petroleum products for process heat and for operating heavy equipment, machinery, and vehicles. Residential and commercial customers would incur an additional $50.6 billion and $43.1 billion in non-transportation petroleum product costs, respectively, from 2021 to 2025. These additional costs are mainly for space and water heating.

Table 1: Increased Petroleum Product Costs for End-Use Customers in HF Ban (2019 $ billions)

Sector	2021	2022	2023	2024	2025	Total
Residential	$8.5	$13.1	$13.0	$9.7	$6.3	$50.6
Commercial	$7.3	$11.2	$11.1	$8.2	$5.4	$43.1
Industrial	$73.1	$112.4	$111.4	$83.0	$54.1	$434.0
Transportation	$229.1	$352.1	$349.0	$259.9	$169.3	$1,359.5
Total	**$318.0**	**$488.8**	**$484.5**	**$360.8**	**$235.1**	**$1,887.2**

Figure 42 shows gasoline prices at the pump in real terms and inclusive of federal and average state fuel taxes.[36] From 2005 through 2014, the average U.S. gasoline purchaser paid between $2.58 per gallon and $3.90 per gallon. The highest prices were observed in the economic run-up before the financial crisis and the Great Recession. Gasoline prices remained in this range until 2015, when large increases in U.S. shale petroleum production began.

Absent the ban, retail gasoline prices are expected to remain close to $2.10 per gallon throughout the early 2020s, as shown in Figure 42. With a hydraulic fracturing ban, retail gasoline prices would increase to nearly $3.50 per gallon in 2021 and over $4.20 per gallon in 2022 before declining to $3.20 per gallon in 2025 as more international crude supplies come online.

These higher prices would affect households and businesses, who would have lower real incomes and purchasing power as their fuel expenditures increased.

Diesel would follow a similar pattern to gasoline, which is intuitive because both product prices are highly correlated with crude prices. Diesel prices oscillated from $2.79 per gallon to $4.20 per gallon from 2005 until 2014. As U.S. tight oil production came online at scale in 2015, retail diesel prices declined to $2.00 to $2.25 per gallon, which is where they are expected to remain in the Base Case. A hydraulic fracturing ban would increase retail diesel prices to over $4.50 per gallon in 2022 and 2023 before declining to $3.40 per gallon in 2025.

Figure 42: Historical and Forecasted Retail Gasoline Prices (2005-2025)

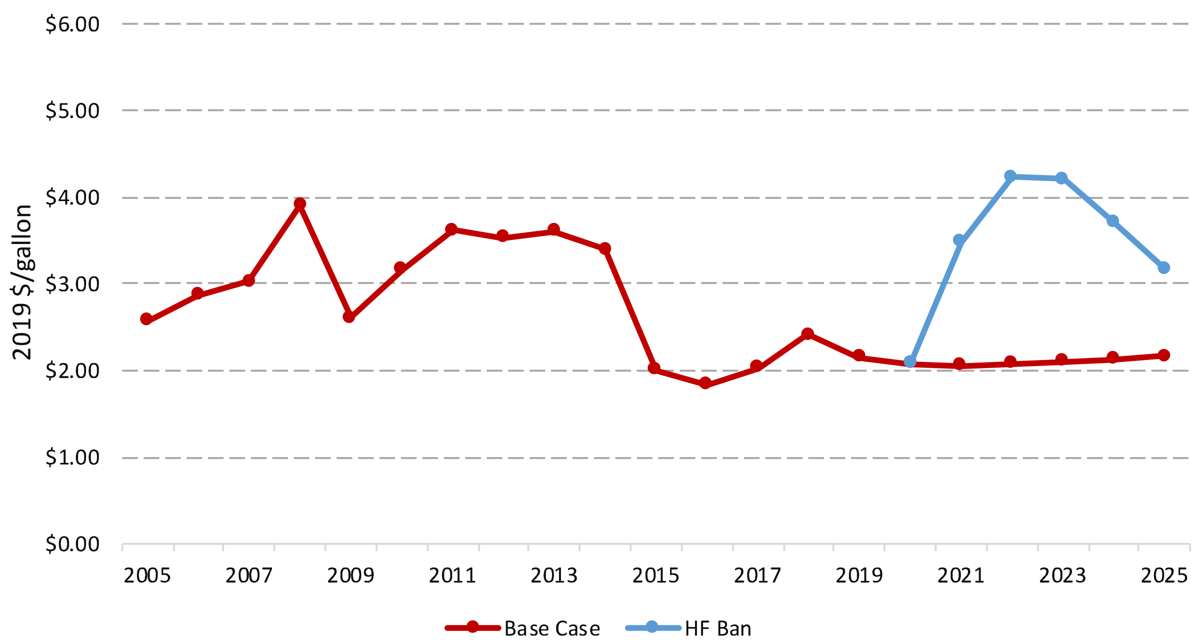


Figure 43: Historical and Forecasted Retail Diesel Prices (2005-2025)

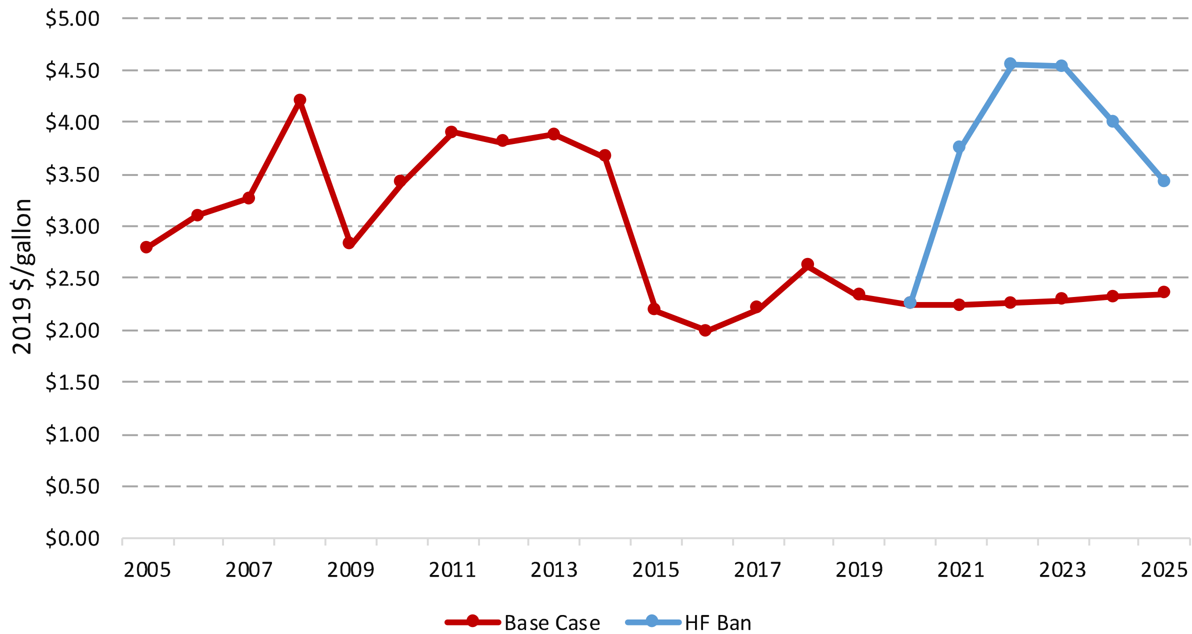


Table 2 summarizes the cost increases for electricity end-users. Electricity costs would increase by more than $450 billion between 2021 and 2025. Residential customers would have the largest increase in cost (over $180 billion, more than an average of $36 billion per year), followed by commercial and industrial customers who would also face substantially higher costs because of their individually higher levels of electricity demand.

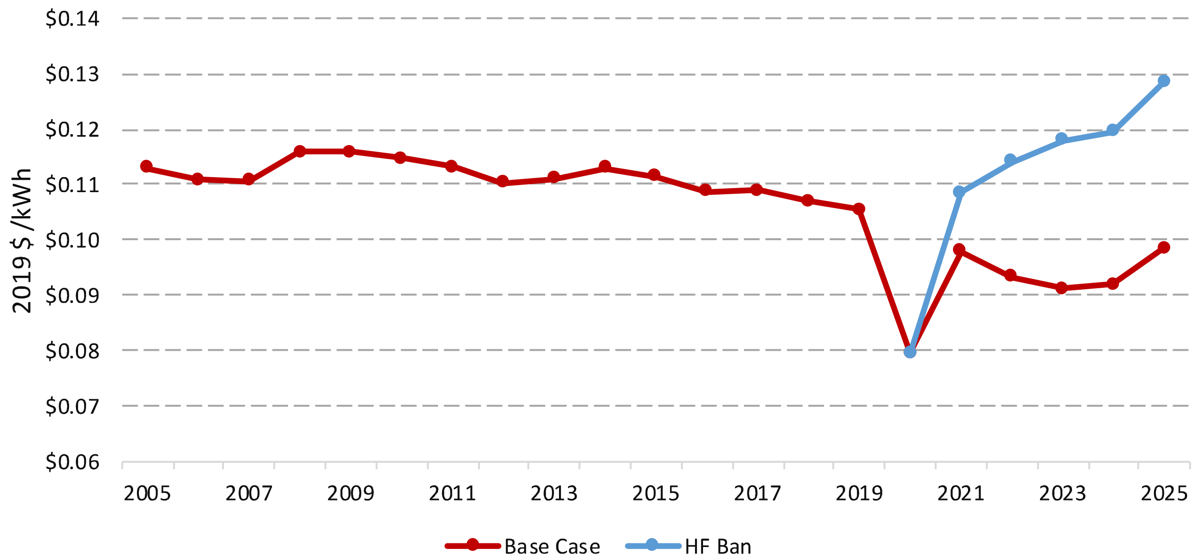
Table 2: Increased Electricity Costs for End-Use Customers in HF Ban (2019 $ billions)

Sector	2021	2022	2023	2024	2025	Total
Residential	$16.4	$32.3	$42.3	$44.2	$48.7	$183.8
Commercial	$15.6	$30.5	$39.6	$40.9	$45.0	$171.7
Industrial	$11.2	$22.4	$29.6	$31.1	$34.2	$128.4
Transportation	$0.1	$0.2	$0.2	$0.2	$0.2	$0.9
Total	**$43.2**	**$85.3**	**$111.5**	**$116.1**	**$127.8**	**$483.9**

U.S. average retail electricity prices have remained steady between $0.11 per kWh and $0.12 per kWh during 2005 and 2019, as shown in Figure 44. Year to date prices in 2020 are exceptionally low because of the disruptions of the COVID-19 pandemic, which decreased electricity load, lowered demand for natural gas, and decreased natural gas prices.

Absent the ban, electricity prices are expected to decline in the early 2020s because of continued low natural gas prices and investment in various types of renewable power. A ban on hydraulic fracturing, on the other hand, would increase average electricity prices to $0.12 per kilowatt-hours (kWh) in 2023 and $0.13 per kWh in 2025, the highest levels in the past 15 years.

Figure 44: Historical and Forecasted Average Retail Electricity Prices



As shown in Table 3, households and businesses would sustain more than $400 billion in higher natural gas costs in a HF Ban scenario. Industrial customers would incur the largest direct cost impact of $201 billion over five years as they rely heavily on natural gas as a feedstock for process heat and steam production. Residential customers would experience the second-largest impact of $105 billion over five years as they use natural gas for space heating, water heating, and cooking. Commercial customers also would see substantial impacts amounting to $70 billion over five years.

Table 3: Increased Natural Gas Costs for End-Use Customers (2019 $ billions)

Sector	2021	2022	2023	2024	2025	Total
Residential	$8.9	$18.2	$23.5	$25.8	$28.6	$105.1
Commercial	$6.2	$12.3	$15.6	$17.0	$18.7	$69.8
Industrial	$16.0	$33.7	$44.6	$49.6	$56.9	$200.8
Transportation	$1.0	$1.0	$1.5	$1.3	$1.5	$6.2
Total	**$34.4**	**$70.4**	**$90.9**	**$97.9**	**$108.8**	**$402.5**

Table 4 summarizes the additional direct energy costs that consumers would experience under a HF Ban scenario. The table accounts for all energy price impacts including higher prices for natural gas, petroleum products, and electricity. Between 2021 and 2025, consumers would experience energy cost increases of more than $2.8 trillion in total. The transportation sector represents almost half of the total cost increase at $1.4 trillion. Second to transportation would be the industrial sector, incurring an increase in total costs of $0.8 trillion. The residential and commercial sectors would experience noteworthy increases in their costs, as well, with each sector sustaining approximately $300 billion in additional costs over five years.

Table 4: Total Costs for End-Use Customers (2019 $ billions)

Sector	2021	2022	2023	2024	2025	Total
Residential	$33.8	$63.7	$78.8	$79.7	$83.6	$339.6
Commercial	$29.1	$54.0	$66.3	$66.2	$69.0	$284.5
Industrial	$100.3	$168.5	$185.6	$163.7	$145.1	$763.3
Transportation	$230.2	$353.3	$350.7	$261.4	$171.0	$1,366.6
Total	**$393.4**	**$639.5**	**$681.4**	**$571.0**	**$468.8**	**$2,754.0**

To put the results in Table 4 in perspective, U.S. GDP in 2019 was approximately $21.5 trillion. The $2.8 trillion in increased costs from 2021 to 2025 is approximately 12.8 percent of current GDP or 2.6 percent of GDP in each year of analysis on average.

These costs, along with a decrease in U.S. oil and natural gas production, would have substantial economic impacts like lower employment and economic activity associated with extraction activities and their supply chain, lower incomes and purchasing power for households, and higher costs for businesses. All of these factors would contribute to a weaker U.S. economy.

The next section describes the large economic impacts under a possible HF Ban scenario and other effects in the context of macroeconomic modeling.

IV. Modeling the Macroeconomic Impacts of a Hydraulic Fracturing Ban, 2021–2025

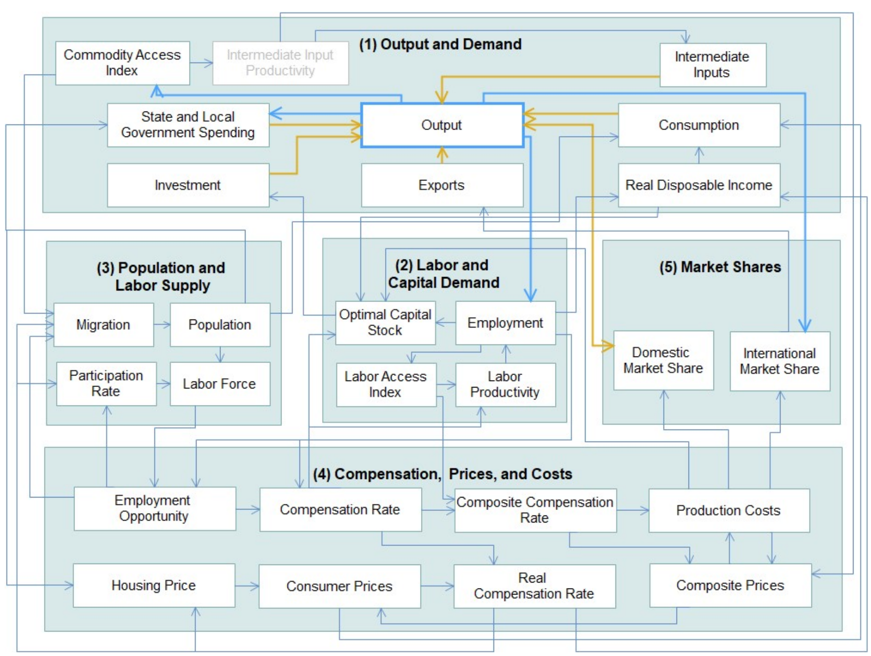
A. Overview

This section describes the broader macroeconomic impacts under a hydraulic fracturing ban scenario. The macroeconomic impacts were developed using the results of the energy market analyses described earlier as inputs into REMI,[37] a standard economic impact modeling platform used by academics, consultants, and government agencies to model the regional and macroeconomic effects of policy changes.

B. Macroeconomic Model

REMI is a dynamic, computable general equilibrium (CGE) model of the U.S. and regional economies and It is a common tool used to forecast the future of economic growth and its responses to policy stimuli. Figure 45 summarizes the structure of REMI, a model which has a series of five blocks representing different portions of the economy. The figure includes the five blocks, the individual concepts within the blocks, and their linkages represented with a series of connecting arrows.

Figure 45: REMI Model Structure



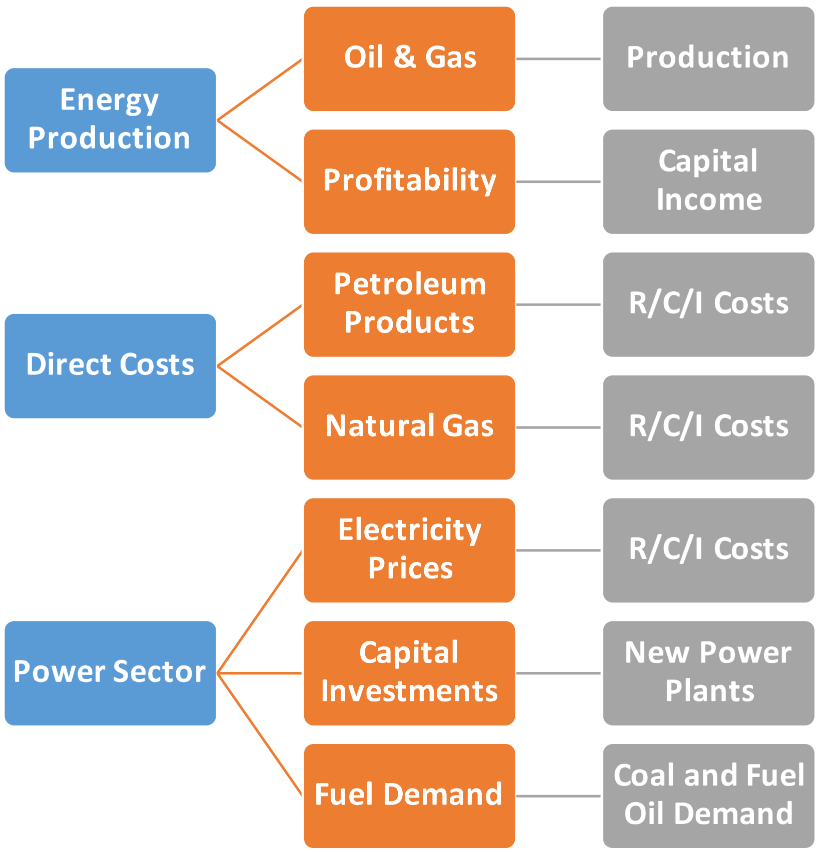
Block 1 includes aggregate demand, supply, and GDP components, such as consumption, investments, government spending, and net exports. Block 2 is the perspective of producers throughout the economy and their demand for capital and labor in production decisions. Block 3 is the demographic portion of the model, including natural demographic changes, domestic migration, and labor supply.

Block 4 covers the markets for various commodities, services, and goods. Block 5 models the relative competitiveness of the U.S. economy.

C. *INPUTS TO REMI*

As shown previously, a HF Ban scenario would significantly impact the U.S. energy sector prices and production. These energy market and consumer cost impacts were converted into inputs for REMI. Figure 46 summarizes REMI inputs, such as energy production, costs for customers, and the impacts in the electric power sector.

Figure 46: Inputs to REMI



For example, a HF Ban scenario would decrease U.S. oil and natural gas production, which REMI reflects through reduced output for the extraction sector. Additionally, a HF Ban scenario would result in higher prices for petroleum, natural gas, and electricity, which REMI includes as a higher cost of living (a reduction in real purchasing power) for households. Lastly, a HF Ban scenario would increase production costs for U.S. commercial and industrial customers, which REMI reflects as added costs.

REMI also incorporates the counterintuitive yet critical result that a hydraulic fracturing ban would increase the remaining oil and natural gas producers' profitability if oil and natural gas prices rise faster than energy production declines. This dynamic may create windfall revenues for the remaining producers.

These windfall profits enter REMI through an increase in the capital income to households through higher incomes and dividends and mainly benefit higher-income households. Households would spend this additional income on consumer goods and services, stimulating the economy through their expenditures.

Additional inputs from the Electricity Market Model would include variables related to changing investments in power generation resources, such as reduced investment in gas plants, increased investment in wind and solar, and changing fuel expenditures.

The modeling makes two implicit assumptions about the economic response to a hydraulic fracturing ban based on REMI's inputs and structure. These include:

1. By default, REMI allows for higher production costs for U.S. commercial and industrial sectors to degrade their competitive position relative to the rest of the world. Normally, this would decrease U.S. exports and increase U.S. imports if the impacts were isolated to the U.S. However, because a hydraulic fracturing ban would likely increase global energy prices, this approach conservatively assumes that higher prices would not put U.S. businesses at a competitive disadvantage.
2. For this analysis, it was assumed that a monetary policy response could not counteract potential contractions to the labor market through 2025 resulting from a ban on hydraulic fracturing. Because of the upsets owing to the COVID-19 pandemic, the federal funds rate is already very close to zero.[38] The Congressional Budget Office (CBO) does not expect the federal funds rate to exceed 0.1 percent until 2026,[39] which leaves the Federal Reserve with little room to maneuver interest rates.

D. Macroeconomic Impacts

A nation-wide ban on hydraulic fracturing ban would cause a significant upset to the U.S. economy. Decreased energy production and increased energy costs for U.S. consumers would derail the recovery underway from COVID-19, increasing the risk of another recession in the early 2020s. This section summarizes these impacts in terms of their influence on leading macroeconomic indicators, such as employment and GDP, across different economic sectors, and on property values and tax revenues nationally.

Figure 47 shows the REMI forecast of U.S. employment with and without a ban on hydraulic fracturing. Before the COVID-19 pandemic, in 2019, U.S. employment peaked at 202.8 million jobs after adding between 2 million and 4 million jobs each year the previous five years.[40] The model estimates U.S. employment in 2020 will average 191.1 million – a drop of 11.7 million resulting from the pandemic, using currently available data.

U.S. employment forecasts diverge starting in 2021 as shown in Figure 47. In the Base Case, the U.S. economy would gain 7.0 million jobs in 2021, and total employment would surpass the pre-recessionary peak of 202.8 million jobs in 2023 and would eventually reach 208.4 million jobs by 2025. In the HF Ban scenario, the labor market would add only 3.7 million jobs in 2021 because of the ban's impact on energy production and prices. These impacts would grow over time, and, by 2025, U.S. employment would total 200.7 million jobs, 7.7 million fewer jobs than in the Base Case, and below the pre-recession peak of 202.8 million jobs.

The difference in U.S. employment between the two scenarios is significant. For example, the HF Ban scenario results in employment of 3.2 million fewer jobs in 2021 relative to the Base Case. By 2024 and 2025, the HF Ban scenario employment impact would grow to 7.7 million fewer jobs in each year. In the long term, the U.S. economy may start to adapt to higher energy prices with new investments and technologies, such as efficiency and investments in new power generation assets. Nonetheless, disruptions to the labor market would be severe between 2021 and 2025.

Figure 47: Historical and Projected U.S. Employment (2016-2025)

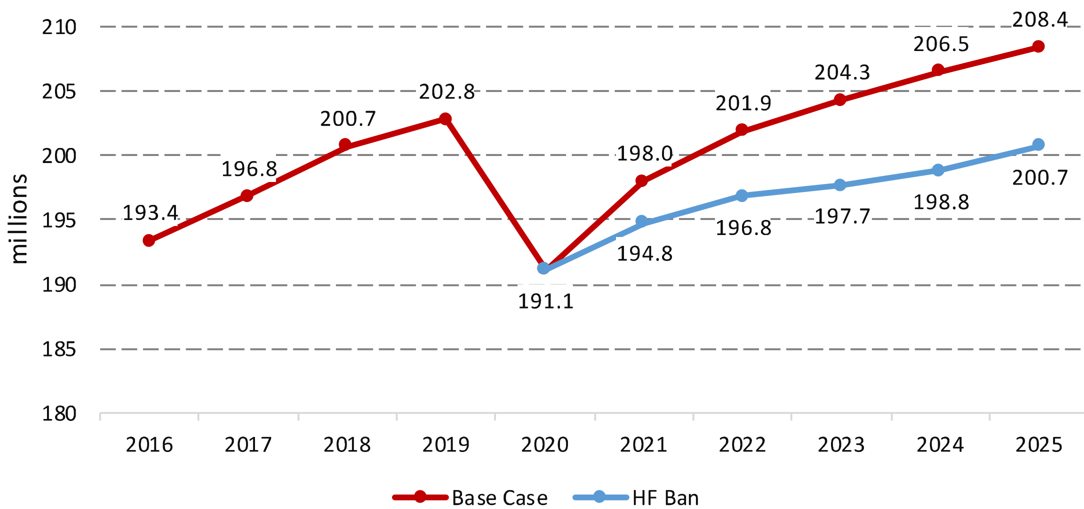


Figure 48 shows the economic impacts to U.S. GDP. By 2024, the ban would reduce U.S. GDP by over $1.1 trillion per year. The general trends in Figure 48 are similar to those in Figure 47. Before the COVID-19 pandemic, the U.S. GDP was growing steadily between two percent and three percent per year. Figure 48 shows a commensurate disruption because of the pandemic, followed by a split in the forecast for the two scenarios. Without the ban, the U.S. GDP is expected to grow to $23.5 trillion by 2025. With the hydraulic fracturing ban, U.S. is projected to have much lower GDP levels, with the lost GDP starting at $0.4 trillion in 2021 and rising to $1.1 trillion in 2024 and 2025.

Figure 48: Historical and Projected U.S. GDP (2016-2025)

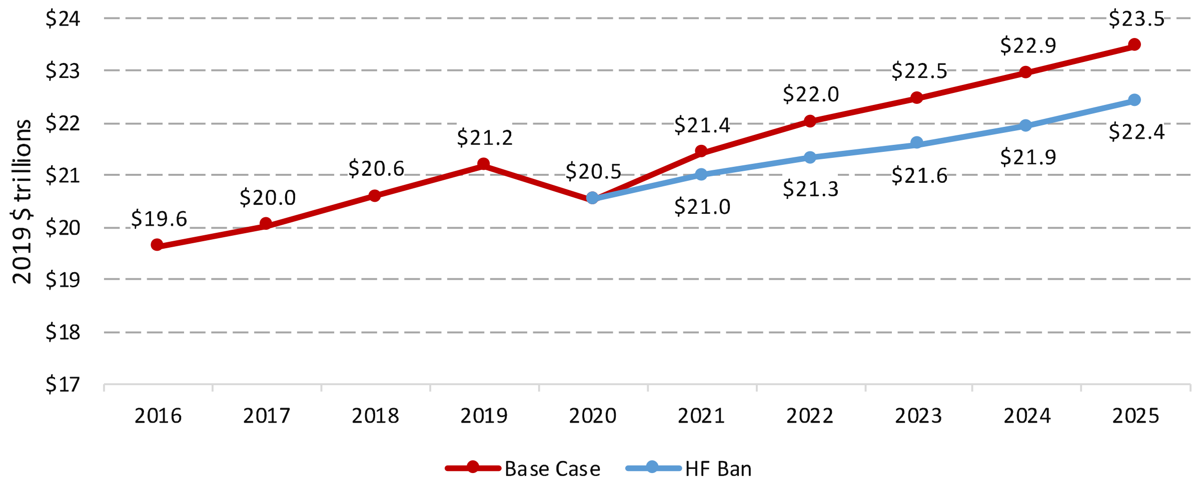
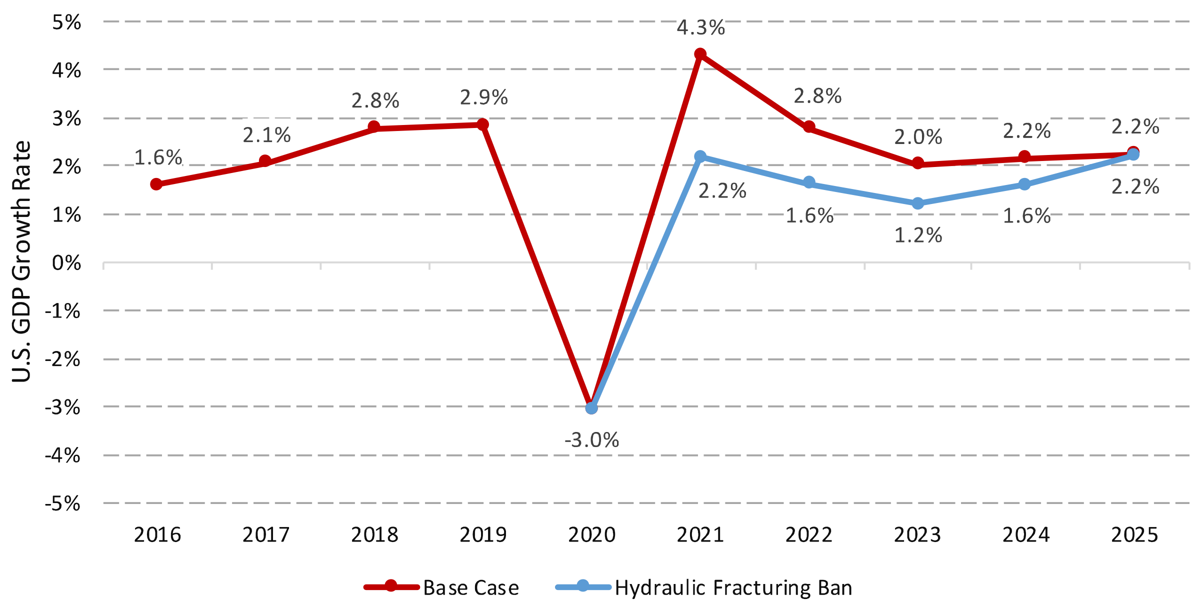


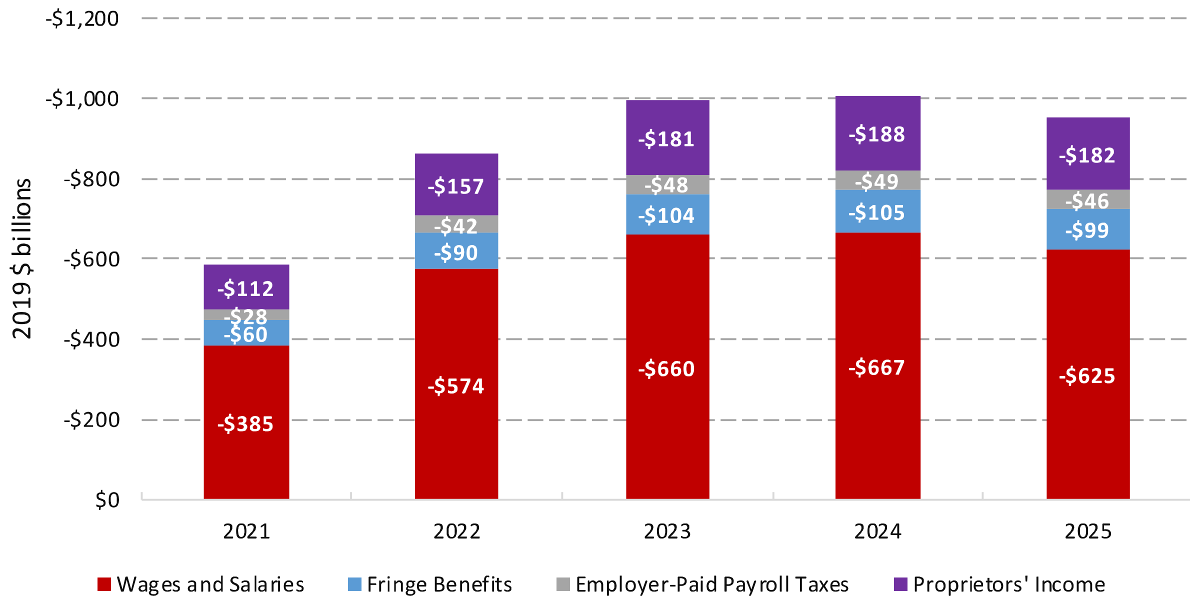
Figure 49 shows the growth rate for U.S. GDP between the two scenarios. In the Base Case, U.S. GDP growth would exceed 4.0 percent in 2021 and be 2.0 percent or greater through 2025. Under the HF Ban scenario, the 2021 growth rate for U.S. GDP would be 2.1 percent and would below 1.75 percent annually from 2022 through 2024 before recovering to above 2.0 percent in 2025.

Figure 49: Historical and Projected U.S. GDP Growth Rate (2016-2025)



A hydraulic fracturing ban would have a significant contractionary effect on the wages and overall compensations paid to American workers. Figure 50 summarizes these results by category, including wages, salaries, fringe benefits, payroll taxes, and the proprietors' income.

Figure 50: Impact to Labor Income from Hydraulic Fracturing Ban (2021-2025)

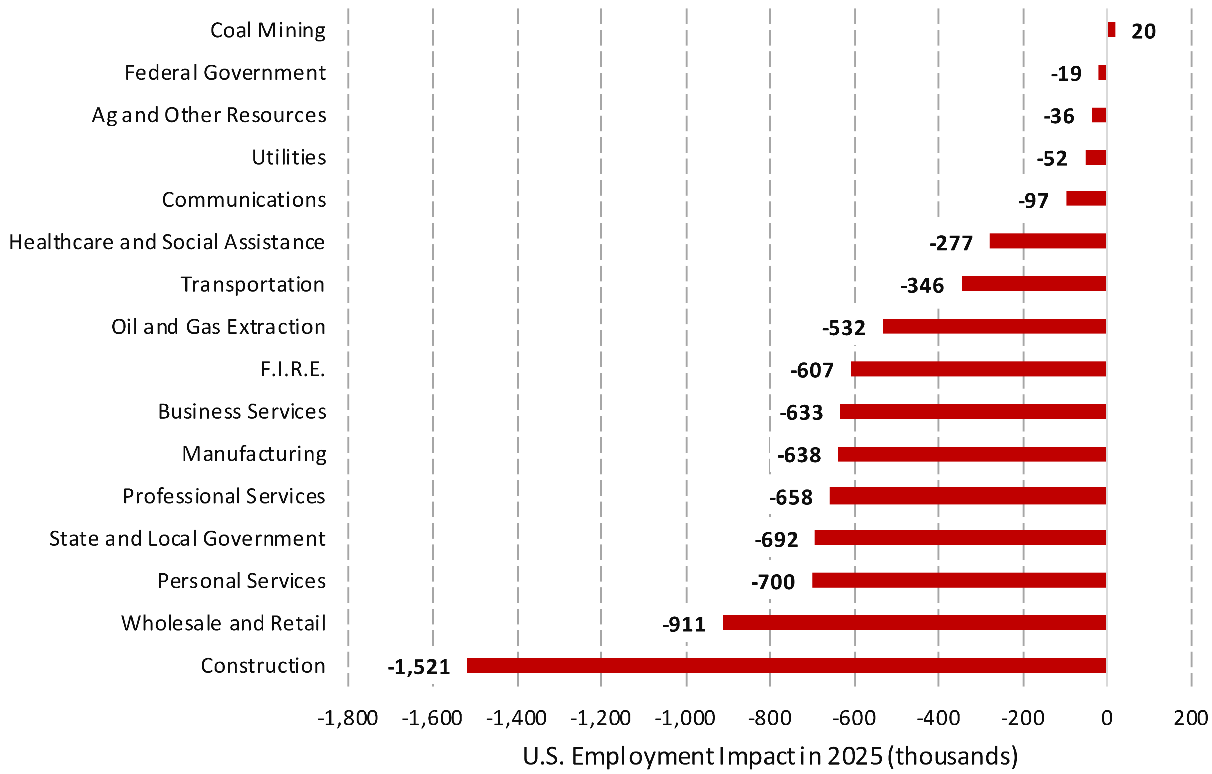


Wages and salaries include all the cash income paid to employees. Fringe benefits consist of various non-cash forms of compensation. The largest two components of fringe benefits are employer-sponsored health insurance and employer-paid contributions to pensions and nongovernment retirement savings. Employer-paid payroll taxes represent the 7.65 percent tax on employee payrolls paid by employers, representing their contribution to Social Security and Medicare. Proprietors' income is income for the self-employed in sole proprietorships or partnerships.

The peak impact to wages and salaries would be $667 billion in 2024 along with $105 billion in lost fringe benefits, $49 billion in lost employer-paid payroll taxes, and $188 billion in lost proprietors' income relative to the Base Case.

The impacts of a hydraulic fracturing ban would not be equal across economic sectors and industries. Figure 51 categorizes the economy into 16 sectors based on an aggregation of the North American Industry Classification System (NAICS),[41] the standardized system used by statistical bureaus and REMI to describe the economy's structure. Figure 51 arranges employment impacts in 2025 from sectors most positively affected to those most negatively affected.

Figure 51: Impact to Employment by Economic Sector from Hydraulic Fracturing Ban (2025)



Every sector except for the coal sector, which benefits from increased coal demand from electricity markets due to higher natural gas prices, would have lower employment levels in 2025 relative to the Base Case. The ban's disruption would not be confined to the extraction of oil and natural gas.

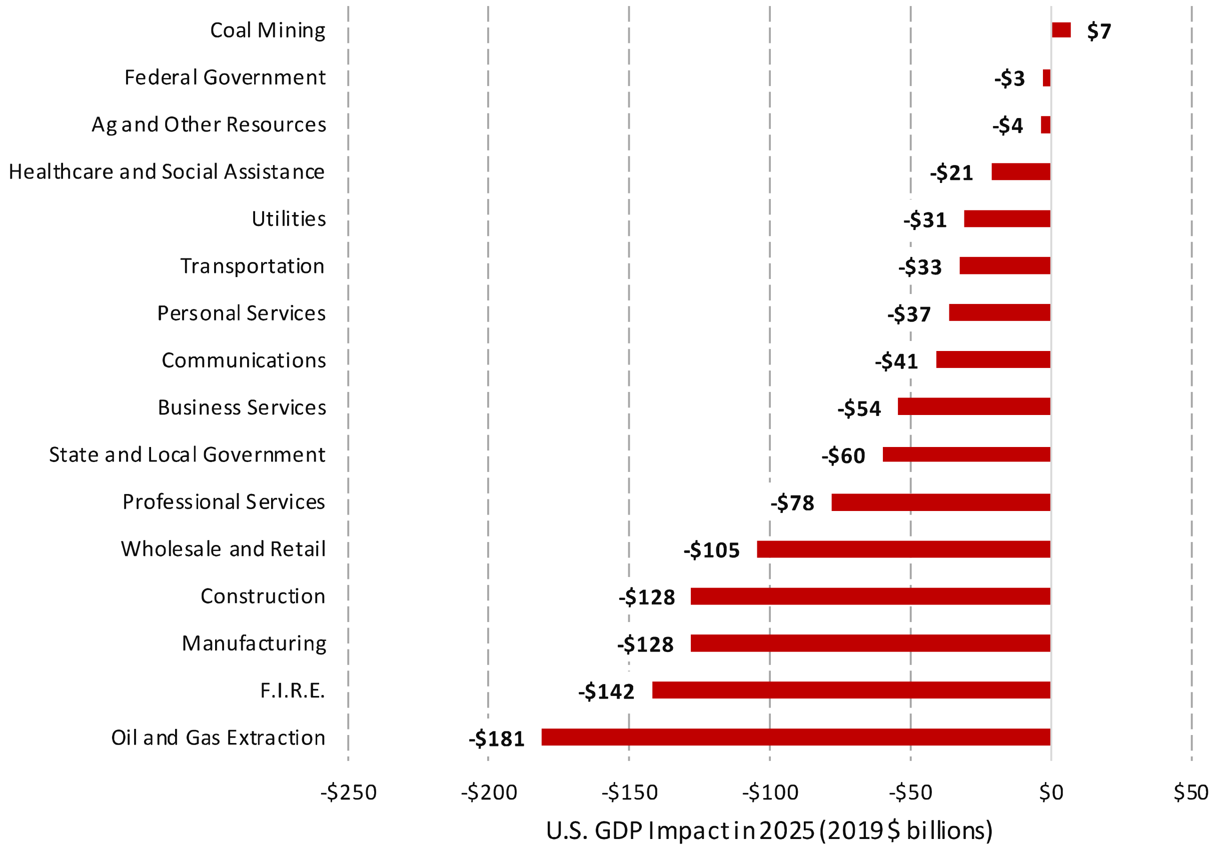
The effects would be widespread across socioeconomic strata. High-wage industries such as finance, insurance, and real estate (F.I.R.E.); business services; and professional services would each have over 600,000 fewer jobs in 2025 because of the ban. Low-wage sectors, including personal services, wholesale, and retail sectors would also be impacted.

Manufacturers would experience pressure from two sides in the event of a hydraulic fracturing ban. Their energy costs would rise significantly, and sales orders would decline because consumers, who would themselves face higher energy costs and a weaker labor market, would have less income and purchasing power to buy the goods that manufacturers produce. The effect would be the same for communications, healthcare, transportation, and personal services.

Two sectors with large employment impacts would be state and local government and the construction sector. State and local governments would have 692,000 fewer jobs in 2025 because of reduced income, sales, and property tax revenues. Construction is one of the largest economic sectors (with over 10.7 million jobs in 2019).[42] Construction supports the other economic sectors by building and maintaining infrastructure, homes, commercial and industrial buildings, and installing capital equipment for other businesses. Generalized economic contractions always tend to affect the construction sector, which Figure 51 shows strongly.

Figure 52 shows sectoral GDP contributions. The ordering of impacts in Figure 52 contrasts slightly with the ordering in Figure 51 because the sectors have differing labor intensities per dollar of GDP contribution.

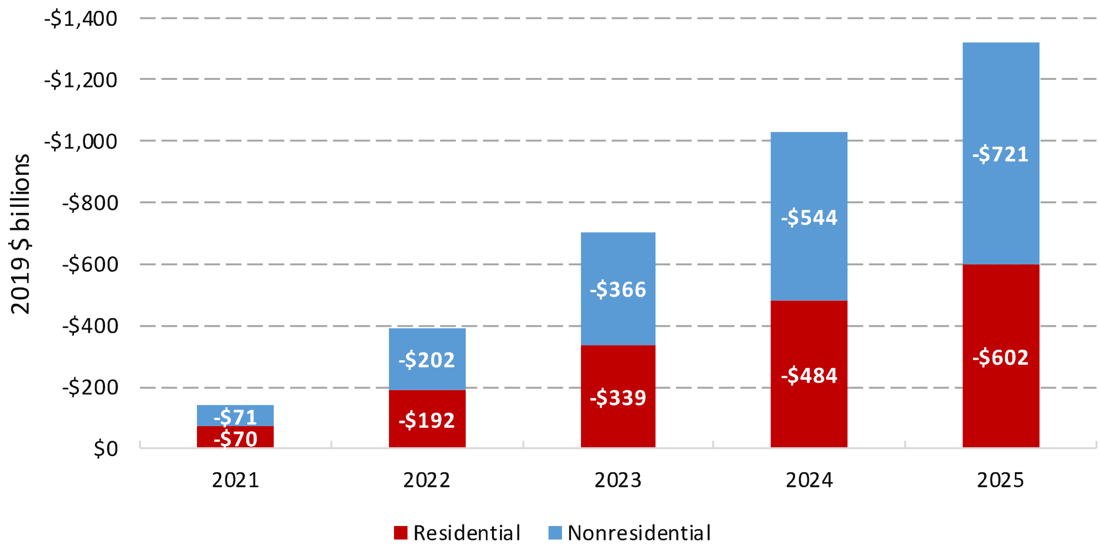
Figure 52: Impact to GDP by Economic Sector from Hydraulic Fracturing Ban (2025)



As in Figure 51, the only sector that would see an increase in its economic contribution in 2025 under a hydraulic fracturing ban would be coal mining. The sector with the most negative impact would be oil and natural gas extraction, which would experience a decrease in its GDP contribution of $181 billion in 2025 in the REMI simulation. Other sectors with large decreases to their GDP contributions would be F.I.R.E., manufacturing, construction, and the combined wholesale and retail sector.

Another impact of the ban would be a decrease in American homes' property values and the values of landholdings and other structures (such as commercial or office space and industrial facilities). These impacts would come about when a weaker economy (described in Figure 47, Figure 48, and Figure 49) has depressive effects on real estate markets. A weaker economy than the Base Case would mean households have less income, reducing the home prices they can afford and putting downward pressure on home prices. The same process would play itself out for nonresidential real estate when businesses, facing higher energy costs and lower sales orders because of reduced GDP, have less to spend on real estate or rents, which puts downward pressure on prices.

Figure 53: Impact to Real Estate Valuations from Hydraulic Fracturing Ban (2021-2025)



By 2025, real estate valuations would decrease by $602 billion for residential real estate and $721 billion for nonresidential real estate. According to the U.S. Census Bureau,[43] in 2019 there were 139.7 million housing units nationally. Dividing the $602 billion results from 2025 by 139.7 million housing units in the U.S. implies an average impact to home prices of around $4,300 each.

The results also include a "fiscal impact analysis" – that is, the impact of the hydraulic fracturing ban on federal, state, and local tax revenues and, by extension, the availability of public funds to pay for such priorities as schools, public universities, healthcare, and transportation.

Figure 54 shows the results for federal tax revenues. The federal government primarily relies on workers and investors' income for revenues through federal income and payroll taxes. When these decrease, as Figure 48 and Figure 49 show for GDP (GDP is the sum of national income) and Figure 50 shows for American workers' income, federal tax revenues decrease. By 2025, the impact to federal tax revenues would be $167 billion, or approximately the annual budget of the Department of Labor or the Department of Agriculture, according to the CBO.[44]

Figure 54: Impact to Federal Tax Revenues from Hydraulic Fracturing Ban (2021-2025)

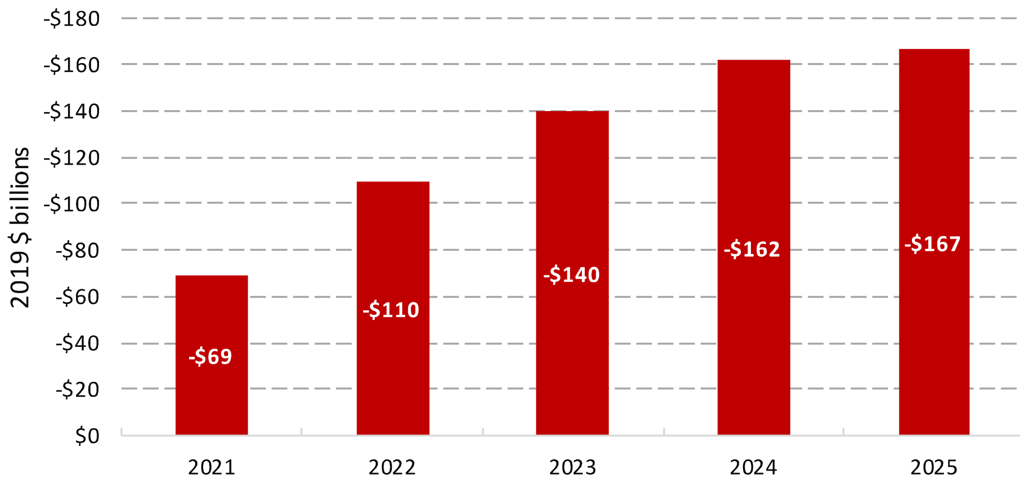


Table 5 describes the fiscal results for state and local governments. The table allocates total state and local tax revenues to different spending priorities based on the share of historical spending from each of those priorities provided by the National Association for State Budget Officers for states[45] and from the U.S. Census Bureau for local government entities.[46]

Table 5: Impacts on State and Local Tax Revenues from Hydraulic Fracturing Ban (2019 $ billions)

Expenditure	2021	2022	2023	2024	2025	Total
K-12 Education	-$8.6	-$15.1	-$18.3	-$18.8	-$18.4	-$79.3
Higher Education	-$1.3	-$2.2	-$2.7	-$2.7	-$2.7	-$11.6
Public Assistance	-$0.7	-$1.2	-$1.4	-$1.4	-$1.4	-$6.1
Healthcare	-$2.5	-$4.4	-$5.2	-$5.2	-$5.1	-$22.3
Corrections	-$0.6	-$1.0	-$1.2	-$1.3	-$1.2	-$5.3
Transportation	-$1.8	-$3.1	-$3.8	-$3.9	-$3.8	-$16.5
All Other	-$12.6	-$22.3	-$27.0	-$27.9	-$27.4	-$117.2
Total	-$28.0	-$49.3	-$59.6	-$61.3	-$60.0	-$258.3

The impacts from Table 5 would include $79.3 billion less for K-12 education from 2021 through 2025, $11.6 billion less for colleges and universities, and $258.3 billion less overall. The lower revenues in Table 5 would force states and localities to make difficult decisions regarding which of their public services to prioritize (or they would require more federal assistance).

Figure 55 shows the national impact on severance tax and impact fee revenues from the hydraulic fracturing ban. Because so many of the largest oil- and natural gas-producing states base their severance tax on the value of the extracted material rather than the fuels' volume or energy content, the hydraulic fracturing ban would increase severance tax revenues through at least 2025.

Examples of the major oil and natural gas states basing their severance tax on the value of extraction include Texas, Louisiana, North Dakota, Alaska, Oklahoma, and Colorado.[47]

Figure 55 shows severance tax revenues increasing through 2025 as the relative increase in energy prices outweighs the relative decrease in energy production. While the HF Ban scenario would benefit severance tax and impact fee revenues, the larger impact of higher energy prices and decreased production would have larger impacts on the broader economy, as the previous figures and tables demonstrate. For example, the decrease in income, sales, and property taxes paid by households and businesses would be far more than any increase in severance tax and impact fee revenues.

Figure 55: Impact to Severance Tax and Impact Fee Revenues from HF Ban (2021-2025)

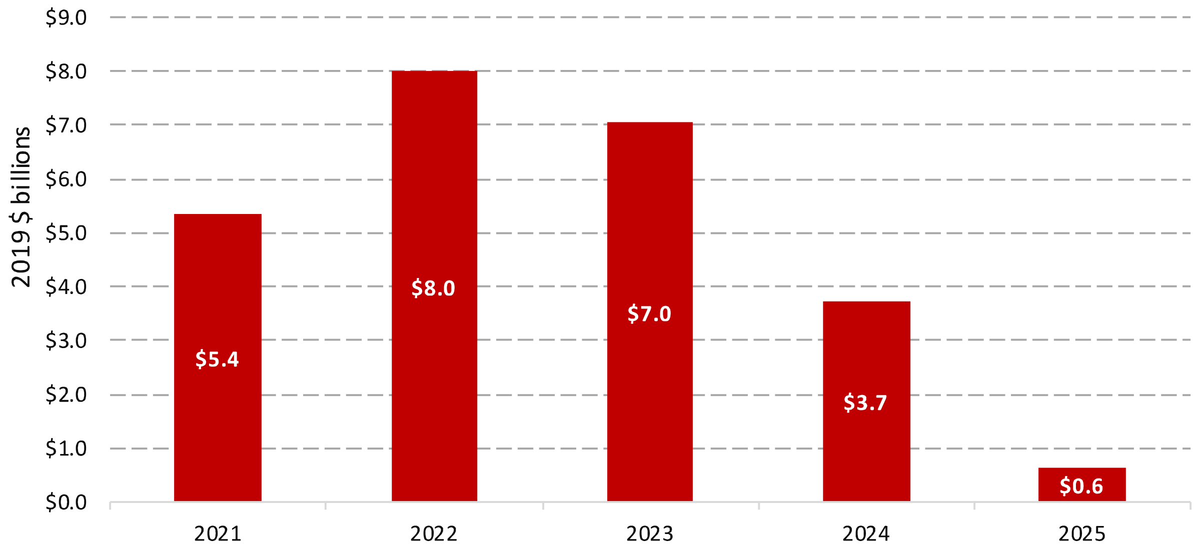
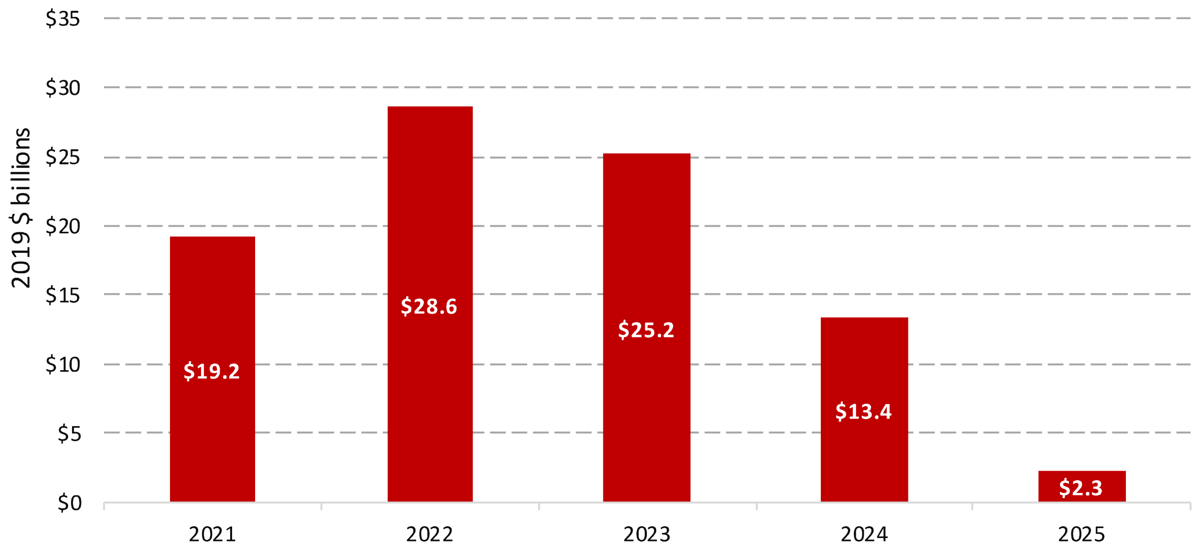


Figure 56 shows the estimated impact to royalties nationwide from the ban. Similar to severance tax and impact fee revenues shown in Figure 55, royalties would increase because the relative increase in energy prices would outweigh the relative decrease in energy production. The largest oil and gas royalty increase would occur in 2022. Royalty increases would then subside by 2025 as oil and natural gas prices stabilize while oil and natural gas production decline.

Figure 56: Impact to Royalties from Hydraulic Fracturing Ban (2021-2025)



E. Comparisons to Previous Studies

Three previous studies analyzed the energy market and macroeconomic impacts of a hydraulic fracturing ban in a manner akin to this research. Those three previous studies are:

1. "America's Progress at Risk: An Economic Analysis of a Ban on Fracking and Federal Leasing for Natural Gas and Oil Development," American Petroleum Institute (API)[48]
2. "What if Hydraulic Fracturing Were Banned: The Economic Benefits of the Shale Revolution and the Consequences of Ending It," Global Energy Institute at the U.S. Chamber of Commerce (GEI)[49]
3. "The Impact of a Fracking Ban on Shale Production and the Economy," Michael C. Lynch, Energy Policy Research Foundation (EPRINC)[50]

The results of the API study are broadly consistent with the results of this report. The API forecasts the U.S. economy would lose a maximum of $1.2 trillion in GDP, similar to the $1.1 trillion found here for 2023 and 2024. Additionally, the API study finds a peak employment impact of 7.5 million jobs, similar to the peak employment impact found here of 7.7 million jobs in 2024 and 2025.

The API relies on the National Energy Modeling System (NEMS) model[51] built by DOE for its energy outlooks. Pairing the dynamic NEMS energy model with a dynamic macroeconomic model allows API to ask and answer the question about the energy and economic impacts of a hydraulic fracturing ban in a similar manner to the methodology here. Instead of NEMS, this study uses the implied elasticities of energy supply and energy demand within the Oil and Natural Gas Model, the Electricity Market Model for the electricity sector (NEMS addresses the dispatch of plants and net capacity expansion in a similar manner), and the dynamic REMI model for the economic impact analysis, leading to this convergence of results.

The GEI report uses a simpler methodology than API and the approach here. The energy supply and energy cost side use a similar methodology to the one described earlier. However, the macroeconomic model underlying the GEI report is IMPLAN, a static model, unlike REMI.

The GEI report finds much larger economic impacts than the others here. For instance, in 2025, it finds employment impacts of 19 million and GDP impacts of $2.3 trillion, both approximately twice the findings here and in the API report. The likely cause of this discrepancy is the use of a static IMPLAN model instead of a dynamic macroeconomic model.

The EPRINC report does not include a similar macroeconomic analysis to this report or those found in the API and GEI reports. It does, however, analyze the impacts on energy markets from the hydraulic fracturing ban. EPRINC applies a similar methodology to the one here to estimate production from shale oil and natural gas resources going forward after the ban using historical decline curves.

EPRINC provides a range of energy price impacts and does not make point estimates. For example, the report estimates $80 to $100 per barrel crude prices resulting from the ban. For gas, the report estimates, "The shift from exporting 4 Tcf/yr to net imports of as much as 4 Tcf/yr would clearly tighten that market and bring prices for internationally traded natural gas close to parity with oil prices, in other words, over $10 per MMBtu."[52] The EPRINC study estimates U.S. gas prices would range from $7.5 per MMBtu to $10 per MMBtu.

The forecasted peak WTI prices in this study at $130 per barrel in 2022 are higher than EPRINC's study. However, after 2022, the prices decline to less $100 per barrel and reach $93 per barrel by 2025, within the EPRINC range. For natural gas, prices in this study forecast between $6 and $9 per MMBtu at the Henry Hub, eventually reaching $8.80 per MMBtu in 2025. These results are similar to the EPRINC study.

V. NATIONAL SECURITY IMPACTS OF A HYDRAULIC FRACTURING BAN

A. OVERVIEW

The increase in U.S. oil and natural gas production since the early 2000s has enabled the country to achieve energy security, which has eluded Administrations since the 1970s energy crisis. Today, the U.S. is energy independent on a net energy basis – that is, the country exports more energy than it imports.[53] The trajectory of domestic oil and natural gas production has taken America from preparing for scenarios of resource constraints to operating under resource abundance. Despite a history that includes long lines at gasoline pumps, curtailments of natural gas at schools and factories during the 1970s, and dire warnings of impending "peaks" in domestic oil and natural gas production capacity in the 1990s, the U.S. now exports natural gas and natural gas liquids, and imports progressively lower volumes of crude oil.

As domestic oil and natural gas production has expanded, America's reliance on foreign energy supplies has declined, dramatically enhancing U.S. energy security.

"Access to domestic sources of clean, affordable, and reliable energy underpins a prosperous, secure, and powerful America for decades to come. Unleashing these abundant energy resources…stimulates the economy and builds a foundation for future growth."[54]

U.S. energy security has historically meant adequacy and diversity of oil supply. By that measure, the U.S. has a much stronger energy security position now because it is the top producer of liquid fuels in the world. However, the factors that affect the U.S. and its allies' energy security have become more complex due to changing global trade flows, the evolving threat to the environment, and new global security challenges in various regional settings.[55]

Energy security now includes natural gas supply; electricity generation, transmission, and distribution; the functioning of energy markets; and the ability of the energy system to withstand shocks and disruptions, whether from natural disasters or terrorism.

Increased domestic supply directly enhances energy security at home and grants the U.S. considerable flexibility in dealing with global diplomatic challenges. While unexpected events can cause short-term deviations, there is a clear trend toward energy self-sufficiency.[56] This transformation has provided significant benefits to the domestic economy and consumers. Four decades of investments in research and technology development dramatically changed the domestic oil and natural gas industry's technical capacity, enabling it to provide abundant and affordable oil and natural gas supplies.

Research investments of the 1980s and 1990s, made by industry and DOE's Office of Oil and Natural Gas in response to the oil and natural gas supply crises of the 1970s, built the scientific knowledge foundation that was needed to unlock new sources of oil and natural gas, particularly those found in "unconventional" reservoirs such as organic-rich shales. The application of this science and knowledge during the subsequent two decades led to the U.S. energy revolution and completely changed the energy landscape.

As domestic oil and natural gas production rates have risen, U.S. imports of both commodities have fallen.[57] The U.S. imported about 9.10 million barrels per day (MMbpd) of petroleum in 2019 from about 90 countries, including 6.8 MMbpd of crude oil and 2.3 MMbpd of non-crude petroleum liquids and refined petroleum products. This was the lowest level of total petroleum imports since 1996.

However, U.S. exports of petroleum have increased significantly in recent years. In 2019, the U.S. exported petroleum to about 190 countries. U.S. total petroleum exports averaged about 8.5 MMbpd, including nearly 3 MMbpd of crude oil, equal to about 35 percent of total petroleum exports. U.S. petroleum net imports in 2019 were the lowest since 1954.

Although most of the natural gas produced in the U.S. is consumed here, the U.S. also exports natural gas.[58] Until 2000, the U.S. exported relatively small natural gas volumes, mostly by pipeline to Mexico and Canada. Total annual exports have generally increased each year from 2000 through 2019 as increases in U.S. natural gas production contributed to lower natural gas prices and the competitiveness of U.S. natural gas in international markets.

In 2019, the U.S. exported 4.66 Tcf of natural gas to about 38 countries – the highest volume on record, making the U.S. a net exporter of natural gas for the third year in a row.

Consider the Sabine Pass LNG terminal in Louisiana as an example of this shift in energy flows. Initially constructed and brought online in 2005 by Cheniere Energy as an LNG import facility, rising domestic production caused the company to shift plans and convert to an export facility. Today, it features five liquefaction trains in operation and is one of six operating U.S. LNG export facilities.

In fact, U.S. LNG exports set a record in November 2020, with the U.S. EIA estimating LNG exports reached 9.4 Bcfd, which was 93 percent of peak LNG export capacity utilization.[59]

Anticipating continued robust natural gas production, the U.S. is on track to become the largest global LNG exporter, increasing exports from 6 Bcfd at the end of 2019 to an expected 12 Bcfd by the middle of this decade, surpassing both Australia and Qatar.[60] During 2019, LNG exports created $9.5 billion in revenue and helped to reduce the trade deficit.

U.S. LNG export projects have expanded the global availability of natural gas, driving down gas prices worldwide while diversifying supplies, particularly in countries in Europe such as Poland and Lithuania dependent on Russian natural gas pipeline exports. East Asia and Europe account for 62 percent of global U.S. LNG destinations (36.0 percent and 26.2 percent respectively)[61] during 2016-2019 with the remaining total largely benefitting countries in the Americas.

The increase of U.S.-produced crude oil and natural gas on the global market plays a significant role in diplomacy, geopolitical standing, and overall national security interests. U.S. Secretary of State Mike Pompeo remarked during IHS Markit's CERA Week in 2019 that "o*ur plentiful oil supplies allow us to help our friends secure diversity for their energy resources*."[62]

> The Secretary of State continued: *"We're not just exporting American energy, we're exporting our commercial value system to our friends and to our partners. The more we can spread the United States model of free enterprise, of the rule of law, of diversity and stability, of transparency and transactions, the more successful the United States will be and the more successful and secure the American people will be."*[63]

By supporting the fuel needs of other countries, U.S. LNG offers a reliable alternative to natural gas and oil produced elsewhere and the opportunity for the U.S. to promote "prosperity," as Secretary Pompeo remarked at CERA Week 2019, across the globe:

"Our model matters now, frankly, more than ever in an era of great power rivalry and competition where some nations are using their energy for malign ends, and not to promote prosperity in the way we do here in the West. They don't have the values of freedom and liberty, of the rule of law that we do, and they're using their energy to destroy ours."[64]

B. ENERGY SECURITY PRINCIPLES

At the request of Congress, DOE published a report in January 2017 titled *Valuation of Energy Security for the United States.*[65] This report presented an analysis of how energy-related policies and actions are valued, both qualitatively and quantitatively, concerning their energy security effects. The report identified a new framework for the Nation's energy security goals that reflects the complex and interconnected nature of global and domestic energy markets.

The energy ministers of the Group of Seven (G-7) member countries—Canada, France, Germany, Italy, Japan, the United Kingdom, and the U.S.—agreed in June 2014 to a set of principles that reflect broader ideas of energy security both for individual nations and collectively. To articulate a new energy security paradigm, the G-7 endorsed a set of seven energy security principles:

1. Development of flexible, transparent, and competitive energy markets, including gas markets.
2. Diversification of energy fuels, sources and routes, and encouragement of indigenous sources of energy supply.
3. Reducing our greenhouse gas emissions, and accelerating the transition to a low carbon economy, as a key contribution to enduring energy security.
4. Enhancing energy efficiency in demand and supply, and demand response management.
5. Promoting deployment of clean and sustainable energy technologies and continued investment in research and innovation.
6. Improving energy systems resilience by promoting infrastructure modernization and supply and demand policies that help withstand systemic shocks.
7. Putting in place emergency response systems, including reserves and fuel substitution for importing countries, in case of major energy disruptions.

These principles focus on well-functioning and competitive energy markets, diverse sources and routes of energy supply, environmental protection, efficiency and infrastructure improvements, energy innovation, emergency response, and resilience. In addition, the report identified energy security considerations along several categories:

Consumers and the economy. Energy security is improved to the extent that consumers, defined as both households and businesses, can reduce their fuel expenditures when prices for oil, natural gas, or petroleum products rise. That is most likely to occur when consumers are less dependent on any energy commodity and can consume fuels with greater efficiency.

Energy supply diversity and resiliency. Energy security is improved when firms cannot exercise market power in oil or natural gas production, processing and refining, or distribution. Similarly, energy security is improved to the extent that the market can be protected from naturally occurring or human-caused disasters either because firms have taken actions to prevent infrastructure from being affected or because enough redundant infrastructure exists.

Well-functioning and competitive energy markets. Energy security is improved when markets are transparent, liquid, and have low barriers to entry.

U.S. trade balance. The balance of trade and its effect on exchange rates or investment flows can have economic consequences, but those are separate from the G-7 energy security principles. The effect of varying levels of energy imports and exports can affect energy security but do so primarily through an effect on U.S. gross domestic product.

National security objectives. Energy security is improved when the U.S. government can take actions during an emergency to reduce the economic effects of disruptions in energy markets.

Environmental considerations required by Federal law. Energy security is improved when energy consumption can be increased without posing an increased threat to the environment, from either higher greenhouse gas emissions or other risks (such as water pollution or seismic activity).

C. National Security Implications of a Hydraulic Fracturing Ban

The U.S. shale revolution has been the single most significant contributor to enhancing U.S. energy security. As a result of U.S. oil and natural gas production strength and resilience, the U.S. is far less impacted by global oil price shocks, consumers and manufacturers enjoy the benefits of reliable, affordable power, and energy is an important foreign policy tool. Instituting a ban on hydraulic fracturing would introduce several national security uncertainties.

Fundamentally, energy security can be defined in a national security context using a three-tiered approach to national security itself. That is, national security as the functionality of military capabilities and security services at the primary level; as the functioning of critical domestic energy supplies and services at the secondary level; and as economic well-being and prosperity at the most removed, longest-term level.[66] A ban of HF would affect all three levels of this national security paradigm. While the ban itself would not directly induce a lessening of the national security posture, it would introduce more uncertainties, requiring additional scenario planning as the U.S. and our allies' reliance on foreign oil and natural gas would increase.

On the most basic level, national security assets are still largely dependent on liquid hydrocarbon fuel sources to power the engines of U.S. military vehicles and technologies. Aircraft require the lion's-share of these resources, meaning that the bulk of the U.S. military's forward-projection capabilities are reliant upon affordable and abundant fuel sources. Likewise, ground and sea-based military capabilities (except for nuclear-powered aircraft carriers and submarines) are also dependent on ready access to these fuels. From a training and readiness perspective to power-posture and actual combat operations, maintaining a steady and secure supply of fuels is necessary for the modern military and security apparatus. Activities, such as a ban, that would reduce the secure and reliable domestic source of these fuels would insert uncertainty into the energy supply chain.

Beyond the primary level, the safety and reliability of the broader energy supply infrastructure and resources also plays a key role in overall national security. Severe supply disruptions to the overall economy, whether from natural disasters, confrontational tradecraft, or even open hostilities, could result in domestic unrest. There are several potential chokepoints in international trade routes, largely shipping lanes that could be used to cut off fuel supplies to the U.S. economy in the short-to-mid-term. Additionally, and less dramatically, a trade embargo, like the 1970's OPEC oil embargo, could have a similar effect. While these outcomes would not directly result from a HF ban, increases in reliance on foreign sources of fuel would expose and exacerbate vulnerabilities.

Finally, a thriving and growing economy provides the most significant and most enduring bulwark against national security threats. As was stated in the United States Senate's *Global Economic Security Strategy of 2019*, "the national security of the United States depends in large part on a vibrant, growing, and secure United States economy;"[67] As has been described in detail throughout the report, a potential HF ban is projected to have an impeding effect on overall economic growth, and to ultimately reduce the number of jobs, wages and tax revenues collected. These effects would compound over time, eventually weakening the economy and national security.

Enacting a nationwide ban on the technology that has unlocked America's energy revolution jeopardizes newfound gains in energy security and poses a significant threat to America's national security. Hydraulic fracturing and horizontal drilling are directly responsible for most domestic oil and natural gas production. Taking away hydraulic fracturing technology from America's oil and natural gas industry removes the primary technique needed to efficiently and responsibly extract abundant U.S. energy resources. Without new wells brought online, U.S. natural gas and oil production would rapidly fall, reversing the past decade's energy security gains.

Importantly, the U.S. would lose its energy independence, and, since demand for reliable, affordable energy would remain, America would again turn to the Middle East and Russia for imports. An important asset in diplomacy would be sidelined and allies across the globe – from Southeast Asia to Europe and South America – would be cut off from a valuable, trusted energy trading partner.

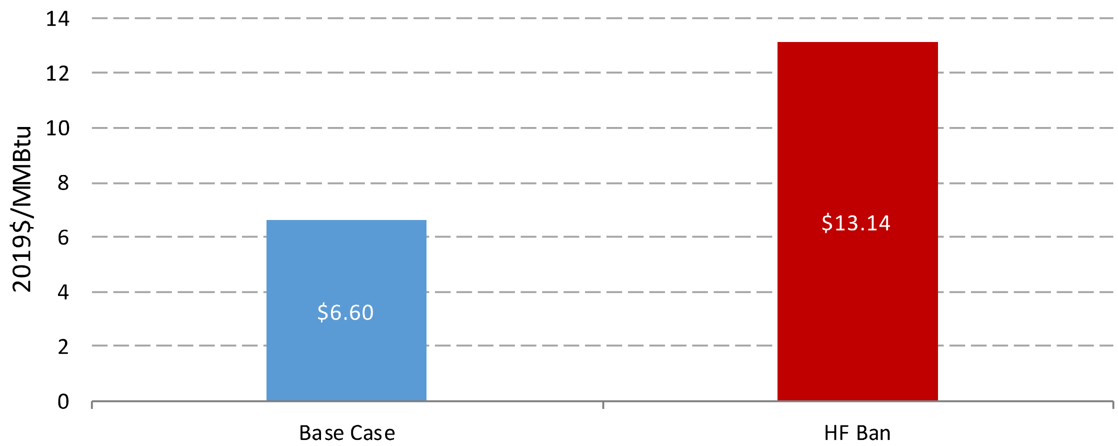
D. Changes in U.S. and Global Oil and Natural Gas Trade Flows under a Hydraulic Fracturing Ban

1. Global LNG Trade

Under a Base Case scenario, the global LNG market will grow 205 million metric tons per year (MTPA) from 355 MTPA in 2019 to 560 MTPA in 2025, assuming an annual growth rate at historical levels of 8 percent. The market will rely heavily on U.S. LNG to provide the majority of future supplies. The U.S. could build as much as 200 MTPA (or 26.31 Bcfd) or two-thirds of the almost 300 MTPA of liquefaction projects that are in "advanced" stages, i.e., those that are approved, have reached final investment decisions (FID), or are under construction.

An HF Ban scenario would completely upend the U.S. as a major supplier in the natural gas market. U.S. projects not yet under construction could be severely delayed or even canceled, creating a capacity gap of up to 100 MTPA to serve expected demand under a Base Case scenario. A global LNG model was used to forecast the impacts of a HF Ban Scenario.[68] As shown in Figure 57, global LNG prices in 2025 would almost double from $6.60/MMBtu in a Base Case Scenario to $13.14 per MMBtu in a HF Ban Scenario, levels not experienced in the last five years.

Figure 57: Projected Global LNG Prices in the Base Case and HF Ban Scenarios (2025)



The higher prices in an HF Ban scenario would induce a demand response as shown in Table 6. Under a HF Ban scenario, the global LNG market would decline by approximately 60 MTPA from Base Case levels in 2025 or almost 11 percent. The growth rate would decrease to six percent annually from eight percent annually.

Table 6: Base Case and HF Ban LNG Imports by Country / Region in MTPA (2025)

Country / Region	Base Case	HF Ban	Change	Percent Change
Japan	81.2	66.9	-14.3	-17.6%
China	146.7	136.9	-9.7	-6.6%
Korea	48.4	39.8	-8.6	-17.8%
India	37.5	34.5	-2.9	-7.8%
Taiwan	20.4	16.9	-3.5	-17.0%
Pakistan	20.0	18.5	-1.5	-7.6%
Southeast Asia	30.5	27.8	-2.7	-8.9%
ASIA	**384.7**	**341.4**	**-43.3**	**-11.2%**
Europe	150.5	121.3	-29.2	-19.4%
EUROPE	**150.5**	**121.3**	**-29.2**	**-19.4%**
North America	11.3	25.5	14.2	125.3%
South America	7.7	7.0	-0.7	-8.9%
AMERICAS	**19.1**	**32.6**	**13.5**	**70.9%**
Middle East	7.3	6.7	-0.6	-7.8%
Africa	0.1	0.1	0.0	-8.8%
MIDDLE EAST & AFRICA	**7.33**	**6.70**	**-0.63**	**-8.6%**
GLOBAL NET Exports	**561.5**	**502.0**	**-59.6**	**-0.1**

The U.S. LNG industry would lose substantially under a HF Ban scenario. The U.S. LNG export facilities that have secured offtake contracts would face supply curtailment because the higher feedgas prices in a HF Ban scenario render U.S. LNG exports uneconomical. In addition, approximately 200 MTPA (or 26.31 Bcfd) of advanced projects likely would not be constructed and put into operation, which means lost opportunity in direct investment, jobs, labor income, and federal, state, and local tax revenues during their permitting and construction periods. Globally, as Steven Winberg, Assistant Secretary for Fossil Energy testified during a 2019 U.S. Senate Energy and Natural Resources Committee hearing: "*Lower energy prices are helping domestic households and businesses, but exports of natural gas are also helping our allies and trading partners with enhanced energy and economic security. According to the International Energy Agency, Europe saved $8 billon on natural gas last year, largely due to US LNG*."[69]

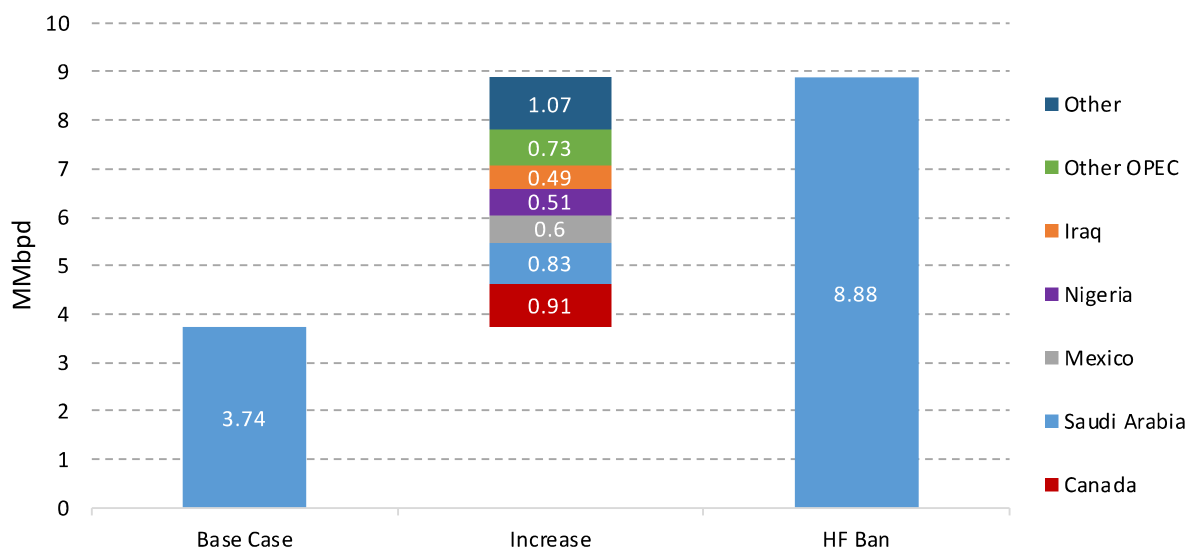
Additionally, the ripple effects from lost opportunity in supply chain economic activity and employee spending would result in further economic lost opportunities. These projects also would lose considerable revenue opportunity during their operations, which supports jobs at the terminals (approximately 1,000 people directly work at Cheniere's Sabine Pass facility[70]), their suppliers, along upstream and midstream oil and natural gas operations.

2. U.S. CRUDE OIL IMPORTS

The U.S. has reduced its reliance on crude oil imports from just over 10 MMbpd in 2005 to 3.8 MMbpd in 2019, a drop of more than 60 percent. By 2025, EIA estimates in the AEO 2020 High Oil and Natural Gas Supply Case that U.S. crude oil imports and exports will be balanced, meaning the U.S. will have no net imports of crude oil.

Under a HF Ban case, the U.S. route to energy independence would be sidelined. The U.S. would go from a forecasted zero net importer of crude oil to a net importer of approximately 8.9 MMbpd. The increased imports will come from a variety of sources as shown in Figure 58. Canada likely would be the largest beneficiary, exporting an additional 0.9 MMbpd beyond what is expected in the Base Case. Saudi Arabia, Nigeria, and Iraq along with other OPEC members could see their crude oil exports to the U.S. increase by 2.6 MMbpd.[71]

Figure 58: Estimated Gross Crude Oil Imports HF Ban vs. Base Case (2025)



This rapid shift under an HF Ban scenario would likely refocus global oil trade flows back to OPEC producing countries, who would likely exert more influence over world oil prices. This will undercut the significant gains in energy security and foreign policy U.S. oil exports have generated. As Dan Brouillette, U.S. Secretary of Energy, said in October prepared remarks: "All our energy exports – LNG, coal, petroleum products – provide energy choice, reliability, and security to our trading partners. Our role as a reliable energy trade partner also strengthens bilateral relationships, which can help act as a counterbalance to the hegemonic ambitions of China and Russia. I believe strongly that by pursuing dominant energy production here at home and promoting energy exports abroad, we are contributing to a more stable, peaceful global order."[72]

VI. FURTHER POTENTIAL IMPACTS

As described in DOE's September 2020 report, *"U.S. Oil and Natural Gas: Providing Energy Security and Supporting Our Quality of Life"*, oil and natural gas play an essential role in modern life that extends beyond the commonly associated transportation fuel, home heating and electricity generation. [73] Oil, natural gas, and natural gas liquids are the foundational elements and raw materials in manufacturing a range of consumer products, including plastic goods. Especially critical during the COVID-19 pandemic, oil, natural gas, and natural gas liquids are key raw materials in the manufacture of plastic medical supplies and personal protective equipment like masks, ventilators, vaccine vials, and syringes.

Further, fertilizers that increase annual crop yields are produced from dry natural gas, and lightweight modern plastics that increase fuel economy and vehicle safety are produced from natural gas liquids. The surge in U.S. oil, natural gas, and natural gas liquids production has given domestic manufacturers a competitive advantage, reducing key input costs to manufacture everyday goods.

Yet, in a hydraulic fracturing ban scenario, this key American manufacturing advantage would be greatly diminished, setting back advancements made in domestic manufacturing. In fact, with oil and natural gas intertwined throughout virtually all aspects of the economy, the consequences of reduced production would reverberate throughout the U.S. and global economy.

While a ban on hydraulic fracturing would directly and negatively impact oil and natural gas sector jobs, broader, less apparent consequences could exist in developing hydrogen-based energy, public and higher education funding, and even wind and solar development.

DOE's Office of Energy Efficiency and Renewable Energy (EERE) and Office of Fossil Energy are actively working on technological advancements to scale hydrogen power technologies. Hydrogen is commercially viable when produced from natural gas, but, in a scenario in which domestic natural gas production plummets and price spikes, hydrogen, a zero-emission technology, would face significant setbacks. [74]

A hydraulic fracturing ban could adversely impact other renewable energy technology growth such as wind and solar. Again, as natural gas liquids are an important raw material input, particularly in plastics and metals production, rising manufacturing costs for solar panels, wind turbines, and associated equipment would not be immune from cost increases. Further, natural gas, which is quickly dispatchable, provides reliable, baseload power, serving as an important partner in continued renewable energy expansion.

Moreover, in addition to consequences for manufacturing and advanced, renewable energy technologies, a hydraulic fracturing ban scenario could negatively impact state and local budgets. As DOE's September 2020 report identified, state and local tax and fee revenue tied to oil and natural gas production *"provide major portions of the funding for schools and public services in many producing states."*[75]

> **From the September report:** *A more detailed look at Texas, the largest oil and natural gas producing state, helps to quantify these revenue benefits further. In 2019, taxes and mineral royalties paid by the oil and natural gas industry to the state of Texas was a record $16.3 billion. During the past ten years these revenues totaled $116 billion.*

As set forth in the recent Texas Independent Producers & Royalty Owners Association (TIPRO) "2020 State of Energy Report," these revenues "…have continued to support all aspects of the state economy, including infrastructure investment, water conservation programs, schools and education, and first responders…." In addition, the Texas oil and natural gas industry in 2019 purchased $220 billion in goods and services, of which 80 percent came from Texas businesses.

In New Mexico, oil production growth on Federal land in the Permian Basin has helped the state's finances and provided the means to expand funding for education and other programs. The New Mexico Oil and Gas Association estimates that $1.2 billion of the state's $6.2 billion budget came from revenue on Federal land, including royalties, bonuses, and other payments. In North Dakota, oil and natural gas taxes provided $18 billion for fiscal years 2008- 2018 for the state, accounting for more than 45 percent of total tax revenues. Crude oil and natural gas production is also a major source of revenue for Wyoming's state and local governments. Given that Wyoming has no state income tax, local and state governments rely on tax revenues from oil, natural gas, and service companies operating in the state to fund many of its essential public services. In 2018, oil and natural gas production contributed $1.39 billion to the state of Wyoming from property taxes, severance taxes, state mineral royalties, and sales and use taxes. These tax revenues were used by the state to support essential public services, including providing $596 million for K-12 education, $510 million to the state's General Fund, and $114 million for public infrastructure, among other uses.

VII. CONCLUDING REMARKS

Over the course of a remarkably short period, the U.S. energy outlook positively shifted, with the rise in natural gas and oil production driving significant and tangible economic, national security, and environmental gains. With the technological advancement of combining the decades-old hydraulic fracturing technique with horizontal drilling, American unlocked its vast hydrocarbon resources that had been trapped in shale formations more than a mile beneath the surface. In fact, from 2005 to 2019, U.S. natural gas production increased 137 percent and crude oil production increased 88 percent, enabling the U.S. to surpass Russia and Saudi Arabia as the world's largest producer – and maintain that position through 2020.

The U.S. continues an upward production trajectory. The domestic abundance of shale oil and gas resources and the low-cost technological means of production ensure the U.S. is unlikely to soon return to prior periods of higher prices, perceived scarcity, and energy reliance on foreign nations.

This domestic energy resource abundance underpins virtually every aspect of the U.S. economy. For example, gasoline prices have fallen considerably over the past 15 years as U.S. shale oil production has increased supply and helped offset possible supply shocks from Middle East unrest. Low-cost natural gas has also been a benefit for consumers, as half of American households rely on natural gas for heating and nearly all are realizing electricity savings tied to the shifting U.S. power generation mix.

While America's economy is stronger as a leading natural gas and oil producer, U.S. geopolitical standing and national security is enhanced as well. Export of natural gas and crude oil provide the U.S. an important diplomatic tool and add further energy supply to the global market. This enhanced supply has the effect of reducing global energy costs and, in many situations, can help lift billions of people out of energy poverty.

The generational economic and national security gains made over the past 15 years would be effectively eliminated if the U.S. bans hydraulic fracturing technology use.

Over just five years, America would shed millions of jobs, GDP would plummet by one trillion dollars and the U.S. economy would likely sink back into recession status. These costs would be devastating to the fragile economic recovery underway and force burdensome energy cost spikes on the American consumer.

Moreover, amid this massive cost, America's environment would be negatively impacted, as critical air emissions including NO_x, SO_2, and CO_2 are projected to rise in the first year of a hydraulic fracturing ban as part of the market response to fuel generation mix changes.

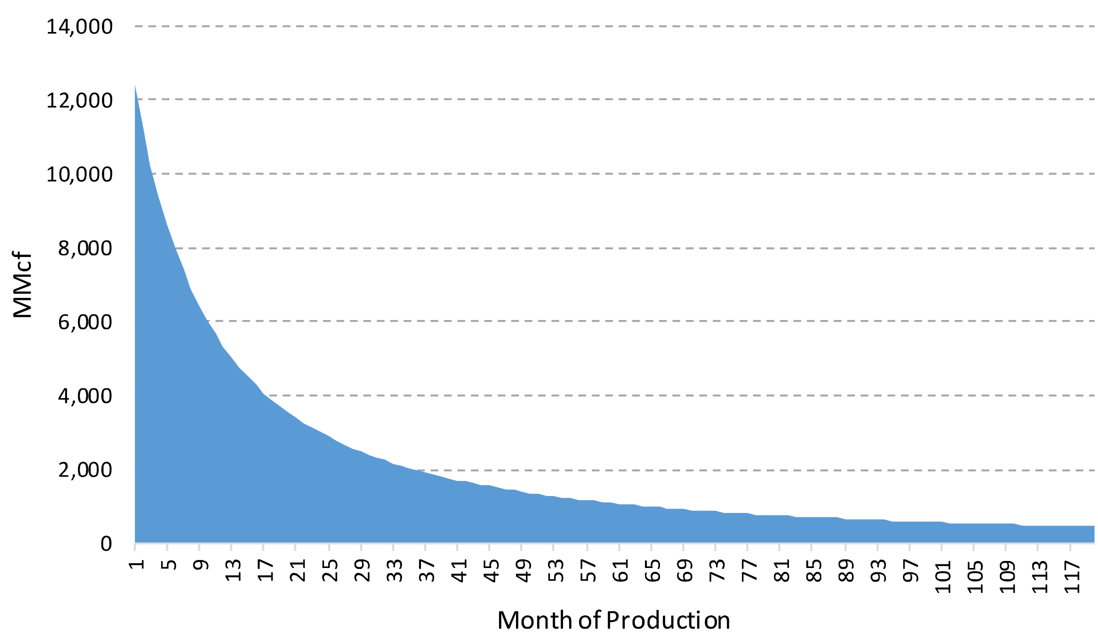
Given the interconnectedness of the global economy, these costs would reverberate across the world, affecting economic growth and the outlook from Asia to Europe. With a weakened American economy, the U.S. would experience a national security setback, becoming reliant, once again, on foreign nations for energy needs.

VIII. APPENDIX A: OIL AND NATURAL GAS DECLINE CURVE ANALYSIS

Future oil and natural gas production depend on production from existing wells and production from newly drilled wells. As such, the first step in estimating future oil and natural gas production is to extrapolate future production from existing wells. To do so, we obtained historical well-level production data for all operating wells in the conterminous U.S. from the data vendor WellDatabase.

Oil and natural gas production from a given well, over time, can generally be described quite well by a set of mathematical equations describing the well's "decline curve." Decline curves show how production from wells generally declines from the initial production level in a non-linear fashion. The most widely used functional forms for constructing decline curves are exponential and hyperbolic curves. Figure 59 shows a decline representing an average new gas well in Susquehanna County, Pennsylvania, constructed using EIA parameters.

Figure 59: Example Gas Decline Curve, Susquehanna County, Pennsylvania



A decline curve was fit to each of the operating wells from WellDatabase, selecting the best fit (minimum sum of squared errors) functional form from a combination of exponential and hyperbolic forms. With both forms, additional options were evaluated for build-up (where a well's production builds up to a peak before declining) and curtailment (where well production is "choked back" to keep production flat for some period before declining), again seeking to minimize the sum of squared errors.

Once decline curves were fit to each well, the wells were aligned through time based on the month of first production and compared the resulting state production totals to those reported by the EIA. We then made balancing adjustments where necessary. The resulting production forecast from existing, operating gas wells is shown in Figure 60 below and from oil wells in Figure 61.

Figure 60: Existing Gas Well Production Forecast by State (2020-2025)

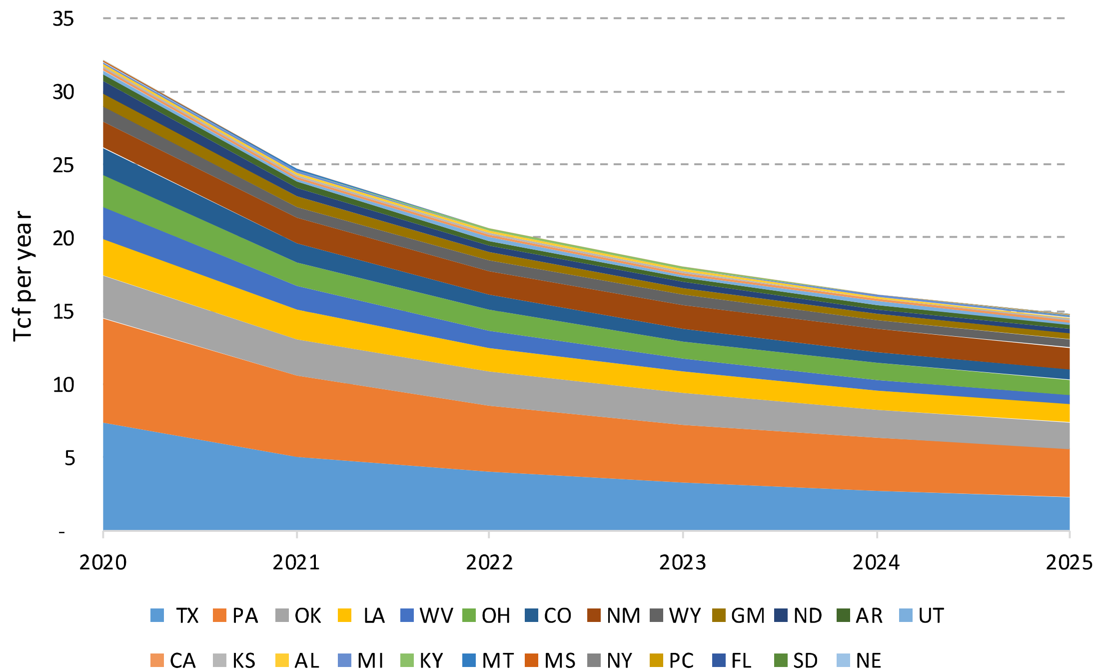
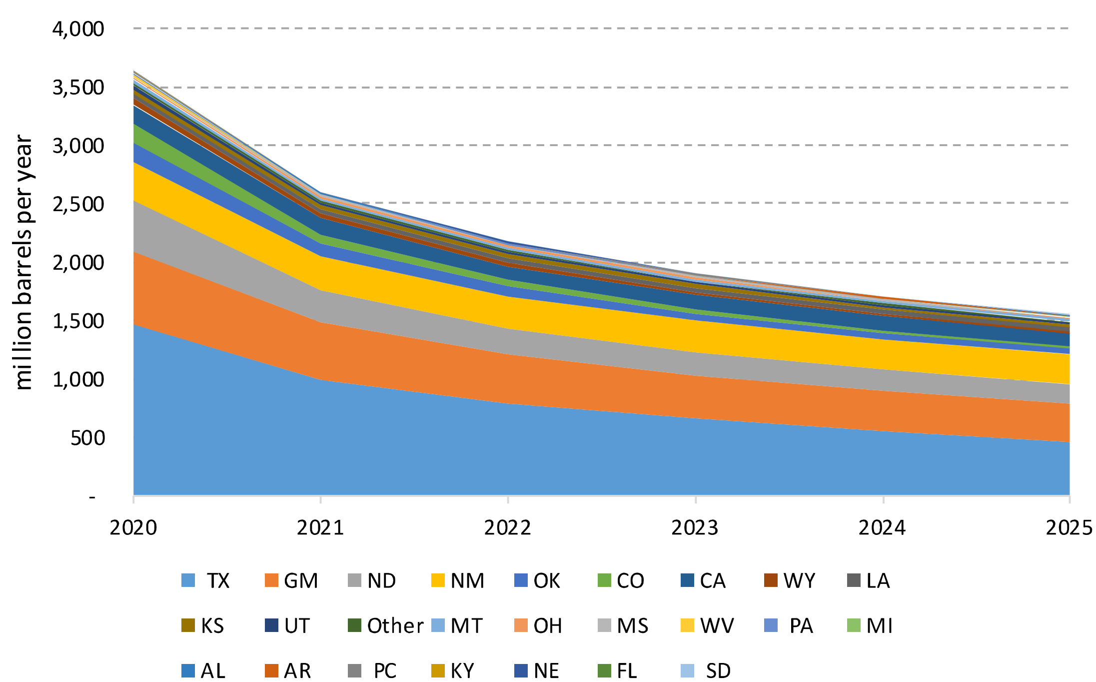


Figure 61: Existing Oil Well Production Forecast by State (2020-2025)



IX. Appendix B: Electric Power Sector Emissions Coefficients

Table 7 below shows the average CO_2, NO_x, and SO_2 emissions rate averages for each generation type by primary fuel type from EPA's 2018 eGRID data, the most recent year of data available. Of note, oil-fired generation on average emits significantly more NO_x and SO_2 than coal-fired generation. However, oil-fired generation only accounted for three percent of generation in 2005, and 0.4 percent in 2019.

Table 7: EPA 2018 eGRID Generation-Weighted Average Emissions Coefficients

Generation Type	CO_2 Emissions (lbs/MWh)	NO_x Emissions (lbs/MWh)	SO_2 Emissions (lbs/MWh)
Biomass	498.9	2.2	1.5
Coal	2,168.3	1.4	2.1
Gas	895.4	0.4	0.0
Geothermal	150.7	0.0	0.3
Hydro	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0
Oil	1,456.2	3.4	4.8
Solar	0.0	0.0	0.0
Wind	0.0	0.0	0.0

Table 8 shows the emissions coefficients presented in Table 7 but indexed to coal emissions. As the table shows, on a MWh basis, replacing coal-fired generation with gas-fired generation reduces CO_2 emissions by an average of 59 percent, NO_x emissions by an average of 73 percent, and SO_2 emissions by an average of 99 percent.

Table 8: EPA 2018 eGRID Generation-Weighted Average Emissions Coefficients Indexed to Coal

Generation Type	CO_2 Emissions	NO_x Emissions	SO_2 Emissions
Biomass	23%	149%	68%
Coal	100%	100%	100%
Gas	41%	27%	1%
Geothermal	7%	0%	15%
Hydro	0%	0%	0%
Nuclear	0%	0%	0%
Oil	67%	233%	227%
Solar	0%	0%	0%
Wind	0%	0%	0%

Endnotes

[1] According to 40 CFR § 60.5430, "hydraulic fracturing or refracturing means the process of directing pressurized fluids containing any combination of water, proppant, and any added chemicals to penetrate tight formations, such as shale or coal formations, that subsequently require high rate, extended flowback to expel fracture fluids and solids during completions."

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