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U.S. Natural Gas in the Global Economy

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This report summarizes a one-day CSIS-International Energy Agency (IEA) workshop held in May 2017, with government, industry, and policy experts exploring the outlook for natural gas markets in the global energy landscape. The workshop addressed key issues concerning the role of natural gas in North America, as well as the evolving strategic role of U.S. natural gas exports and liquefied natural gas markets (LNG) in the global energy system. The workshop was the third in a three-part workshop series, with the first workshop examining key issues concerning the role of U.S. tight oil production in the global economy and the second workshop focusing on the societal and environmental risks associated with U.S. onshore oil and gas development.

Executive Summary

The outlook for natural gas markets is evolving rapidly under pressure from two significant developments, the shale revolution in the United States and the advancement of LNG markets. The shale revolution, made possible by the economically viable extraction of large natural gas (and oil) deposits trapped in geologic formations, has seen natural gas production in the United States increase by nearly 50 percent over the past 10 years. The United States is producing and consuming natural gas at record levels, bringing with it an array of economic and strategic advantages in improving U.S. trade and industrial competitiveness, while altering the electric power mix and thus providing for environmental benefits.

With natural gas production growth outpacing the growth in domestic consumption, the United States is positioning to be a net exporter of natural gas on an average annual basis in 2018. The rapid growth in U.S. exports of natural gas is being made possible by the major advancements seen in the LNG industry, allowing gas to be shipped over long distances at increasingly competitive rates, thus challenging the long-established dependence on pipelines for gas trade and in turn testing traditional gas business and pricing models. Facilitated by these developments, U.S. natural gas exports are expected to more than double over the next five years making the United States one of the largest gas exporters in the world.

The growth of U.S. LNG exports will be a major force in the development of more liquid and globally integrated gas markets, supporting further opportunities for natural gas to transform electric and heating supply mixes, supplement industrial and transportation fuel mixes, improve energy security, address climate change and local pollution, provide better energy access in developing economies,

and create new economic opportunities in the global economy. Gas still faces obstacles in many markets, however, and turning this new potential for more abundant and available supply into strategic opportunities is not without its challenges. A few key findings from the workshop include:

The Role of Natural Gas in North America

- In the United States, the increased availability of low-cost gas has reduced electric power emissions, but low prices for electricity brought on by an abundance of gas (along with other factors) is presenting economic pressure on other fuel sources. On the industrial side, new investments bring opportunities to regions with abundant gas resources but the supply adequacy of low-cost gas, often related to leads and lags in the investment cycle and the adequacy of midstream infrastructure to transport gas, continues to be a concern.
- While natural gas production and consumption has exhibited rapid levels of growth in the United States in recent years, the outlook going forward for further levels of growth is limited and highly dependent on prices and environmental policies.
- The rapidly increasing levels of gas exports via pipeline to Mexico and LNG exports to global markets will bring a range of strategic, economic, and security advantages to the United States; however, the magnitude of such benefits may be up for debate if domestic prices increase.

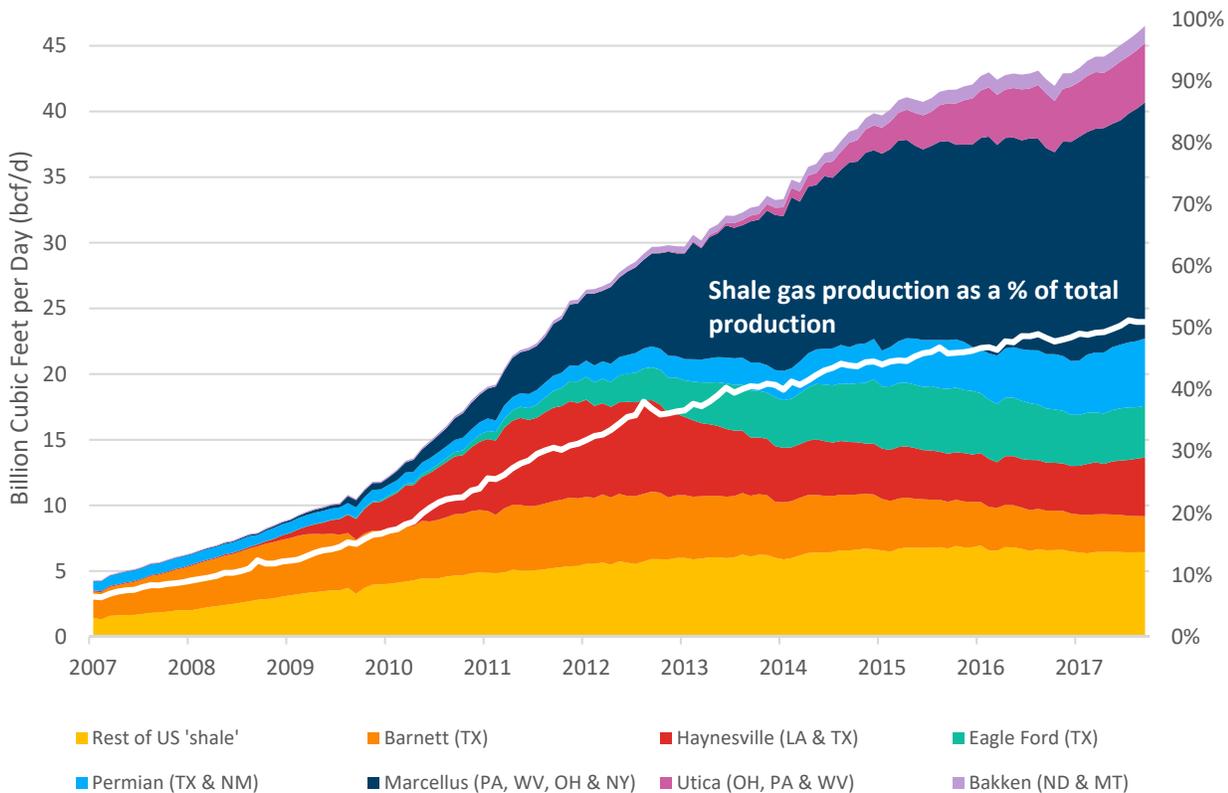
The Competitive Landscape for LNG Markets and the Role of U.S. LNG in the Global Marketplace

- LNG supply is becoming increasingly flexible in terms of volume, destination, and pricing. By the early 2020s, there will likely be no single dominant supplier globally. The market is also experiencing new types of demand, such as smaller volumes and joint procurement by buyers from multiple countries. While the market today is still dominated by destination restrictions and rigid contracts, it is widely anticipated that future and renegotiated deals will be more flexible.
- In the current low oil price environment, U.S. LNG is not necessarily the cheapest potential source of supply for most markets. Once the full costs of liquefaction, shipping, and regasification have been factored in, natural gas from Qatar or Russia is generally a cheaper source of supply for Asia and Europe. However, U.S. LNG could provide a price ceiling on gas imports from other sources, while increasing supply-side options and security of supply for many markets.
- U.S. LNG over a longer time frame is seen as a major force of disruption in global gas markets. U.S. exports are free from destination restrictions and are priced off Henry Hub and so generally do not rely on oil indexation, meaning that U.S. LNG exports are challenging the traditional pricing and contract structures of global LNG markets.

The Role of Natural Gas in North America

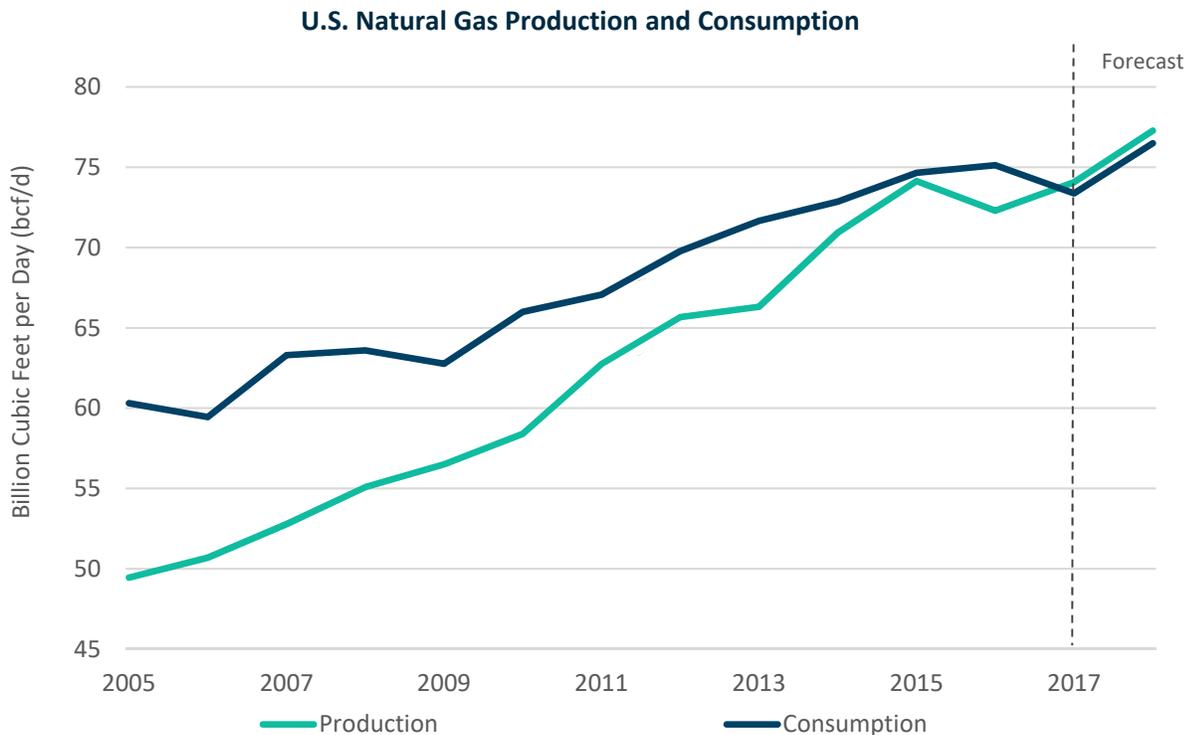
The rapid increase in production of shale gas in the United States over the course of the past decade has been nothing short of phenomenal, rising from next to nothing to account for approximately half of domestic natural gas production today. During the early stages of the U.S. shale revolution, questions arose about the ability to sustain the growth in production of these resources. High production decline rates, uncertainties regarding the size and scale of the resource base, and concerns over environmental impacts and local opposition led many companies, policymakers, and analysts to question whether this revolutionary method in developing oil and gas reserves was a permanent or more temporary phenomenon. Nearly a decade on, concerns regarding the ability to sustain production of U.S. shale gas still exist but have largely subsided as the pivotal issue around the future of production. With overall resource estimates being revised upwards, further technological progress yielding structural cost reductions in conjunction with increasing levels of associated gas production from the tight oil boom, the United States has seen further upward revisions in forecasts for gas production.

U.S. Shale Gas Production by Play



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 Source: Adapted from U.S. Energy Information Administration data (October 2017).

This new gas reality in the United States has had far-reaching implications for natural gas markets in North America. It has brought an array of economic advantages by improving U.S. trade and industrial competitiveness, while bringing environmental benefits. Going forward, sustained growth in natural gas production will have an array of implications for North American natural gas markets in addition to several potential strategic advantages or disadvantages for the United States as it moves to assume the role of a principal exporter of this commodity.



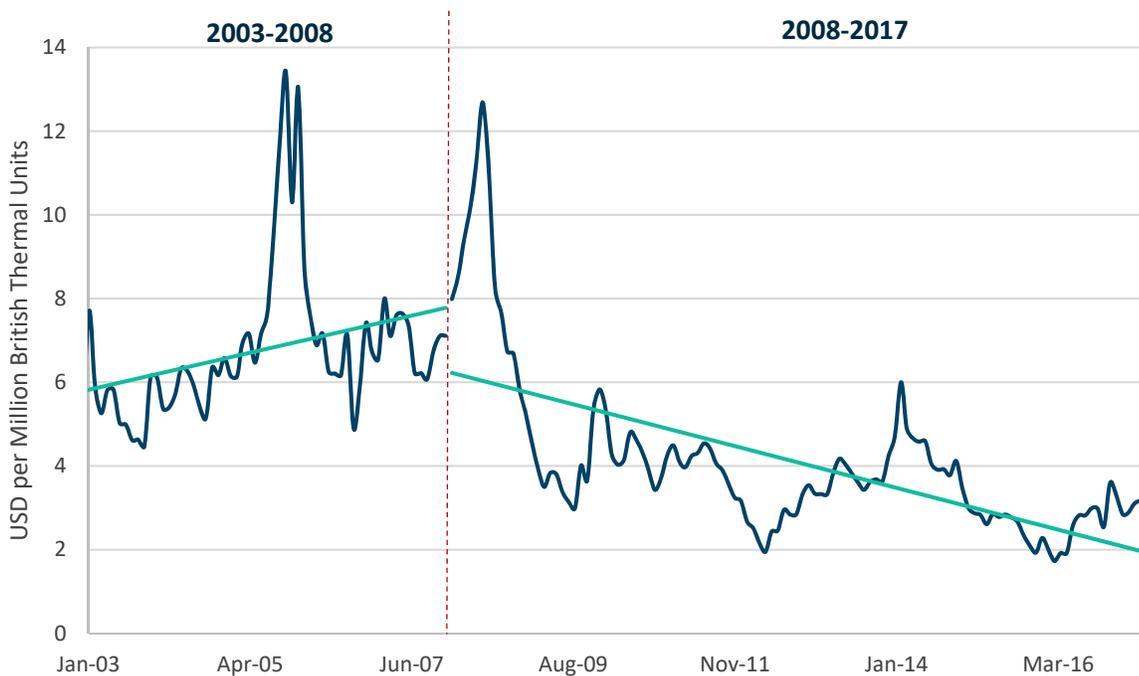
*Center for Strategic and International Studies | Energy and National Security Program
Source: Adapted from U.S. Energy Information Administration data (October 2017).*

The United States produces more natural gas than any other fuel and its consumption of gas is second only to petroleum.

Before the onset of the shale revolution, the forecasts at the time indicated that U.S. natural gas imports from Canada and Mexico via pipeline and other countries by way of LNG would continue to rise, because of growing levels of consumption and diminishing volumes of domestic production. Between 2003 and toward the end of 2008 natural gas prices in the United States were trading at historical highs, with the average Henry Hub spot price over that time frame standing north of \$7 per million British thermal units (mBtu) and occasionally reaching as high as \$13 mBtu. However, this high-price environment for natural gas coupled with low interest rates incentivized the industry to explore and produce previously untapped shale gas resources through the combination of horizontal drilling and hydraulic fracturing. Drilling a vertical shaft to the shale seam, pivoting the drill bit horizontally along oil- and gas-bearing shale zones, and then fracturing the shale along these laterals

with a combination of water, sand, and chemicals allowed for tight oil and shale gas to flow into the well. The uptake of these techniques brought tremendous volumes of gas to the domestic market, which not only offset declining supplies from conventional production but led to significant levels of growth in overall terms. Consequently, the price for natural gas in the United States fell relative both to its historical highs and to other markets for gas elsewhere around the world, with the average Henry Hub spot price from the end of 2008 to present day standing at approximately half the \$7 mBtu seen between 2003 and 2008.

Henry Hub Natural Gas Spot Prices (Monthly)



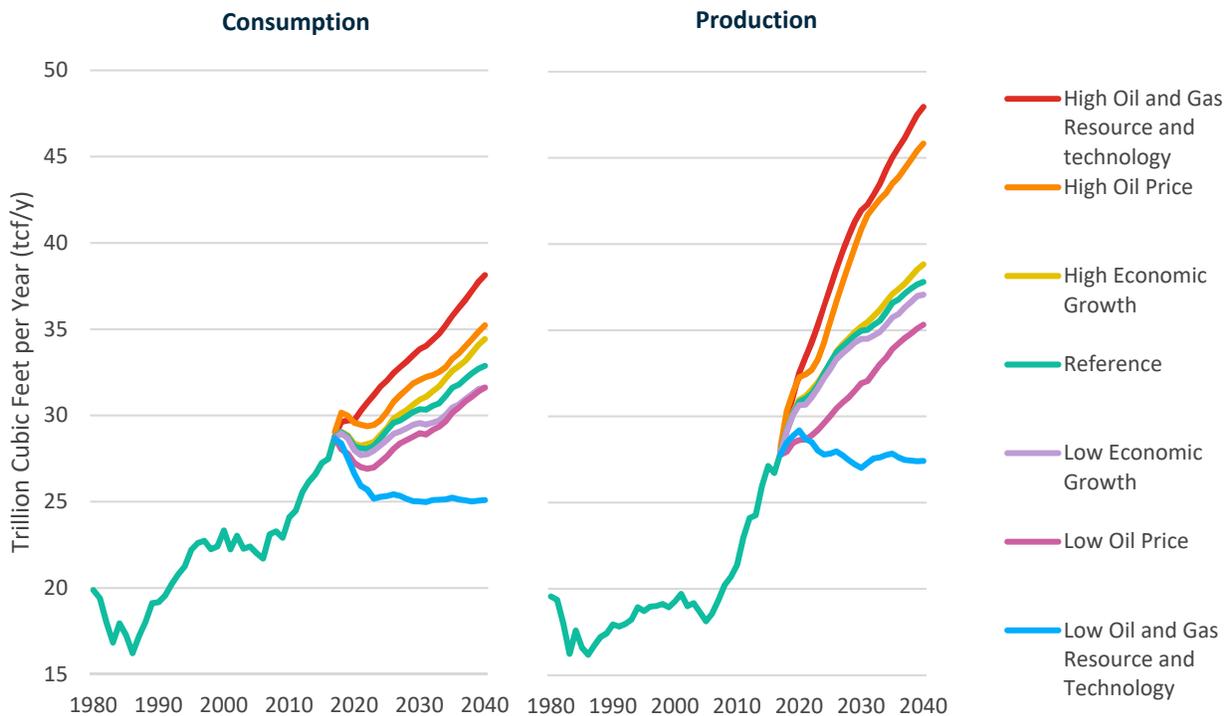
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 Source: Adapted from U.S. Energy Information Administration data (October 2017).

Natural gas has risen to overtake coal as the single largest source of power generation in the United States.

The rapid increase in natural gas supply, resulting in historically low gas prices, together with the availability of preexisting under-utilized gas capacity at existing power plants and a well-developed network of pipelines and various environmental policies, pushed gas to become the single largest source of fuel for power generation in the United States, accounting for approximately a third of generation today. The unprecedented switch from coal to gas saw a near doubling of power generation from natural gas since 2005. While natural gas consumption in power generation has exhibited rapid levels of growth in recent years, the outlook going forward for further levels of growth

in gas consumption in the power sector is limited and highly dependent on both prices and environmental policies.

U.S. Natural Gas Consumption and Production Projections by EIA Scenario

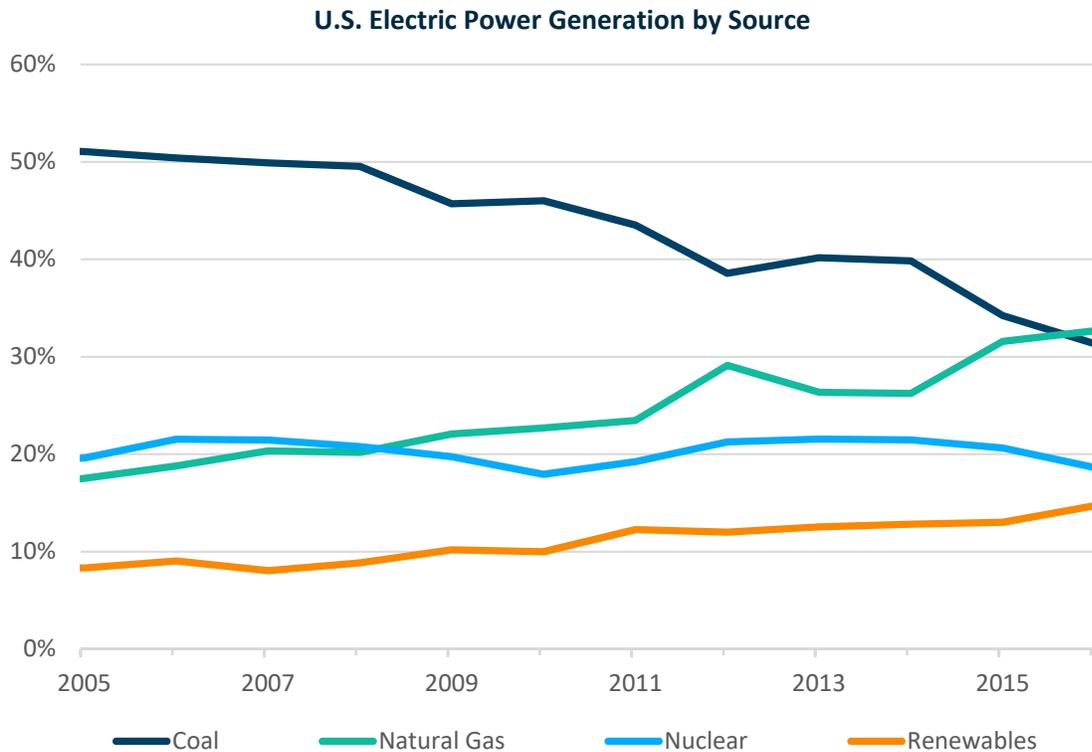


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 Source: Adapted from U.S. Energy Information Administration data (October 2017).

Environmental regulations are an important factor that has helped to boost the competitiveness of gas in the electric power mix.

Environmental regulations targeting local air and water pollution as well as greenhouse gas emissions have contributed to the retirement of aging coal-fired power plants and have thus played a secondary role in driving coal’s decline. Between 2012 and 2016, about 42.7 GW (or 14 percent) of coal-fired power generation shut down and in 2015, coal alone made up more than 80 percent of the 18 GW of retired electricity generating capacity, with some of these retirements coming as direct result of a suite of environmental performance regulations put in place at the federal, state, and local levels. As such, environmental regulations have been an important, contributing factor in the increased competitiveness for gas over the last decade and for the future competitiveness of gas going forward. While the most prominent factor in determining the outlook for overall gas consumption is the relative availability of gas supply, environmental regulations also have a significant impact on the level of gas use. Take, for example, estimates of natural gas consumption under the Clean Power Plan

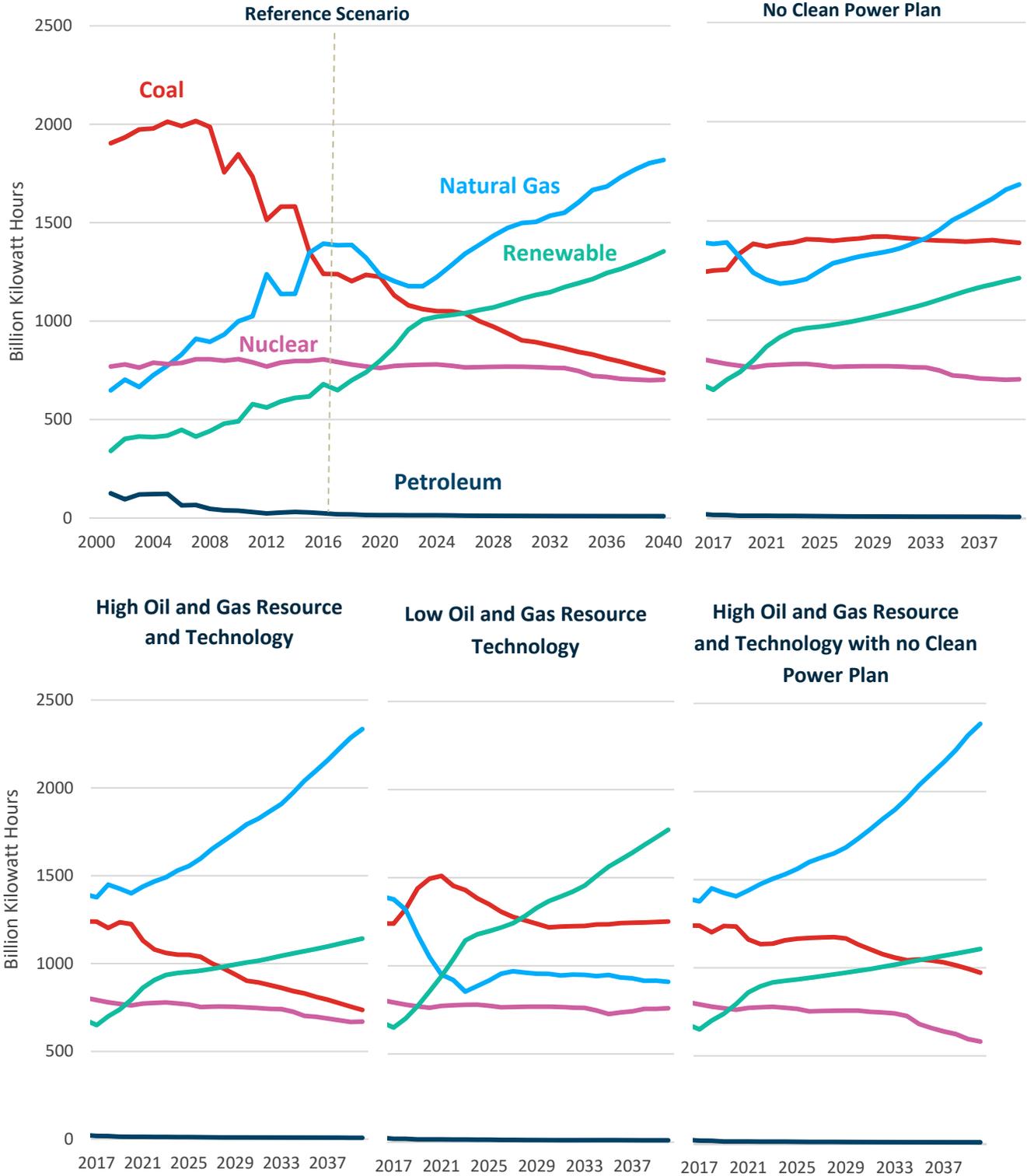
(CPP), a regulation finalized under the Clean Air Act that aims to control greenhouse gas emissions from power generation. It is estimated that if the CPP were to take effect in the reference case, natural gas power generation could account for more than double the amount of power generation from coal by 2040, whereas without the CPP the difference between coal and natural gas consumption is projected to be half this amount.



*Center for Strategic and International Studies | Energy and National Security Program
Source: Adapted from U.S. Energy Information Administration data (October 2017).*

At present, environmental regulations remain a major area of uncertainty rather than a robust driver for natural gas demand. The CPP is under judicial review following legal challenges from 24 states and several industry associations. Further, as of late September, the Trump administration has announced its intent to revise and propose a new rule as well as review and potentially revise a suite of other environmental regulations affecting the upstream portion of the coal and gas industries. Uncertainty over the future of this type of environmental regulation could dampen the shift toward more gas power generation but it is unlikely to prompt new investment in coal-fired power generation capacity in the United States. Even without the CPP, coal’s share of the power mix is still projected to follow a long-term negative trajectory from 2020/2021 onwards. Coal plants are typically built on a projected operating horizon of 40–50 years. Given the time horizon involved in the investment, the prospects of a carbon price and more stringent emission policies must be factored into investment decisions in power generation capacity. With coal having a CO₂ content

Scenarios of U.S. Electric Power Generation by Source

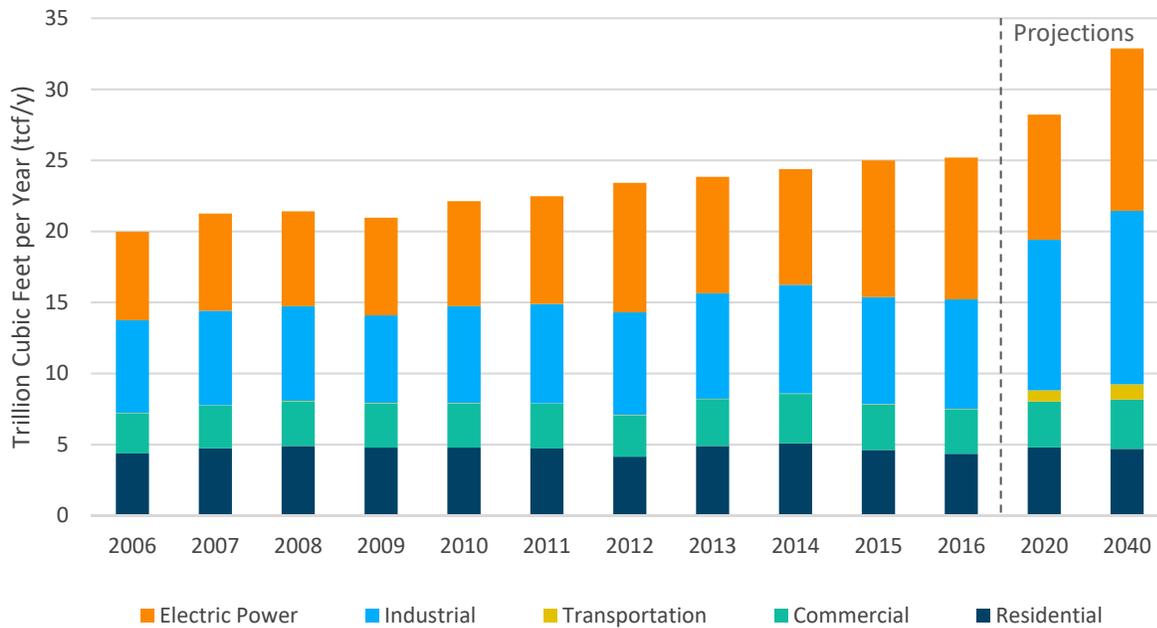


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 Source: Adapted from U.S. Energy Information Administration data (October 2017).

significantly higher than that of natural gas, a price on carbon would have a far greater impact on the delivered price of coal as opposed to natural gas. Also, while many existing coal plants may continue to run for some time, most factors and therefore scenarios indicate that over the longer run that there will be a continuing decline or stagnation of coal in electric power generation while natural gas and renewables will grow to fill its place.

Natural gas is also the leading fuel source for the industrial, commercial, and residential sectors of the U.S. economy. While natural gas consumption has stayed relatively flat in terms of commercial and residential use over the past 15 years or so, consumption in the industrial sector has grown since 2009 when it had previously followed a downward trajectory. This uptick in consumption was linked to several factors, most predominantly including the increase in marginal consumption from industrial facilities recovering from low rates of consumption brought on by the financial crisis of 2007–2008. While the industrial sector is slower to respond to changes in price than the electric power sector, with new petrochemical or manufacturing facilities taking several years to come online and existing facilities having limited flexibility in terms of altering feedstock sources, some of this growth in natural gas consumption over the longer run will come as a result of investments that have taken place as result of low natural gas prices.

U.S. Natural Gas Consumption by Sector

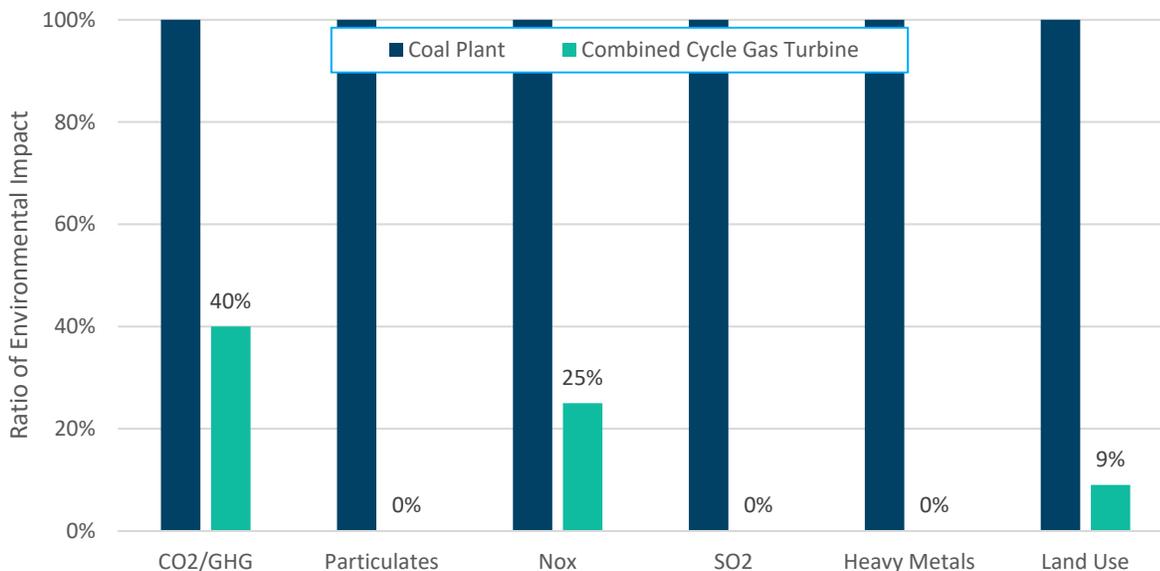


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 Source: Adapted from U.S. Energy Information Administration data (October 2017).

Natural gas can contribute to the reduction of greenhouse gas emissions relative to coal and oil but questions remain as to how an increased uptake of natural gas will eventually affect the energy system transition toward carbon neutrality.

Energy production and consumption account for most of the air pollution arising from human activity, but natural gas produces less carbon dioxide (CO₂), sulfur dioxide (SO₂), nitrogen oxides (NO_x), and fine particulate matter (PM) emissions than the combustion of oil, coal, or biomass. For example, in 2016 coal combusted for electric power generation in the United States produced over 40 percent more CO₂ emissions than the combustion of natural gas for the same end use, even though natural gas accounted for a greater share of electric power generation than that of coal. On a global basis, coal accounts for more than half of all energy-related SO₂ emissions, and for three-quarters of the power sector’s SO₂ emissions, as well as 70 percent of its NO_x emissions and over 90 percent of its PM_{2.5} emissions. The increased uptake of natural gas is therefore one important solution from a variety of available fixes to reduce overall emissions and improve local air quality. The United States is already a good illustration of this case in point. The surge in consumption of natural gas in power generation following the onset of the shale revolution has seen coal consumption fall by over 30 percent since 2005, which in turn has been the single largest contributing factor in the reduction of energy-related carbon dioxide emissions in the United States, which have fallen by approximately 14 percent in that time frame. Furthermore, the availability of gas can play a key role in the backup of renewable power generation thus also helping to improve energy security while achieving emission reductions. Natural gas has the required flexibility to cope with the intermittency of renewables, with gas-fired power plants having a shorter startup time in comparison to coal or nuclear. However, questions do remain about natural gas as a fuel enabling a transition toward a low-carbon economy and how that transition will come about. Natural gas is a hydrocarbon after all and the development of carbon capture and storage (CCS) or carbon capture, utilization, and storage (CCUS) has been a relatively slow one.

Environmental Impact of Coal Plants versus Gas-Fired CCGT



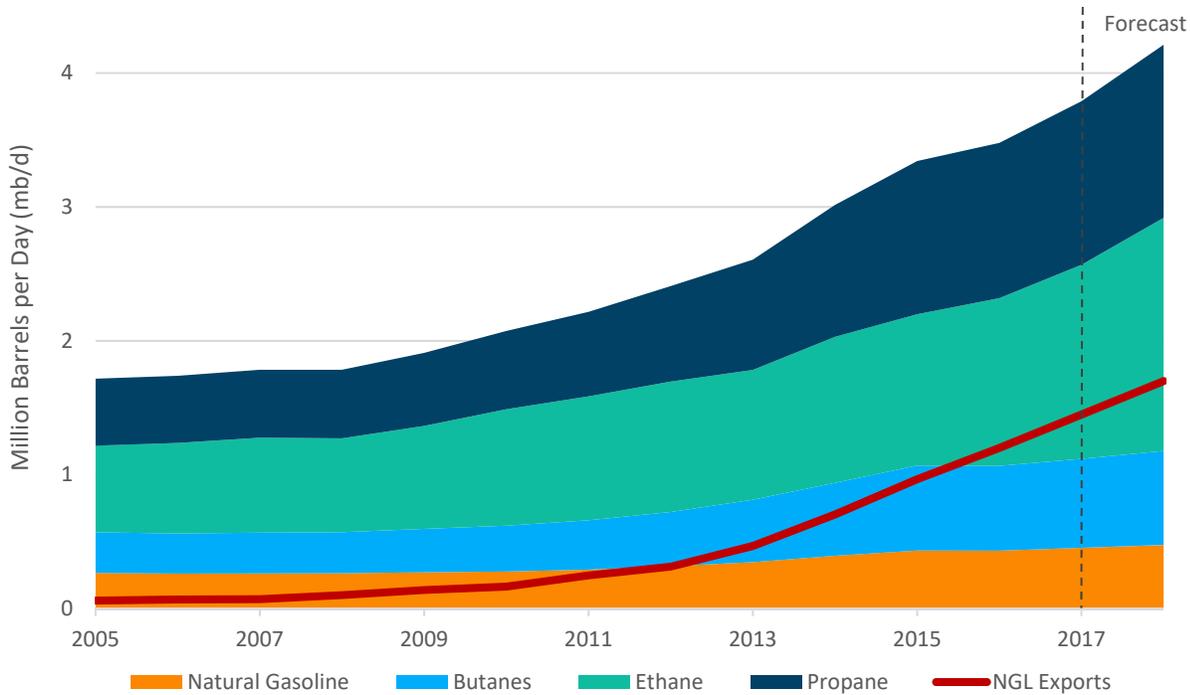
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 Source: Statoil (June 2017).

The increased availability of natural gas offers significant opportunities to facilitate emissions reductions not just in electric power generation but in several other sectors of the economy. For residential and commercial buildings, piped natural gas is a safe, reliable, and flexible source of energy, that when combined with modern gas boilers is an efficient and lower-emissions source of energy than coal or oil. In terms of the industrial sector, gas is of course a vital source of feedstock for petrochemical production but increased access and application of natural gas as a fuel source can further help reduce reliance on higher carbon intensive fuels such as coal. In terms of transportation, natural gas is a cost efficient, clean alternative to diesel or fuel oil. As such, natural gas consumption is beginning to see new applications being made in road transport, through the use of LNG and compressed natural gas in vehicles, particularly in long-haul, heavy-duty, and public transport. The shipping industry, however, is seeing the fastest level of gas consumption growth within the transport sector, with significant opportunities existing for maritime transportation to benefit from the application of natural gas in the form of LNG for bunkering to all types of vessels.

Expanded domestic production of natural gas has led to increases in exports of natural gas, gas liquids, and petrochemical products, thus improving U.S. industrial and trade competitiveness.

The United States has turned its unconventional gas resources into a growing source of export commodities. Between 2005 and 2016, U.S. gas exports have more than tripled from 0.7 trillion cubic feet (tcf) in 2005 to 2.3 tcf in 2016. The growth in production of natural gas in the United States has also led to a rise in the production of natural gas liquids (NGLs). NGLs consist of both natural gas plant liquids and liquid refinery gases, including the likes of ethane, propane, normal butane, isobutane, and natural gasoline. NGLs due to their versatility and high energy density in liquid form are useful for a variety of purposes. The majority of NGLs are consumed within the industrial sector including agriculture, manufacturing, and as a feedstock in petrochemical facilities, which has majorly benefited U.S. industrial competitiveness. In addition, this growth in production has also benefited the U.S. trade balance, having become a net exporter of NGLs in 2010 and having seen gross exports grow from 68 kb/d in 2006 to over 1 mb/d in 2016.

U.S. Natural Gas Liquids Exports and Production by End Product



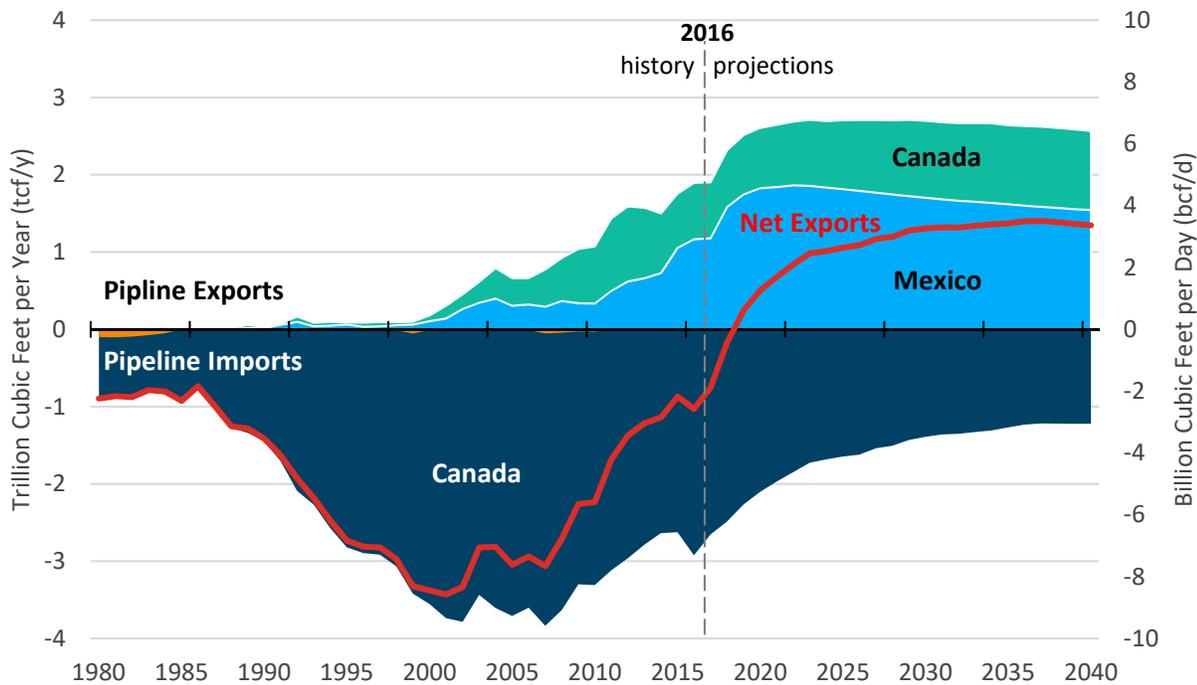
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 Source: Adapted from U.S. Energy Information Administration data (October 2017).

The price of natural gas in the United States has been considerably lower than in other markets due to the dramatic increase in gas production. Low gas prices can present challenges for gas producers, particularly for those who are solely reliant on natural gas and lack a stream of liquids production, which currently offers a price premium. However, low prices for natural gas and NGLs is an attractive market condition for the petrochemical industry, which is reliant on these commodities as feedstock. Consequently, lower gas prices have attracted new investments in petrochemical facilities. According to the American Chemistry Council, cumulative investment in the chemical industry linked to abundant and relatively cheap natural gas and NGLs from shale formations since 2011 reached a cumulative total of \$179 billion at the end of 2016, a significant proportion of which has come from overseas. This has amounted to 294 chemical industry projects creating an estimated 665,000 jobs both directly at facilities and indirectly in supplier industries and in communities where wages are spent. As such, the economic benefits of these investments have not just been confined to the regions of production but have spread to the areas where new facilities dependent on natural gas have opened.

The United States is projected to become a net exporter of natural gas in 2018 due to sustained production growth, increased demand from Mexico, and the expansion of LNG markets.

The U.S. Energy Information Administration (EIA) projects that the United States will become a net exporter of natural gas on an annual average basis as soon as next year. While the forecasts indicate that U.S. LNG exports will almost double in 2018 to reach 1.02 tcf/y, U.S. pipeline exports to Mexico are also expected to see rapid levels of growth, with forecasts indicating a 35 percent increase on 2017 levels to reach 1.58 tcf in 2018. This increasing level of demand for U.S. natural gas from Mexico has come as the government has upped its efforts to move away from the combustion of fuel oil and coal in electric power generation. Consequently, Mexican consumption of natural gas is expected to see sustained growth out to 2030. And while Mexico has considerable levels of untapped shale gas resources, the development of these reserves is moving slowly, with PEMEX facing a number of financial constraints. The eventual development of these reserves through further energy-sector reforms may see the rate of growth of pipeline exports to Mexico begin to level off in 2020; however, it is expected that these exports that currently account for 60 percent of total U.S. natural gas export volumes will still represent 50 percent by 2020 and 35 percent by 2030.

U.S. Natural Gas Pipeline Exports and Imports



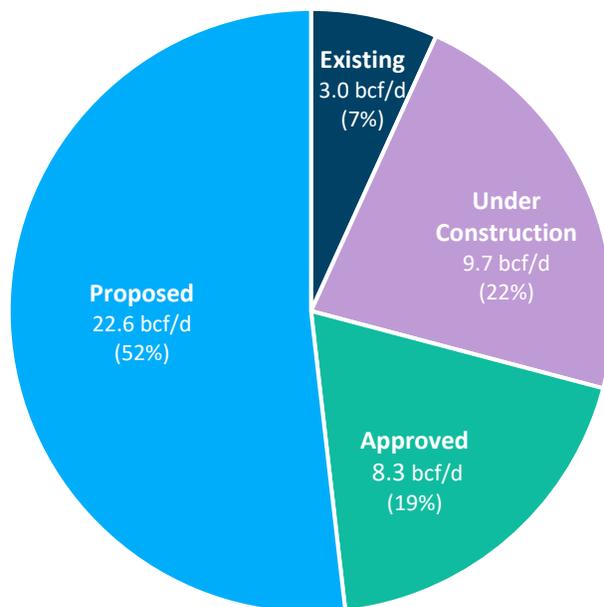
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 Source: Adapted from U.S. Energy Information Administration data (October 2017).

The Trump administration has highlighted natural gas production and exports as important parts of its energy dominance vision.

The Trump administration has seized on natural gas exports as an important tool for domestic and international energy policy citing natural gas exports as a component of their efforts to create jobs and expand the U.S. economy. Gas exports have thus far served a prominent role in bilateral talks with

major economies in which the United States shows its willingness to sell gas to other countries and in so doing bolster respective ties while also improving the trade balance. Examples of this include the bilateral meeting with China and India and several mentions of expanding gas trade to Europe. The administration is also keen to capitalize on demand from markets that are too small to merit large-scale LNG projects such as in the Caribbean, Central America, and South America. In early September, the administration proposed expedited approval for small-scale LNG exports (no more than 0.14 bcf/d) to serve said markets and within a few weeks approved a 10 million cf/d project in Florida while the proposed rule change remained open for comments (until October 16). It must be said, however, that beyond formal permitting processes, the administration has no control over pricing, contracting, or selling gas to other countries. In addition, the volumes of potential future exports are still to be realized.

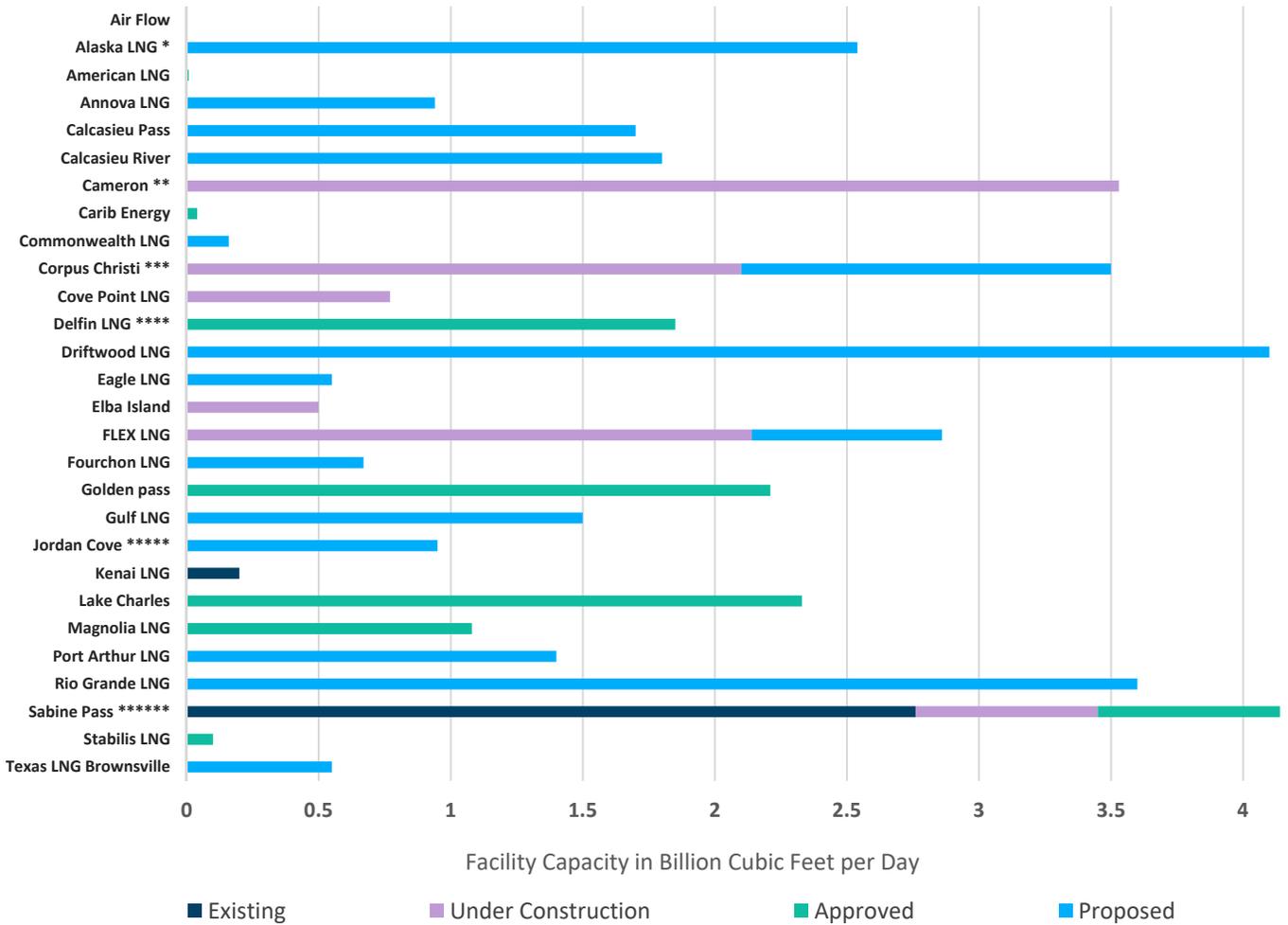
U.S. LNG Export Capacity Status
 Total Possible Capacity: 43.6 bcf/d



*Center for Strategic and International Studies | Energy and National Security Program
 Source: Adapted from Clearview Energy Partners (October 2017).*

While more than 20 bcf/d (153.3 mtpa) of LNG export capacity has received final approval by the Department of Energy (DOE) and Federal Energy Regulatory Commission (FERC), only ~3.0 bcf/d (23 mtpa) is operational and ~10 bcf/d (~75 mtpa) is under construction, while development on the rest has yet to commence. The future of these projects will depend most importantly on the strength of the market for LNG exports, but areas like trade, foreign, and security policy could also influence gas exports more broadly.

U.S. Existing, Under Construction, Approved, and Proposed LNG Export Terminals



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 Source: Adapted from Clearview Energy Partners (October 2017).

* Alaska LNG has received a conditional approval from DOE. Project sponsors have submitted a formal application for the siting, construction, and operation of the project and are currently completing the EIS section of the FERC process.
 ** The approved column consists of the approvals for the Cameron 15-63-LNG, 11-162-LNG, and 15-90-LNG DOE Dockets.
 *** The proposed subtotal consists of Trains 4 and 5, FERC Docket PF15-26.
 **** While FERC has approved the construction of the onshore pipeline portions of the Delfin LNG site, its offshore facilities fall under the jurisdiction of U.S. Maritime Administration (MARAD), rather than FERC. As of October 2017, MARAD has approved Delfin’s application, but the license issuance remains pending.
 ***** Jordan Cove has received a conditional approval from DOE. FERC is expected to issue its decision on Veresen’s application in November 2018.
 ***** The existing column consists of both the nominal capacity of Trains 1–4 (2.2 bcf/d) as well as the “expansion” of Trains 1–4 (0.56 bcf/d), which accounts for the larger-than-expected size of the plant. In assessing Trains 5-6, we assumed that Train 5 (currently under construction) and Train 6 (approved but not under construction) were of equal size, and thus assigned them half of the 1.4 aggregated total capacity estimated by FERC.

Renegotiation of NAFTA has the potential to disrupt supply chains and natural gas trade, particularly with Mexico.

In a business-as-usual case, the outlook for U.S. exports of natural gas is positive due in large part to the growth in gas demand from Mexico via pipeline and LNG. EIA forecasts suggest that it will not be until 2020 that LNG exports will exceed pipeline exports, with most natural gas exports reaching Mexico and Canada by pipeline. With 60 percent of total U.S. gas exports going to Mexico today, the administration's decision to renegotiate the North American Free Trade Agreement (NAFTA) could have serious implications for U.S. gas exporters. Any renegotiation increases the threat of rising political tensions and cross-border tariff retaliation. A loss of such a major outlet could significantly impact oil and gas production in the Permian Basin, where output is expected to double over the next six years. Operators are already expected to run into pipeline capacity constraints by 2018, so a distribution to supply chains could hamper the level of expected growth. Furthermore, a renegotiation could also affect the price of imports of natural gas that come from Canada to areas where U.S. natural gas cannot currently serve.

The political support for increased levels of natural gas exports from the United States may change if domestic prices increase.

When companies began to apply for licenses and permits to export LNG earlier this decade, there was a significant delay in the process while lawmakers debated and the Obama administration considered the potential benefits and risks to the domestic economy, national security, and environment of exporting U.S. natural gas resources. Several studies were conducted to assure policymakers that if the United States exported significant volumes of gas, the resource base would be able to support it and prices for the domestic consumer would not rise to unreasonable levels. According to the EIA, 12 to 20 bcf/d of natural gas exports would increase domestic gas prices by just 4 to 11 percent. However, insofar as the United States has yet to export significant amounts of gas relative to total levels of gas production, the debate concerning the impact of gas exports on domestic supply and price levels seen earlier this decade may resurface as exports of natural gas rapidly increase.

In Australia, significant price increases for the domestic market resulted from a rapid increase in exports of gas combined with drilling limitations, and led to export restrictions being implemented by the government. There is potential for this debate to arise in the United States if prices increase, notwithstanding some major differences between the United States and Australia, such as the lack of extensive pipeline infrastructure and deep and liquid domestic market in the latter. Yet, the lack of additional infrastructure development, due for example to environmental objection to pipeline construction, could create a similar situation in the United States with any significant price increase raising the potential for lawmakers to raise the issue of adverse impacts of increased exports on the availability of gas supplies at an affordable level to American households and industries.

The Competitive Landscape for LNG and the Role of U.S. Gas in the Global Marketplace

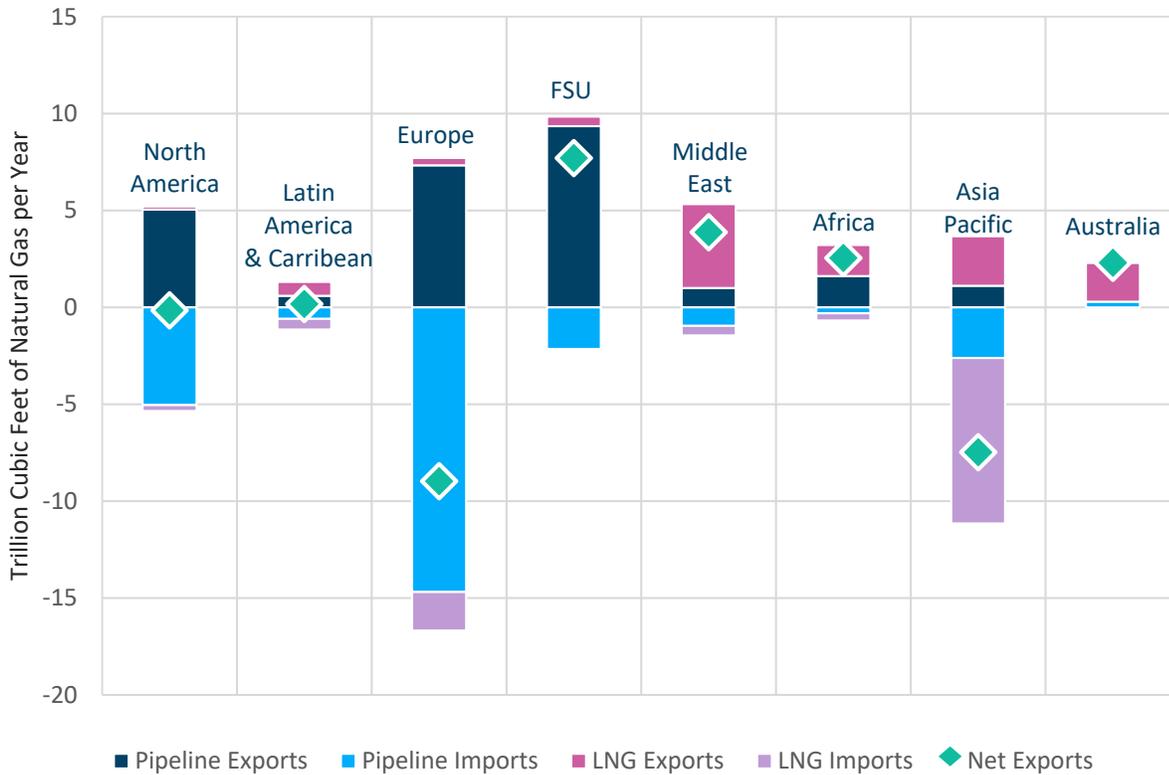
The competitive landscape for LNG markets has evolved rapidly in the past few years, with increasing levels of market liquidity, due to a growing number of industry participants in terms of both supply and demand. By the early 2020s there may no longer be one dominant supplier globally, with Australia and the United States rapidly expanding its LNG export capacity to rival that of Qatar. As such, LNG supply has become and is increasingly becoming more flexible in terms of volume, destination, and pricing. The market is not only experiencing a diversification in supply but an increasing level of sophistication in demand, with the expectations of lower prices creating new LNG import markets. While the LNG market today is still subject to destination restrictions, rigid contracts, and lacks financial instruments for hedging, the market is becoming increasingly integrated and global. Going forward, gas producers and consumers are expected to innovate on today's business models to bring more gas to market. Things like smaller volume and shorter-term contracts for gas and the creation of an LNG futures market are among the ways in which the competitive landscape for LNG is likely to continue to shift.

Australia and the United States are leading the way in LNG supply growth.

For the third consecutive year, global LNG trade has set a record, reaching 33.9 bcf/d (258 million tonnes) in 2016, which represents a more than 5 percent increase on 2015. The majority of growth came from several terminals in Australia, in addition to a ramp-up in exports from the United States. There have, however, also been supply restrictions in the market including those in Trinidad, as well as disruptions in Yemen and Nigeria, which limited the extent of global supply growth.

According to the International Gas Union (IGU), global liquefaction capacity exceeded 39.5 bcf/d (300 mtpa) in 2016 and reached 44.7 bcf/d (340 mtpa) by January 2017. Given abundant gas discoveries, along with the shale revolution in the United States, proposed liquefaction capacity stood at 42.2 tcf (879 mt) by January 2017. However, many of these projects are not expected to go forward as growth in demand remains at a level far below supporting this growth in export capacity. While global liquefaction capacity is expected to grow rapidly over the course of the next few years to reach 59.2 bcf/d (450 mtpa) by 2020, growth is likely to level off thereafter as investment abates, unless demand growth can exceed expectations.

2016 International Natural Gas Trade



Center for Strategic and International Studies | Energy and National Security Program
 Source: Adapted from BP data (October 2017).

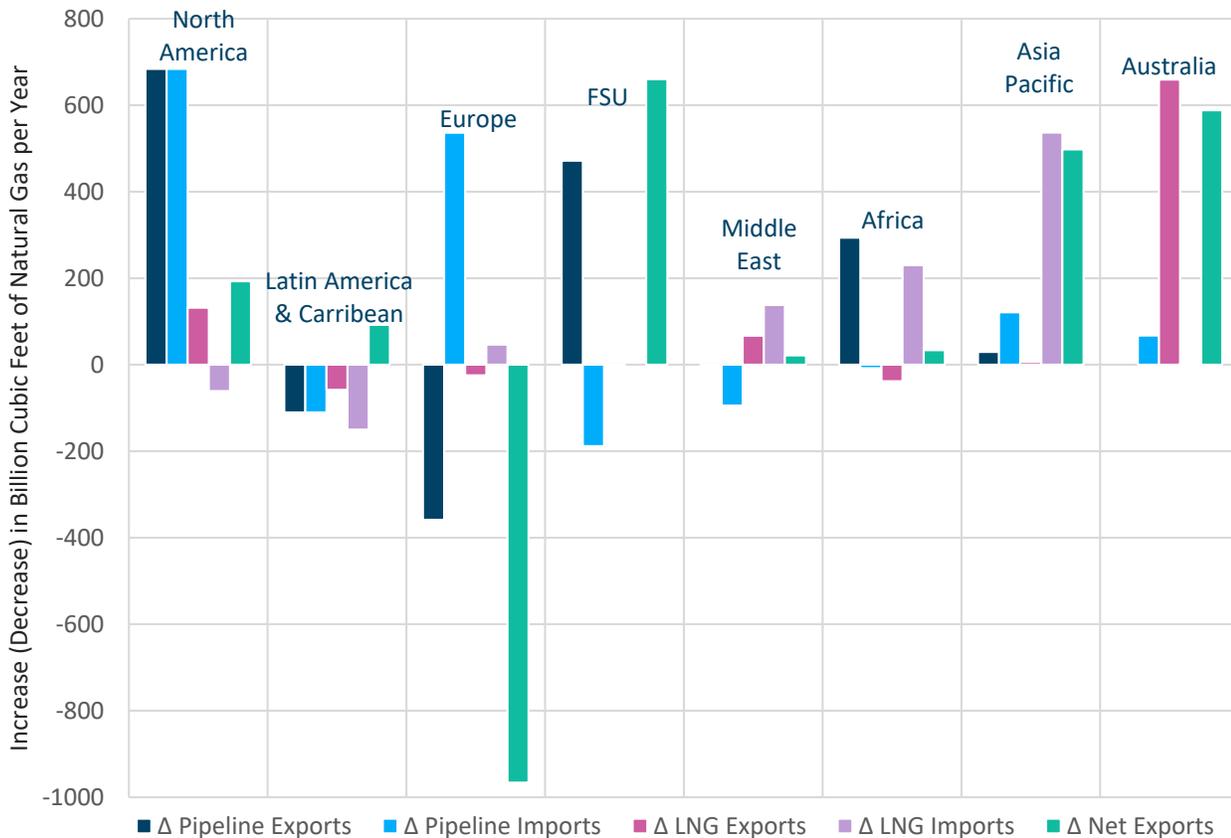
China and India are leading the way globally in LNG demand growth.

China led the way in 2016 in terms of demand growth with a 35 percent year-on-year increase followed by India and Egypt. Favorable pricing dynamics, robust economic growth, as well as a need to clear the air in major cities in Asia spurred this growth in demand. On the reverse side of this, Brazil, which typically relies on short-term contracts, saw the biggest decline in the market for LNG in 2016, due to a favorable year for hydroelectric power. The United Kingdom and Japan also saw declines, but this was largely attributable to the growth in spot market demand, allowing for importers to shed volumes and to take advantage of higher prices in other markets.

Global nominal regasification capacity reached 104.6 bcf/d (795 mtpa) in January 2017, with additional capacity coming online in already-established markets such as China, France, India, Japan, South Korea, and Turkey. An additional 11.9 bcf/d (90.4 mtpa) of capacity was under construction as of January 2017, with the majority of these projects located in both India and China. Looking forward, China along with several other non-Organization for Economic Cooperation and Development (OECD) Asian countries including India will continue to be the dominant forces globally in terms of demand growth for LNG.

Apart from the growth in demand expected from already-established markets in non-OECD Asia, another interesting development on the demand side of the equation for LNG trade is the recent growth of small but new players. This includes the likes of Egypt, Jordan, and Pakistan, which started importing LNG in 2015, and now account for the same level of demand as France and the U.K. Other small-scale player additions include Colombia, Finland, Jamaica, Kuwait, Lithuania, Poland, Singapore, and the UAE. While the extent to which these markets show further growth and how many more small-scale players enter the market is highly dependent on LNG prices and domestic prices for alternative fuels; for the moment at least, the likes of Bangladesh, Ghana, the Philippines, and Uruguay look set to join the market within the next two years. As such, small-scale LNG is expected to be an important factor in global demand growth, with forecasts suggesting its share could represent 20 percent of demand by 2022. A number of these small-scale additions will come in the form of floating storage regasification units (FSRU). FSRU capacity continues to grow, reaching 10.9 bcf/d (83 mtpa) by the start of 2017 with projects in Turkey and the UAE coming online. Further FSRU projects are expected to come online in the coming years in Uruguay, Chile, Puerto Rico, and Russia.

Change in International Gas Trade (2015–2016)



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 Source: Adapted from BP data (October 2017).

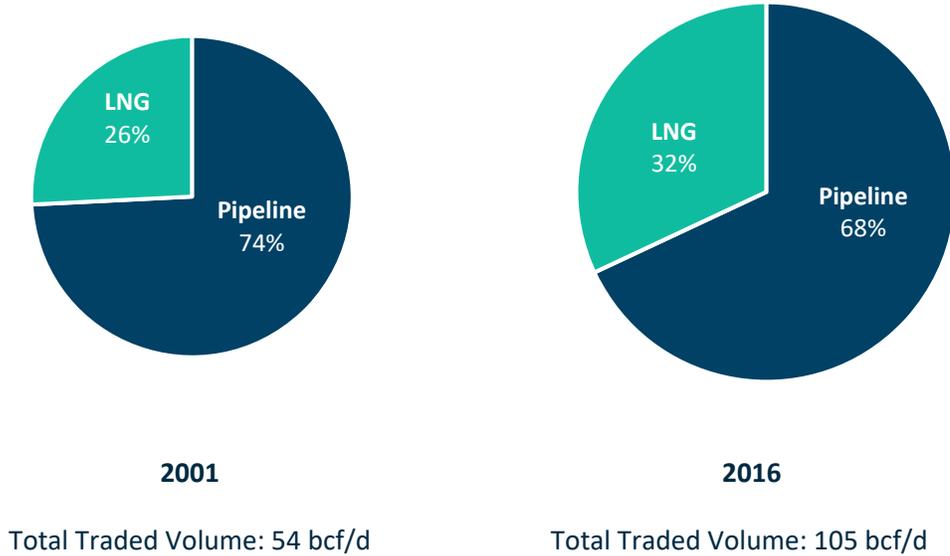
An increasingly over-supplied LNG market has led to an uptick in spot market transactions.

Long-term contracts still dominate the market in LNG trade but traditional contractual terms and pricing arrangements are being tested as new supply hits the market. The United States and Australia have brought on significant additional volumes of LNG to an already well-supplied market, which has led to an uptick in overall short-term and spot market transactions. However, as a percentage of overall trade, short- and medium-term contracts have in fact tapered off from the highs seen in 2013. In 2016, emerging markets such as Pakistan and Malaysia began importing LNG under new long-term contracts and the majority of other liquefaction projects that started in 2015 and 2016 in the Asian Pacific region were also supported by long-term contracts. However, with additional volumes of supplies expected from the United States and with the market facing oversupply out to the early 2020s, spot market transactions and short-term deals will likely increase.

LNG is now estimated to represent 32 percent of international gas trade.

While the growth of its market share has stalled since 2010 as domestic production and piped gas have competed well for growing levels of natural gas demand globally, large additions of LNG supply out to 2020 leave LNG well poised to resume its expansion in the coming years. In particular, its share in the long-distance trade of gas is expected to see a significant uptick. According to BP, the share of LNG in the global trade of gas reached 32 percent in 2016 and the IEA projects that its share in long distance trade could reach 53 percent by 2040. The United States is already beginning to play a major role in the expansion of this trade and as such is seen as a force of disruption in the market, particularly over the longer run as export capacity expands.

LNG Share of Total International Gas Trade

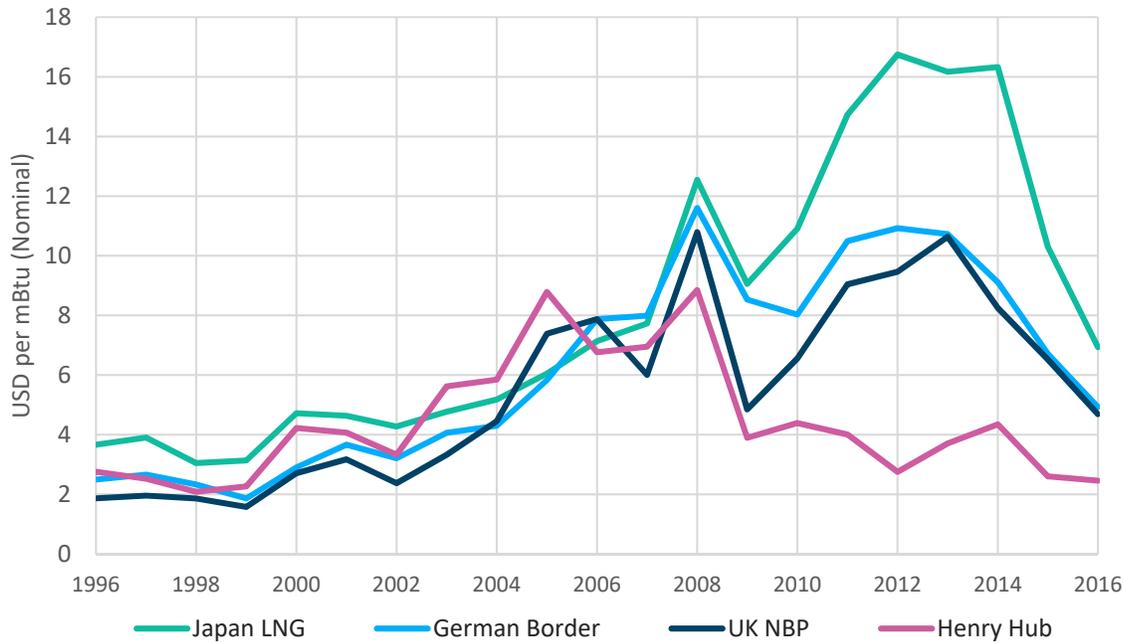


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 Source: Adapted from BP data (October 2017).

The onset of U.S. LNG has facilitated important changes in regional gas markets around the world.

The United States has a large and interconnected gas market in which purchases of gas are indexed against hub-based prices. This differs from many other markets where gas prices are indexed to that of oil. With U.S. LNG being free of oil indexation, significantly greater quantities of LNG using an alternative pricing mechanism are now being offered to the market, which has long been dominated by oil-indexed prices and long-term contracts. As such, U.S. LNG is to a certain extent upsetting the traditional pricing structure used in the market. However, the extent to which “Henry Hub plus” prices have challenged oil indexation has been limited over the course of the past two years due to low oil prices (i.e., when oil prices were high and gas prices low, gas consumers preferred the idea of non-oil-indexed gas prices, but now that oil prices are low the incentives to switch pricing structure have reduced or reversed).

Natural Gas Prices by Region (1996–2016)

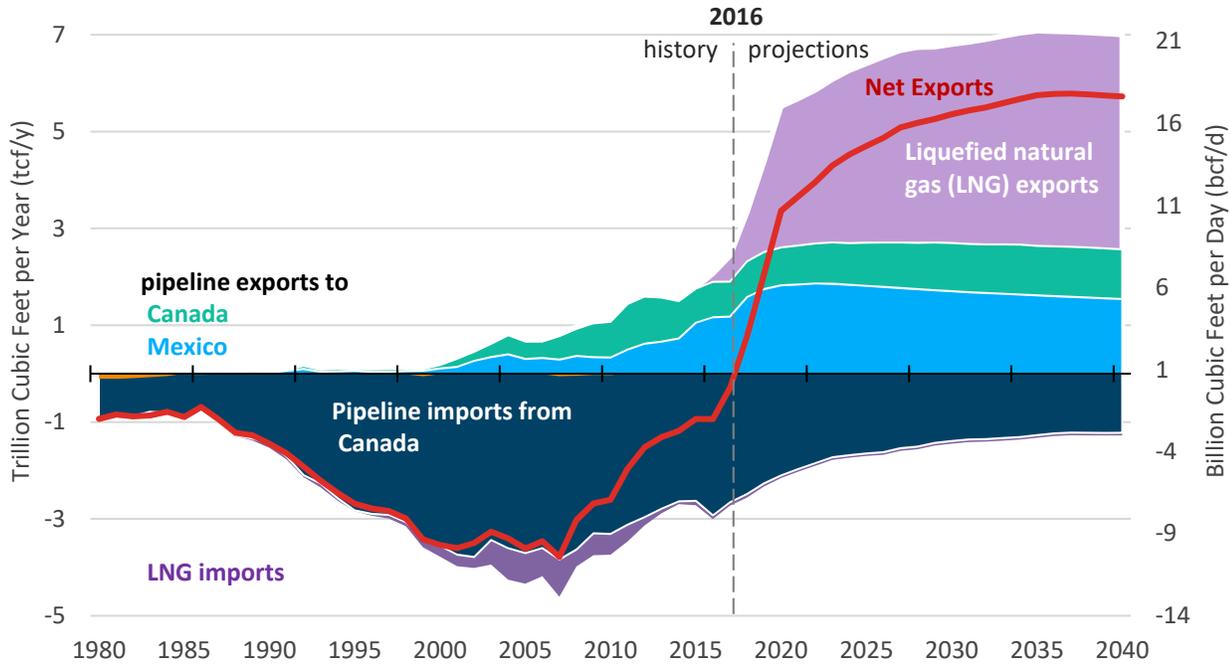


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 Source: Adapted from BP data (October 2017).

Flexibility has been a strong selling point of U.S. gas so far.

U.S. LNG contracts are free of destination clauses that lock sellers into providing the cargoes to one set destination, so U.S. LNG can disrupt global trade flows heretofore defined by rigid contract structures by being more flexible and responsive. This has brought more supply-side options to many regional gas markets and has created greater levels of competition among suppliers. For this reason, many buyers see U.S. LNG and its flexible terms as an important emergency-go-to option.

U.S. Natural Gas Exports and Imports

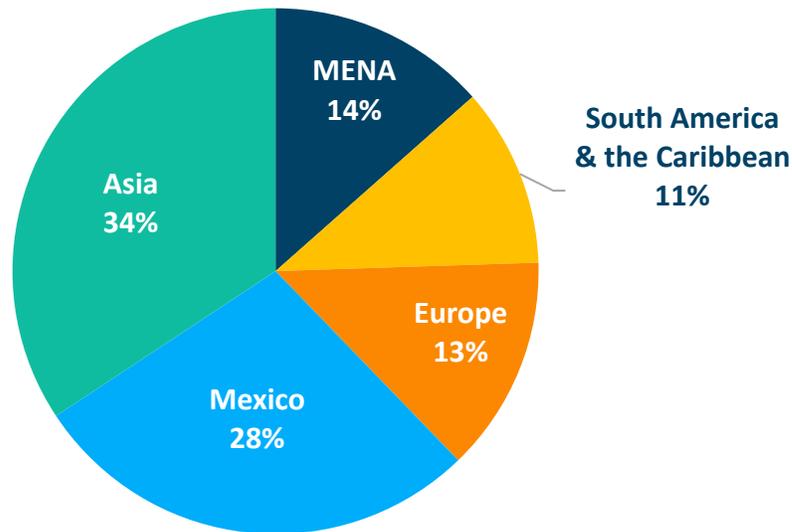


Center for Strategic and International Studies | Energy and National Security Program
 Source: Adapted from U.S. Energy Information Administration data (October 2017).

Given the destination flexibility of U.S. LNG, there is no single dominant market for U.S. exports.

Asia and Mexico have received the largest exports of U.S. LNG so far in 2017, even though Europe was touted to be the largest beneficiary. Europe has only accounted for 13 percent of U.S. LNG exports as Russian piped gas prices have fallen at the expense of LNG demand. While U.S. LNG is struggling to compete with Russian piped gas on a cost basis in Europe, exports going to the Middle East, North Africa, and Asia have so far successfully competed with Qatari and Australian supplies.

Share of U.S. LNG Export Volumes by Region
Since the First Commercial Cargo from Sabine (November 2016)



Center for Strategic and International Studies / Energy and National Security Program
Source: Adapted from U.S. Energy Information Administration data (October 2017).

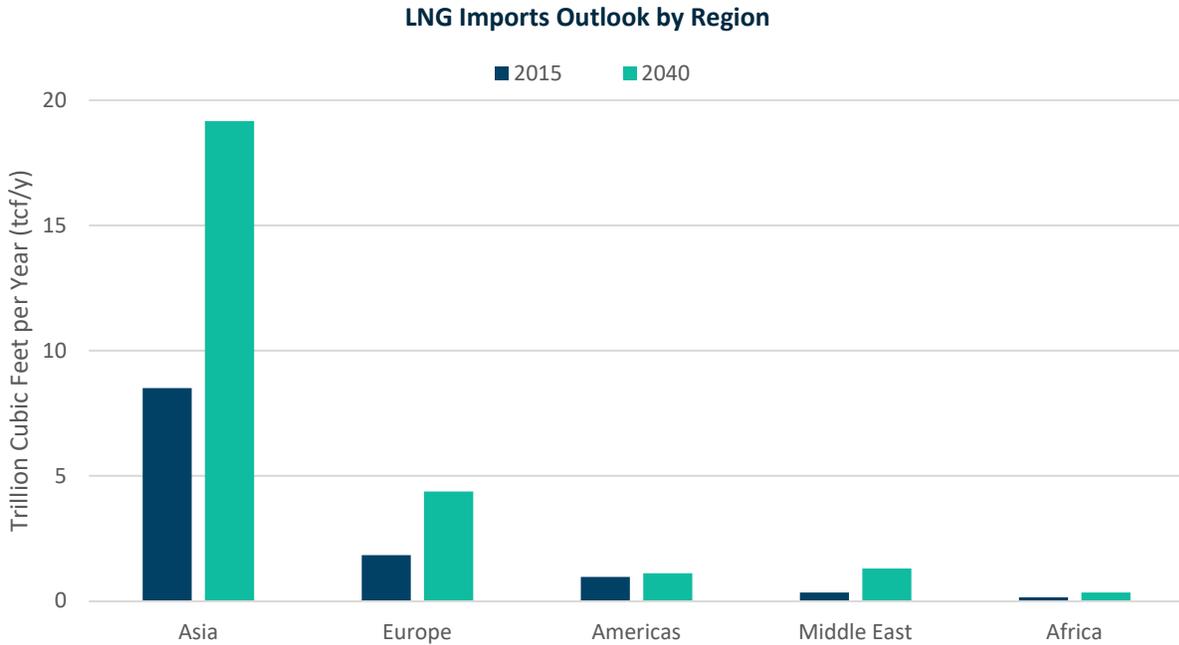
Asia has exhibited sustained growth in demand for all types of energy including large quantities of natural gas and will continue to be the preeminent market for growth in LNG demand globally.

Robust economic growth in tandem with the need to reduce emissions and pollution in cities will see almost half of all global gas demand growth come from Asia out to 2040. Due to a relatively slow level of growth in domestic Asian production of natural gas, LNG imports are expected to account for nearly one-third of the overall growth in demand in the region. Additionally, the current levels of over capacity for LNG exports are expected to suppress LNG prices out to the early 2020s, which is likely to further contribute to increasing levels of demand. However, timing issues persist in the Asian market with lags between growth in demand and the construction of the infrastructure required to facilitate this growth.

Many already well-established LNG import markets in Asia have looked toward U.S. LNG for diversification of both supplies and contractual terms. While the European gas market has gradually embraced alternatives to long-term contracts with destination restrictions, Asian LNG contracts are new to the notions of short-term or spot contracts as well as supplies without destination restriction. As such, long-term contracts account for a greater share of the Asian LNG market compared to that in Europe. The rise of U.S. LNG has served as a much-needed impetus for Asian buyer countries to negotiate/re negotiate for more flexible terms with traditional suppliers.

The combination of resource abundance, market liquidity, regulatory transparency, and contractual flexibilities attracted Asian investment in U.S. LNG liquefaction facilities. In 2012, a few major utilities

and gas companies from Japan and Korea took a position in the LNG export projects to benefit from competitive gas prices in the United States. Despite the sense of over-commitment and the decline in regional spot LNG prices since the second half of 2014—at times lower than comparable spot LNG prices in Europe—Asian importers seem to recognize that the value of U.S. LNG goes beyond price; it alleviates the region’s heavy reliance on the Middle East and the Asia-Pacific for LNG and attendant maritime chokepoints, such as the Straits of Hormuz and Malacca



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Source: IEEJ, Asia/World Energy Outlook 2016.*

LNG is drawing interest in China, where gas is seen as one of the key fuels to help meet its growing energy demand as well as to alleviate the heavy dependence on coal. Pipeline gas from Central Asia accounts for a little over half of Chinese gas imports, which in turn meets about one-third of its total domestic consumption. LNG can diversify China’s gas import profile by broadening its supplier options. China began importing LNG only in 2006, but its LNG import volume has grown to account for 10.4 percent of the world total in 2016, ranking as third after Japan (32.3 percent) and South Korea (13.1 percent). Japan is another good example illustrating the benefits that increased availability of LNG supply has brought to the Asian market. LNG supplies helped Japan avert a massive power shortage despite a 46 GW power-generation capacity hole left by a nuclear power outage following the Fukushima accident, which saw Japan’s LNG import volumes grow by 24 percent, from 9.5 bcf/d (72.8 mtpa) in 2010 to 11.7 bcf/d (89.7 mtpa) in 2013.

Infrastructural requirements, as well as competition from domestically produced coal and the growth of renewables, stand as obstacles to the growth of natural gas demand in Asia.

There are, however, also several barriers faced in the region for the increased uptake of natural gas. One such factor is the infrastructure requirements related to both pipelines and LNG import facilities. These infrastructural developments require large-scale initial investments and for many countries in the region, access to capital will be an issue. Another barrier is related to the level of competition facing natural gas from other energy sources. Asia is a region where there are abundant sources of low-priced coal, which in many countries can be sourced domestically. The incentive to use cheap, secure coal in favor of imported natural gas is strong. Additionally, renewable energy and nuclear also compete with natural gas in Asia. Renewable energy costs are falling rapidly and often enjoy policy support, while nuclear power has seen a limited restart in Japan and a swath of new builds underway in China. So far, U.S. LNG has been quite successful in finding markets in Asia by offering a reliable option with flexible terms but the competitive pressures to secure a growing role for gas in Asia and for U.S. LNG in Asia in will be intense going forward.

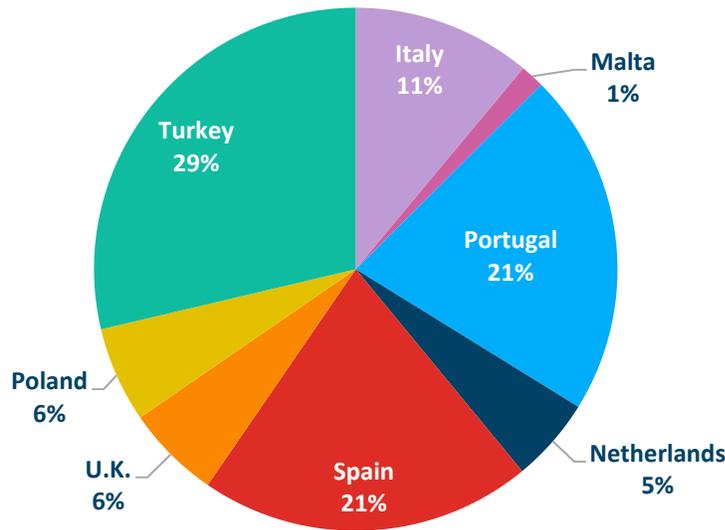
For the moment, U.S. LNG exports to central Europe cannot compete with Russian piped gas in terms of price.

Russia is the largest supplier of natural gas to the European market accounting for over one-third of total natural gas demand in 2016. In recent years, several European countries have built LNG import terminals and signed gas supply contracts with countries outside of Europe in order to diversify their supplies. When European prices are high enough to support the production, liquefaction, and transport costs of sending gas from the United States to Europe, then U.S. LNG can compete on a spot basis in the European market. However, given its abundant gas resources, close proximity, and pipeline infrastructure, Russia has the ability to undercut the price for U.S. gas into the European market. In 2016, Russia's state-owned gas company Gazprom successfully out competed U.S. LNG in Europe with spot prices standing as low as \$4 per mBtu at one stage, a level at which U.S. LNG simply could not compete. Russian pipeline gas prices have slightly increased in 2017 and currently stand at the ~\$5 per mBtu mark; however, the added costs of liquefaction, transportation, and regasification see the price of \$3 mBtu Henry Hub translate to over \$6 mBtu for U.S. deliveries of LNG to Europe. As such it is unlikely that there will be, a major shift in sources of European natural gas imports just yet. While this price level may be favorable for some peripheral markets in Europe, which are isolated from Russian pipeline gas, for the rest of Europe pipeline options from Norway and Russia remain the more attractive source of supply. However, over the longer run Russia may not be able to uphold its volume-over-pricing strategy and so prices may encounter further upward pressure if this strategy is moderated, which would then encourage an acceleration in LNG demand.

An additional factor that may see further levels of growth in LNG demand is related to the current policy stance of the European Union when it comes to Russia gas, which is encouraging further supply diversification through expanding LNG import capacity. For example, Lithuania and Poland have built LNG import terminals in an effort to benefit from supply diversification and more recently to prepare for U.S. LNG cargoes, with Poland receiving its first cargo in July and Lithuania in August. Greater access to LNG supplies is viewed by the European Commission as a means not only to diversify supplies, but to encourage more competitive market-based pricing and to act as a backup in an emergency scenario of pipeline disruptions. As such, the release of the EU's strategy for liquefied natural gas and gas storage in February 2016 has encouraged the building out of greater levels of LNG

import capacity through the EU’s funding support of projects of common interest (PCIs). This strategy will as a result see a rise of LNG import capacity within the EU. For the moment, LNG imports will not experience rapid levels of growth within the European Union for the foreseeable future given the favorable price of piped gas from Russia and Norway, but they can compensate for declining levels of domestic production, serve a number of more illiquid markets located on the peripheries of Europe, and act as an insurance policy for European importers.

Share of U.S. LNG Export Volumes to Europe by Country
 Since the First Commercial Cargo from Sabine (November 2016)



Center for Strategic and International Studies / Energy and National Security Program
 Source: Adapted from U.S. Energy Information Administration data (October 2017).

In addition to being the United States’ single largest market for piped gas exports, Mexico has so far been the largest purchaser of U.S. LNG in 2017.

In the first quarter of 2017 approximately 30 percent of U.S. LNG exports landed in Mexico. Exports to Mexico have received a boost due to an ongoing pricing dispute between Mexico and Peru, along with the maintenance on the 2.1 bcf/d NET Mexico pipeline. However, as seasonal demand increases in Europe and Asia and the NET Mexico pipeline comes back online, it is likely that Mexico’s share of U.S. LNG exports will fall in the latter half of 2017.

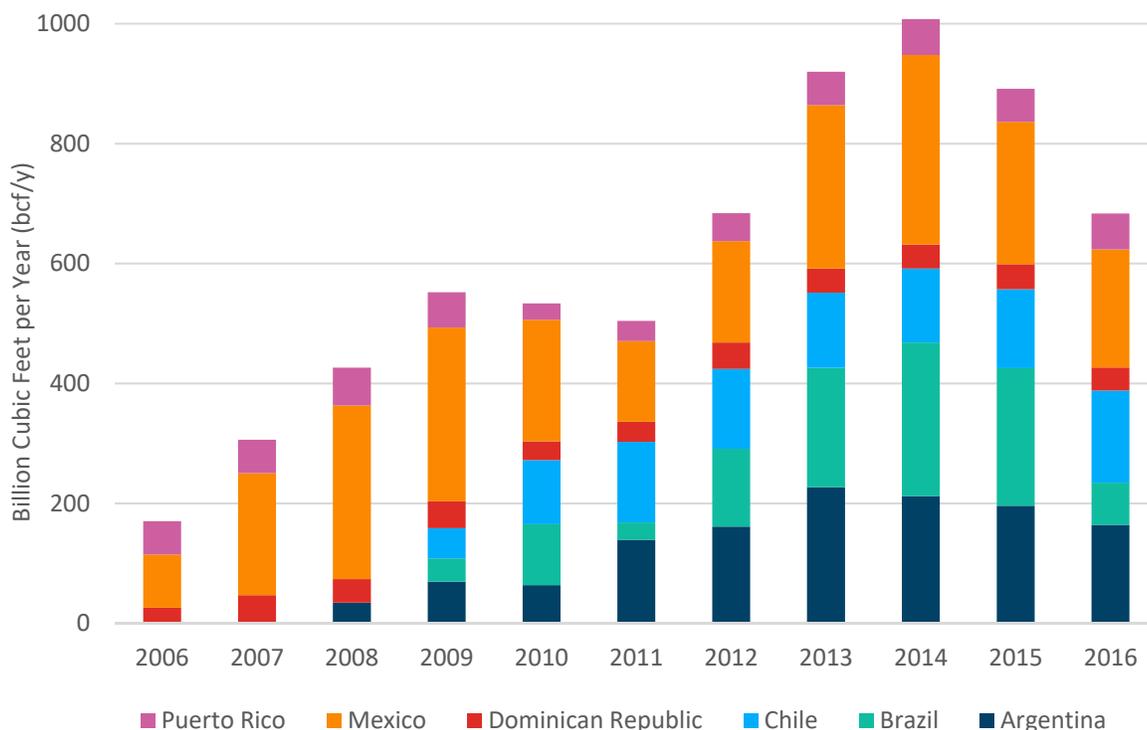
LNG is no longer just an emergency fix in South America, with natural gas making deeper inroads in the region’s energy systems.

Interregional trade of natural gas in South America has traditionally been hampered by an inability to connect the region via the necessary pipeline infrastructure from production to demand centers, as a result of diplomatic and contract disputes and the inability of regional gas resource holders

(Argentina, Brazil, Colombia, Mexico, and Venezuela) to produce enough gas to meet regional demand.

With favorable proximity to the market and its flexible contracts, U.S. LNG is now an attractive proposition for many buyers in this region, especially in coastal demand centers. Increased U.S. LNG exports to South America are, however, contingent on several factors and face several barriers. For example, hydropower plays a significant role for most countries in South America, which is a much less expensive source of energy production. This in turn affects the economic viability of developing large-scale gas power plants. Another factor, which will determine the level of LNG demand, is the pace at which several resource-rich countries can develop domestic reserves.

South America LNG Imports by Country



Center for Strategic and International Studies | Energy and National Security Program
 Source: Adapted from U.S. Energy Information Administration data (October 2017).

A number of specific drivers in several South American countries will likely increase demand for LNG imports. Security of supply concerns for the like of Brazil, in the face of uncertain pipeline imports, is one such driver. Another factor is related to the need for additional supply to complement insufficient domestic gas production in Argentina, Brazil, Colombia, and Mexico. Finally, most of these markets require flexible supply for peak demand, for reasons related to seasonal residential demand fluctuations and variability in power generation from hydropower. Taking these drivers into

consideration, it is clear that flexibility is a key requirement for many markets in South America, so the proximity of U.S. LNG will be a dominant force in the South American market in the years to come.

For most natural gas markets, U.S. LNG is not currently the cheapest potential source of supply. Once the full costs of liquefaction, shipping, and regasification have been factored in, natural gas from Qatar or Russia is generally a cheaper source for Asia and Europe, given the current low oil price environment. However, U.S. LNG could provide a price ceiling on gas imports from other sources, while increasing supply side options and security of supply for many markets. Furthermore, U.S. LNG offers a relatively unique value proposition to the market in terms of both pricing and contract flexibility, and as such the arrival of large quantities of U.S. LNG is at the fore in driving many of the changes underway in the markets today. These changes include the arrival of greater levels of gas-to-gas pricing, more flexible contracts, more hedging mechanisms for volume and price risks, and short-term trading, all of which over the longer run will see the emergence of a truly liquid and competitive global market place for natural gas.

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