



The Role of Natural Gas in the Transition to a Lower-Carbon Economy

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THE INGAA FOUNDATION, INC
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EXECUTIVE SUMMARY



1 Executive Summary

The evolving role of natural gas continues to be at the forefront of US energy industry developments. This evolution to a lower carbon economy, including how growing renewable power generation and battery storage will affect gas-fired power generation, and the resulting effect on the utilization of midstream natural gas infrastructure is an important consideration for natural gas midstream operators and the value chain supporting the construction and operation of midstream infrastructure.

This study on the role of natural gas in the transition to a lower-carbon economy was undertaken to examine trends affecting energy use in the United States over a 20-year horizon, from 2020 to 2040, with a focus on understanding how natural gas complements a lower-carbon economy, while identifying potential challenges and opportunities for the natural gas pipeline industry. As a “Flagship Study” for the INGAA Foundation, this report presents a comprehensive strategic and analytical study to help educate key stakeholders, including energy consumers, infrastructure investors, and policy makers, about how natural gas and natural gas infrastructure will be needed and utilized in a lower-carbon economy.

Over the last decade, spectacular breakthroughs in exploration and production technology have transformed the natural gas industry. Producers have dramatically reduced the time required to drill and complete wells through increased efficiency in their multistage hydraulic fracture stimulations. Increased use of data analytics continues to improve well completion designs and the ultimate recovery from each well. Shale gas production has grown almost 20 percent per year over the last 10 years.¹ Low and stable gas prices have allowed natural gas to become the primary fuel for power generation. The combination of increased production and growing domestic markets created the need for new and reconfigured natural gas pipeline infrastructure. Increasing global consumption of natural gas is also driving infrastructure needs in North America to serve newly-constructed and planned liquefied natural gas (LNG) export terminals along the US Gulf and East coasts and pipeline expansions to deliver natural gas to Mexico.

Simultaneously, the impetus to reduce greenhouse gas (GHG) emissions has triggered state and regional mandates to reduce carbon emissions across all sectors. Some are suggesting that GHG emissions from natural gas combustion and distribution system methane leaks could be reduced by electrifying residential and commercial energy applications that historically have been met with natural gas. Advances in solar and wind generation power generation technology, combined with the extension of the production and investment tax credits, have spurred significant renewable generation capacity additions over the past decade.

The INGAA Foundation Flagship Study examines how these key drivers could affect the role of natural gas and the utilization of gas infrastructure over the next two decades. Our extensive analysis, supported by detailed modeling and industry subject matter expertise, centers around two future scenarios that model different levels of renewable penetration and examine the effect on natural gas demand. These scenarios

¹ US Energy Information Administration (EIA) shale gas dry production (2009-2018).

focus on two possible paths toward an energy portfolio that relies increasingly on renewable energy: one path reflects a result driven by a balance of policy initiatives and market economics (the Balanced Future); an alternative path is driven heavily by policy initiatives intended to accelerate the penetration of renewables in power generation (Rapid Renewables Transition). Our key findings are summarized below.

- **Natural gas will remain a significant contributor to the energy portfolio and economic growth in the United States.**

Over the next 20 years, the current United States natural gas pipeline infrastructure will continue serving both traditional end use sectors such as residential, commercial, and industrial and emerging sectors such as pipeline exports to Mexico and LNG exports to the global market. Rising gas demand and production levels could spur the need for up to 21 billion cubic feet per day (Bcf/d) of new gas pipeline infrastructure to support the shift in demand and supply driven by global LNG demand growth, booming pipeline exports to Mexico, continued demand growth from the petrochemical sector, or enhancing the reliability of the power generation sector.

- **Natural gas fired power generation will continue to play a key role in meeting low carbon initiatives.**

The variability of renewable generation, especially solar and wind generation, will require flexible, fast-ramping generation or energy storage. Natural gas fired generation will allow an increasing amount of renewable energy in the electric generation portfolio by providing electric grid reliability in the form of load and generation profile following, backup power, frequency regulation, and spinning reserves. Battery storage at scale will be able to provide some of these services; current battery technologies, however, do not support the full range of flexibility needed, including for seasonal and daily variations, and therefore cannot displace natural gas fired generation, which is uniquely suited to mitigate this variability. Even assuming technological advancements, declining life-cycle costs, and solutions for disposal issues, battery storage may become economically comparable to gas fired generation only toward the end of the analysis period. Therefore, regardless of any assumptions about increasing renewable generation, natural gas-fired generation will continue to play a crucial role in ensuring that peak electric demand is met reliably.

- **Demand for non-ratable flow interstate natural gas transmission services and hourly nominations will increase.**

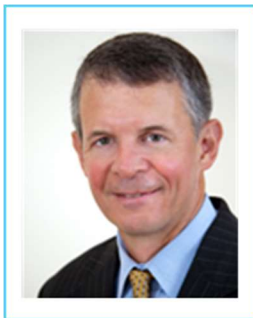
The continued evolution of the gas transmission industry to support a lower-carbon economy over the next two decades will alter shippers' requirements for natural gas pipeline services. Renewable integration will require quick ramping gas fired generation during specific hours of the day. Increased integration of intelligent metering will allow local distribution companies (LDCs) that serve traditional residential and commercial sectors to predict and respond to peak hourly need and offer demand response programs that can reduce overall design day needs. If natural gas fired generators are expected to serve as the backup when renewable generation is unavailable, these shippers may require pipeline services that allow them to nominate on the pipeline with little to no notice and the ability to consume gas non-ratably. In such cases, pipelines must have the capacity to offer such services, and if not,

pipelines must be sized to do so. In cases where existing capacity is insufficient to support such services, the shippers demanding such services must be willing to pay for the needed capacity.

Uncertainty about the energy future is nothing new for natural gas or any other energy source. Market dynamics can change because of any number of factors, including a sudden technological breakthrough or federal or state energy policy decisions. Over the next two decades, global market forces and regional US policy initiatives may change the way we think about the role of natural gas. In the mid-2000s, the United States was positioning itself to import LNG from around the globe and perhaps pipeline gas from the Arctic, as domestic conventional natural gas supplies were steadily declining. This changed rapidly when the shale revolution made domestic natural gas abundant and affordable. Today, we know that there is both a domestic and a global impetus for reducing carbon emissions and transitioning to a lower-carbon economy. Natural gas will play a key role in supporting this initiative by providing a safe, reliable and affordable source of energy.

The INGAA Foundation thanks the Flagship Study steering committee for its oversight and guidance throughout the development of this report.

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BACKGROUND

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2 Background

2.1 Objectives of the Study

Natural gas transmission infrastructure is built to serve the economic needs of the market and is supported by shippers willing to commit to long-term firm transportation contracts to use the capacity. Despite the steadily increasing consumption of natural gas, opponents of natural gas infrastructure projects argue that increased renewable penetration will decrease the demand for natural gas fired generation, thereby leaving gas transmission assets stranded. Demand for gas transportation services from the power sector, however, has not been the primary driver for recently proposed pipeline projects. Rather, other sectors have been the primary drivers of new pipeline infrastructure investments and utilize the majority of existing gas pipeline capacity. These shippers will continue to rely on natural gas and natural gas infrastructure, even as demand for renewable energy increases.

Natural gas usage trends in traditional end use sectors (residential, commercial, and industrial) and non-traditional sectors (LNG exports and pipeline exports to Mexico) will also significantly affect how the natural gas infrastructure will be utilized to meet the needs of all energy consumers in a safe and reliable manner. The INGAA Foundation is seeking to understand the future roles of natural gas and natural gas infrastructure in a lower-carbon economy for a 20-year analysis period, as well as the challenges and opportunities for the natural gas industry as it fulfills these roles.

The continued development of renewable resources across the country, coupled with slower than expected electric load growth, has dampened the need for new baseload generation capacity. Concurrently, the need for dispatchable generation that can quickly ramp up and down has grown. In California, for example, the continued addition of solar resources has significantly changed the typical daily net load profile, with a deep midday drop and steep ramp rates in later afternoon and early evening hours. In West Texas, the significant amount of wind capacity has frequently driven electricity prices into the negative during the off-peak hours. The duration and magnitude of this kind of shift across the country will affect the amount, timing, and duration of demand for natural gas to support the power generation sector and how pipelines and storage facilities will be utilized to facilitate renewable energy growth.

Global and US initiatives to create a lower carbon economy will also impact traditional and non-traditional demand sectors. North America's entrance into the global LNG market will provide Asian and European consumers with the benefits of competition that includes a low-cost supplier. US LNG exports are expected to continue to grow over the analysis period and are expected to have a sustained impact on the need for natural gas infrastructure.

It is the objective of this study to examine how the transition to a lower-carbon economy will affect natural gas pipeline and storage utilization over the analysis period. Given the evolving role of natural gas in the power sector, the report examines how natural gas infrastructure can support renewable power generation development and electric grid reliability.

2.2 Study Methodology

Economic Assessment of the Role of Natural Gas in Domestic Markets

For core domestic demand, Black & Veatch utilized statistical modeling to project natural gas demand from the residential, commercial, and industrial sectors and relied upon ABB's PROMOD electric market simulation model to project daily demand for natural gas from the power sector.

In developing the statistical relationships between residential, commercial, and industrial demand and key drivers such as economic/population growth, weather, relative price of natural gas to alternative fuels, Black & Veatch analyzed the consumption efficiency gains over time and incorporated energy efficiency policy goals in place today.

Black & Veatch used the comprehensive view developed in its latest Energy Market Prospective (EMP) as a starting point for its gas demand projections and reconciled its projections with the most recent load projections that natural gas utilities have filed with regulators. The EMP is an integrated approach to forecasting natural gas and power sector demand. Updates draw upon Black & Veatch's engineering and construction expertise on future generation technology costs in conjunction with our expectations on emissions, nuclear, and renewable energy development; alternative generation technologies; energy efficiency; and coal retirements.

This integrated modeling framework for the gas and electric sectors provides a basis for insights with respect to future renewable integration needs and their impacts on natural gas demand for power generation on an annual, seasonal, and daily basis. In its EMP outlook, Black & Veatch summarized the following:

- State renewable portfolio standards (RPS) and feasible renewable energy resources and technology to meet the RPS goals;
- The impact of energy efficiency, distributed generation, and behind-the-meter solar on net energy load;
- Expected changes in generation resource mix and associated infrastructure developments, such as electric transmission, energy storage, and incremental natural gas infrastructure; and
- The availability of renewable generation and the need for quick ramp capacity to maintain reliability during peak winter and peak summer periods when the natural gas system or the electric system is most constrained.

For LNG exports, Black & Veatch summarized key fundamental drivers of the global LNG market using proprietary research and insights from designing and constructing LNG facilities across the globe and projected gas demand for each LNG export terminal. This understanding of global LNG project development will provide a basis for assessing the relative competitiveness of US LNG exports versus other potential global suppliers.

For pipeline exports to Mexico, Black & Veatch incorporated the latest outlooks provided by the Comisión Federal de Electricidad (CFE), PEMEX, and other state agencies in addition to our proprietary view on pipeline exports to Mexico. As Mexico continues to implement market reforms and build incremental infrastructure to move natural gas further south, US pipeline exports are expected to continue to grow. Black & Veatch examined the key drivers of exports including Mexican demand growth and offshore production expectations over the analysis period.

Scenario Analysis

For this study, we created two possible future scenarios for transitioning to a greener, lower-carbon economy. One scenario assumes an energy future in 2040 that has been driven by a balance of policy initiatives and market economics (the Balanced Future); the other scenario assumes an alternative path that is driven heavily by policy initiatives intended to accelerate the penetration of renewables in power generation (Rapid Renewables Transition).

Balanced Future

Sustained/steady transition to a low carbon economy



- RPS goals met on schedule
- Sustained growth of battery storage additions to meet mandates
- Strong second wave of LNG and pipeline exports
- Economic based investment decisions

Rapid Renewables Transition

Global acceleration to carbon reduction



- Minimum 50% RPS targets
- Accelerated battery storage growth
- Operational and under construction LNG terminals only
- Policy or technology driven investment decisions

Evaluation of Pipeline Needs and Projected Utilization

Black & Veatch utilized RBAC’s GPCM market fundamental model to project utilization of natural gas pipeline and storage infrastructure across the United States. Based on the scenario projections of gas demand and supply, Black & Veatch examined the regional utilization of gas infrastructure and identified the regions with infrastructure constraints. The study examined the annual, seasonal, and daily gas demand projections to provide insights to natural infrastructure operators on designing the most appropriate customized services to resolve these constraint issues.

Opportunities and Challenges for Natural Gas Midstream Sector

The results of the analyses provide key insights on the future role of natural gas in the North American energy market. The evolution of utilization patterns for natural gas pipeline and storage assets as North America transitions to a lower-carbon economy highlights (1) the complementarity of gas and renewables, (2) practical considerations related to timing of technology advancements and penetration of battery storage, and (3) the continued role of natural gas over an extended period of time to ensure a reliable and resilient energy portfolio.

The study identifies the opportunities for the natural gas midstream sector to overcome challenges, including natural gas pipeline and storage services that would enhance natural gas' role as a balancing fuel to support the electric system reliability alongside battery storage and other energy storage options.



THE CURRENT ROLE OF NATURAL GAS

3



3 The Current Role of Natural Gas

Natural gas transmission infrastructure is built to serve the economic needs of the market and is supported by shippers willing to commit to long-term firm transportation contracts to use the capacity. Despite the steadily increasing consumption of natural gas, opponents of natural gas infrastructure projects argue that increased renewable penetration will decrease the demand for natural gas fired generation, thereby leaving gas transmission assets stranded. Demand for gas transportation services from the power sector, however, has not been the primary driver for recently proposed pipeline projects. Rather, other sectors have been the primary drivers of new pipeline infrastructure investments and utilize the majority of existing gas pipeline capacity. These shippers will continue to rely on natural gas and natural gas infrastructure, even as demand for renewable energy increases.

Natural gas today primarily serves residential, commercial, industrial, and power generation customers (Figure 1). Over the past 10 years, natural gas consumption for these sectors in the United States has steadily grown from 58.6 Bcf/d to 68.0 Bcf/d, driven primarily by growth in the power generation sector. The consumption of gas in the power generation sector has steadily grown from 18.3 Bcf/d in 2008 to 25.3 Bcf/d in 2017, which accounts for about 38 percent of the natural gas consumed in the US lower 48 states.

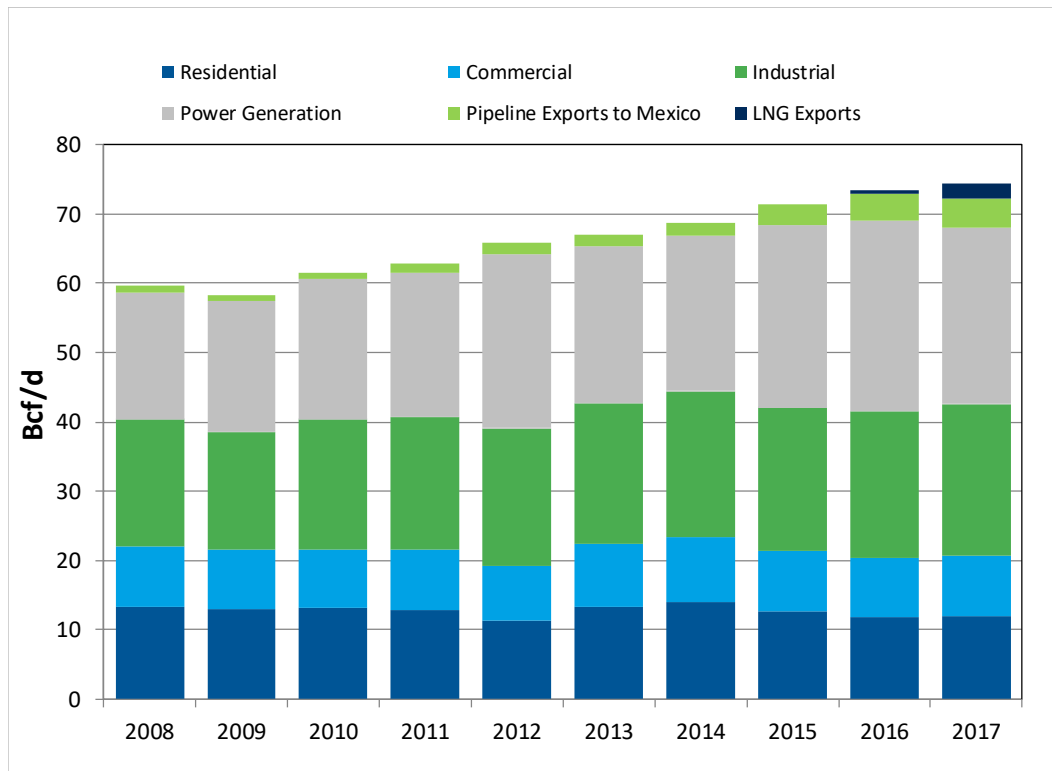


Figure 1. Historical Natural Gas Consumption by Sector (2008 to 2017)

Source: United States Energy Information Administration (EIA)

The primary drivers for the shift to gas fired power generation include lower natural gas prices, life-cycle costs favoring gas-fired generation over other technologies, and environmental regulation. While power

generation has driven growth in domestic natural gas demand, it is critical to note that 60 percent of the natural gas consumed in the United States serves the needs of the residential, commercial, and industrial consumers.

In the past, natural gas LDCs were the traditional anchor sponsors for interstate natural gas pipeline projects, contracting for pipeline capacity to meet design day load requirements. As natural gas demand growth shifts from residential and commercial demand to other sectors, natural gas producers, marketers, and LNG export terminal developers have become the major catalysts for new pipeline capacity investment.

In the past five years, 67 percent of Federal Energy Regulatory Commission (FERC)-certificated interstate natural gas pipeline capacity was added to meet the needs of gas producers, marketers, or LNG export terminal developers. Gas producers have supported new gas infrastructure to maximize the value of their gas, while the developers of LNG export facilities have needed consistent access to low cost, reliable supply over the life of their LNG sales or tolling agreements. Black & Veatch expects that the recently certificated pipeline capacity (2014 to 2018) will be highly utilized for the duration of the initial service agreements and beyond.

Even though demand from independent and utility power generators have not been the primary driver for recent incremental capacity additions, these entities have benefited from incremental natural gas transmission investments through access to the pipeline system via capacity release, interruptible transportation, asset managers or gas marketers. In addition, independent generators and integrated electric utilities have supported pipeline projects to serve their needs in some cases. Continued projected growth in gas-fired generation to replace coal and nuclear facilities and to support variable renewable generation is expected to spur incremental pipeline capacity as discussed later.

3.1 The Primary Role for Natural Gas: Residential and Commercial Heating

Today, almost 30 percent of natural gas consumed in the United States is for residential and commercial end use, according to the EIA. Natural gas is used in furnaces, stoves, ovens, clothes dryers, and water heaters in a majority of homes across the country. Commercial use is similar; heating applications are the primary source of this demand.

Residential and commercial demand has historically underpinned demand for natural gas transmission and storage services. Residential and commercial gas consumption is highly seasonal and fluctuates with weather. Winter design day gas consumption has been the basis for LDCs' need for natural gas transmission and storage services. The growth in demand from these bedrock natural gas consumers creates a corresponding growth in the demand for pipeline and storage services.

Residential and commercial consumption continues to increase. The number of residential customers has grown from 57 million in 1998 to almost 70 million in 2017, growing at a compounded annual growth rate (CAGR) of 0.98 percent (Figure 2). The number of commercial customers has grown at a more moderate 0.42 percent CAGR. Affordable and stable gas prices over the past decade, coupled with reliable firm deliverability, continue to make natural gas an attractive option for residential and commercial customers.

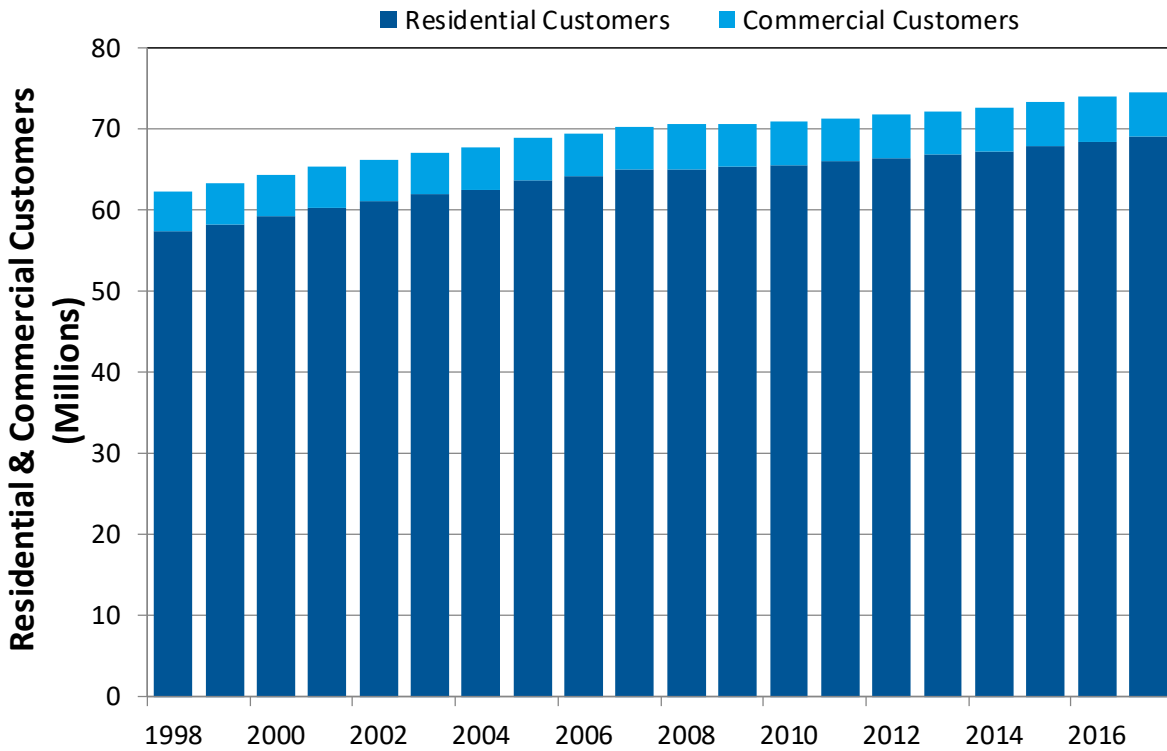


Figure 2. US Residential and Commercial Natural Gas Customers (1998 through 2017)

Source: EIA

3.2 Natural Gas Use for the Industrial Sector

Industrial use is primarily focused on heating industrial processes, on-site power generation, and feedstock for chemical processes, accounting for approximately 30 percent of the United States natural gas consumption. Lower natural gas prices reduce the cost to manufacture plastics and chemicals, which makes the US petrochemical industry more competitive in the international marketplace. This, in turn, will make the industrial sector a sustainable source of demand growth and a continued user of gas transmission services.

Ethylene capacity in the United States is expected to increase by 40 to 50 percent during the next seven years, with most of the production capacity located in the Gulf Coast market (Figure 3), according to Black & Veatch’s 2018 EMP. Low-cost natural gas production provides the United States with a long-term advantage that will support the addition of ethylene production capacity needed to meet rising global demand. We expect that ethane consumption will grow at approximately 6 percent CAGR as US ethylene production capacity gains additional market share and serves Asian and other global growth markets.

Petrochemical plant investments in the United States will continue to be driven by several long-term global market factors:

- Cost of alternative feedstocks;

- Ability to transport feedstock and move end use production; and
- Downstream product export demand.

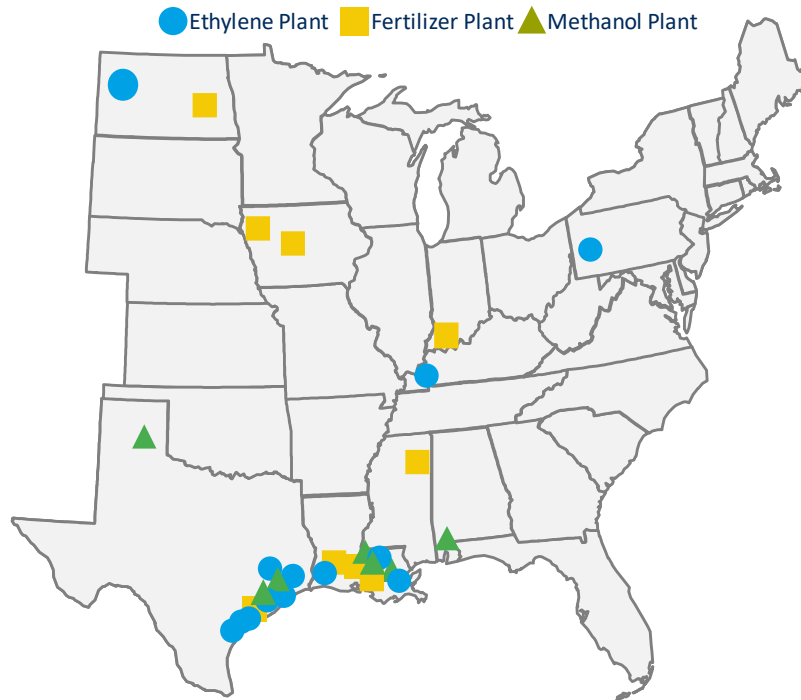


Figure 3. Proposed and Recently Constructed Petrochemical Facilities (2018 through 2025)

Source: Black & Veatch Analysis

3.3 Displacement of Coal Fired Generation and Environmental Benefits of Reduced Emissions

In 2016, natural gas surpassed coal as the leading fuel for electric generation (Figure 4). Natural gas fired generation accounted for 36 percent of the total generation mix in 2018 and should account for 40 percent by 2020. Much of the growth in gas fired generation will result directly from displacing coal fired generation.

Declining natural gas prices over the past decade combined with environmental requirements such as Environmental Protection Agency regulations under the Clean Air Act, including Mercury and Air Toxics Standards, have reduced the dispatch of coal fired generation. Wind and solar thermal and photovoltaic generation increased from 2 percent of total generation in 2009 to 8 percent in 2018, as shown on Figure 2.

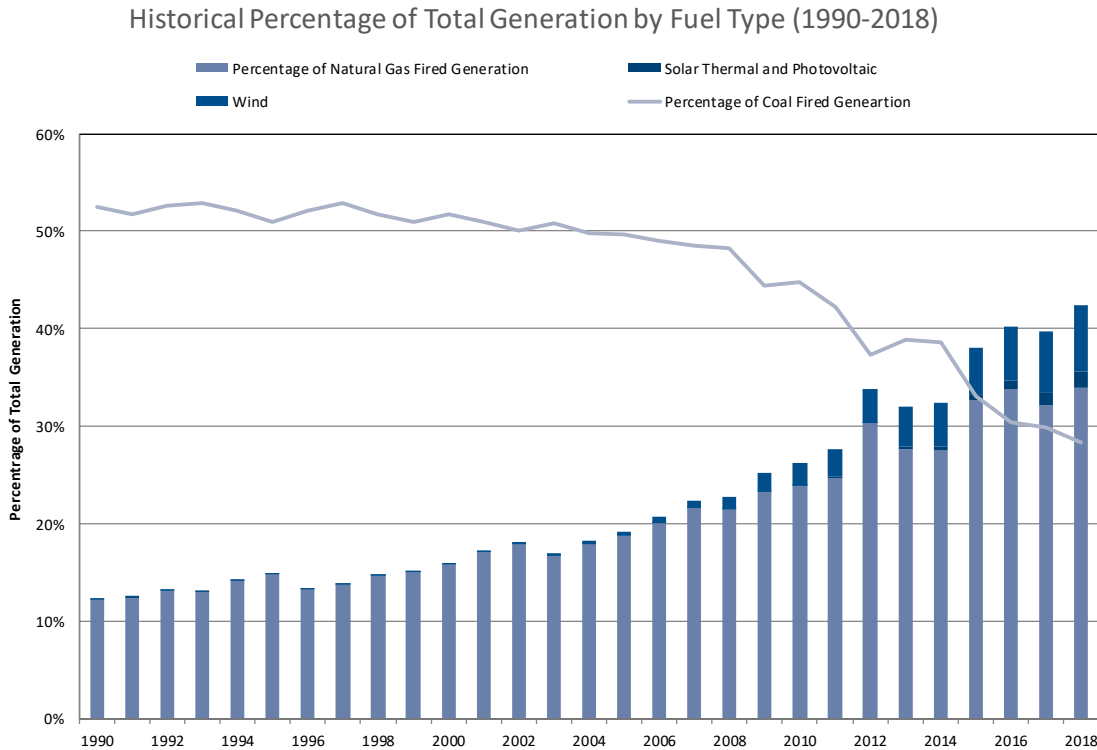


Figure 4. Historical Generation Percentage by Fuel Type

Source: EIA

The growth of natural gas fired generation will create continued environmental benefit by reducing sulfur dioxide (SO₂), nitrogen oxide (NO_x), and carbon dioxide (CO₂) emissions from the power generation sector. Similarly, pipeline exports to Mexico and LNG exports to the global market will contribute to reducing global emissions from the generation of electricity.

According to the EIA², between 2005 and 2017, CO₂ emissions from the electric sector declined by 3,855 million metric tons (MMMT). More than 60 percent of this total (2,360 MMMT) was attributed to natural gas replacing coal and oil based generation resources. Over the same period, the CO₂ emissions reduction attributable to gas-fired generation was greater than the reductions attributable to renewables and other non-carbon generation sources combined. As shown on Figure 5,

² https://www.eia.gov/environment/emissions/carbon/pdf/2017_co2analysis.pdf

since the mid-2000s, gas-fired generation has also reduced SO₂ and NO_x levels by 84 percent and 62 percent, respectively.

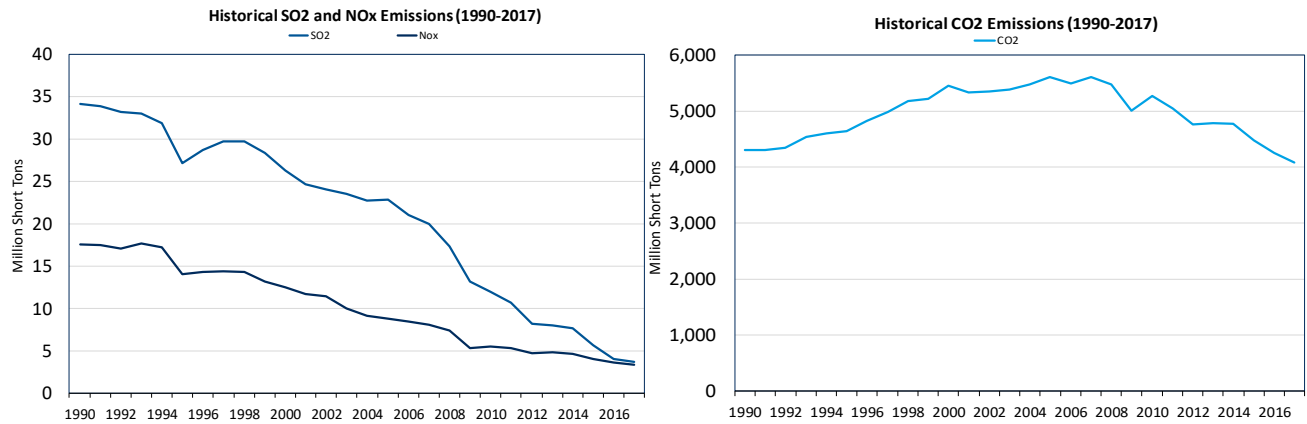


Figure 5. US SO₂ and NO_x Emissions from Power Generation

Source: EIA

We expect that natural gas will continue to play an essential role in replacing retiring coal and nuclear power generation capacity in the next 20 years. In addition, natural gas will play an equally important role in filling the gaps from daily and hourly solar and wind generation variability. This will be especially true in places where large scale energy storage deployment is either not feasible or not economical.

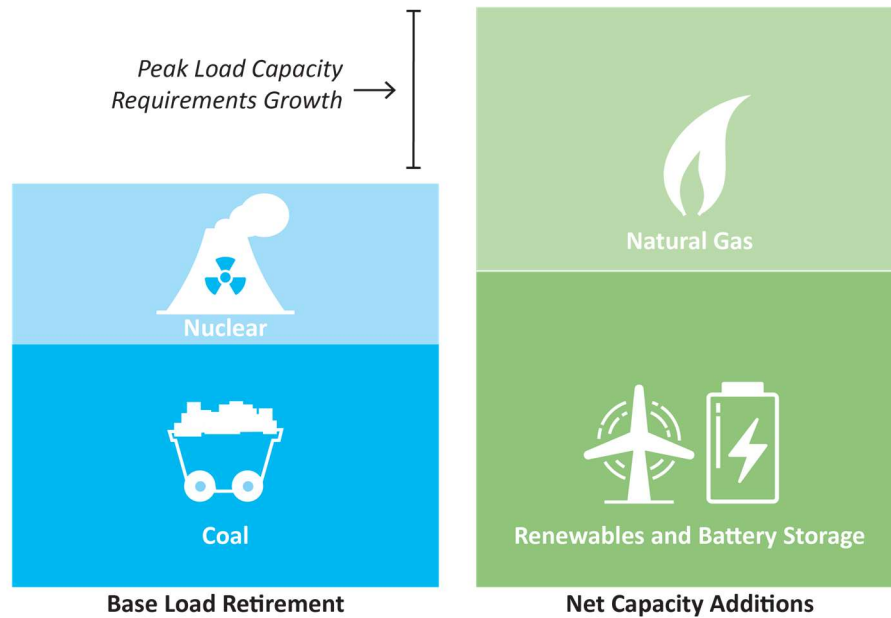
3.4 Baseload Retirements of Coal and Nuclear Capacity

According to the Black & Veatch 2018 EMP, 82 gigawatts (GW) of coal capacity will be retired between 2020 and 2040 because of economic pressures and operators’ strategic portfolio realignment. Nuclear power plants accounting for 48 GW of capacity will reach the end of their 20-year extensions of the initial 40-year operating licenses during this period. Continued operation of these nuclear facilities would require another 20-year license extension.

Low electric prices, costly applications for extensions, and dependence on state financial support will lead to a diminishing role for nuclear generation and create the need for additional renewable and gas fired generation or energy efficiency. Preparing an application for an operating license renewal is a lengthy and costly process that can face public opposition.³ To date, the owners of only 5.7 GW of nuclear generation have made, or plan to make, regulatory filings to request operating license renewals for their facilities. Approximately 11.7 GW of nuclear capacity are operating under special state financial support plans in Illinois, New Jersey, New York, and Connecticut, where the nuclear reactors are classified “at risk” for retirement over the next decade without financial support. These increasing financial pressures will allow natural gas to continue to play an essential role in replacing retiring coal and nuclear power

³ <https://www.commondreams.org/newswire/2018/11/20/beyond-nuclear-opposes-second-license-extension-peach-bottom-nuclear-plant>

generation capacity in the next 20 years. This will be especially true in places where large scale energy storage deployment is either infeasible or uneconomical.



Florida provides an example of how much natural gas will be needed to replace various existing forms of generation. Black & Veatch projects that an additional 12,000 megawatts (MW) of natural gas fired generation capacity will be required between now and 2040 to replace coal and nuclear capacity retirements in Florida. In contrast, 15,222 MW of imported wind from Texas or Oklahoma and 13,390 MW of demand response and energy efficiency would be required to provide the same energy output. This amount of imported wind would equate to over 50 percent of the total wind capacity in Texas and Oklahoma today. Thus, natural gas fired generation will be crucial in Florida because renewable resources cannot be scaled to meet the entirety of the state’s future generation capacity needs.

3.5 Natural Gas Supports Renewable Integration and State RPS Goals

Over the past five years, the United States has installed 96 GW of wind and solar capacity. In 2018, 8 percent of the total 4,018 terawatt-hours (TWh) of electricity generated in the United States was produced by wind and solar resources. Renewable energy is rapidly becoming cost effective as an energy generation resource because of the declines in solar module material costs and the continued efficiency gains from automation in manufacturing. With significant reductions in the cost of renewable generation and 30 states working toward meeting RPS, renewable resources are poised to become an even more important source of power generation (Figure 6).

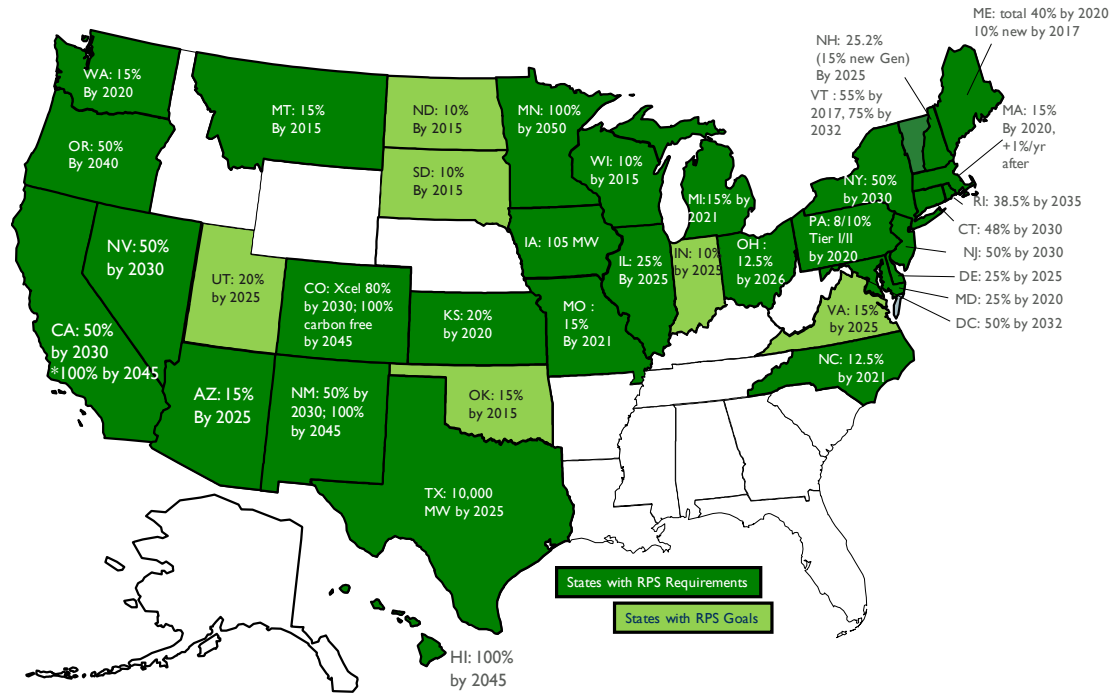


Figure 6. US Renewable Portfolio Standard Requirements and Goals

Source: State websites, Database of State Incentives for Renewables & Efficiency (DSIRE)

As shown on Figure 7, over the past 10 years, wind and solar generation capacity has grown by 13 percent.

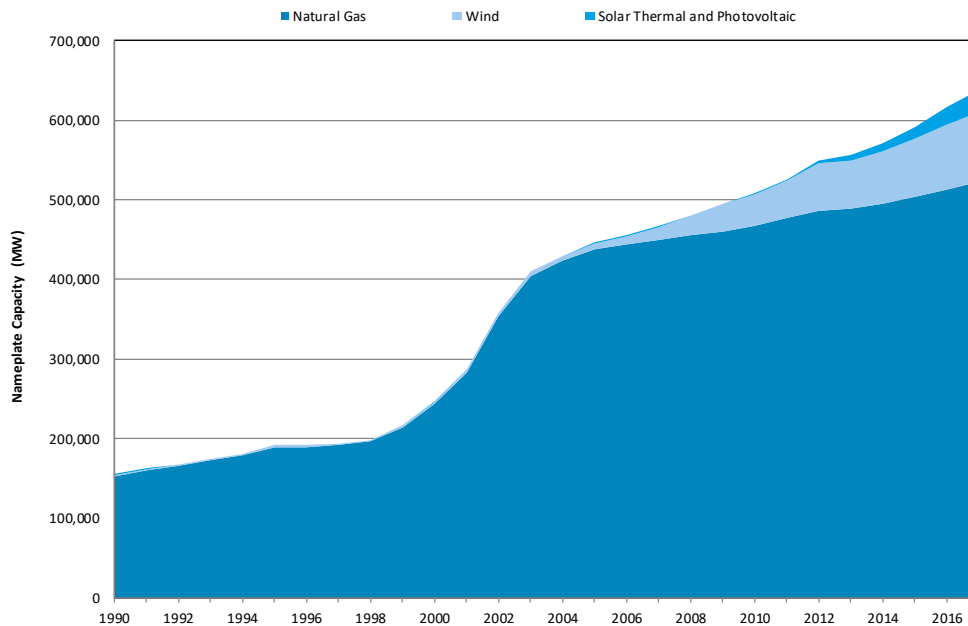


Figure 7. United States Natural Gas, Wind, and Solar Generation Capacity

Source: EIA

The rapid rate of renewable generation growth has displaced some gas fired power generation. The intermittency of renewable generation, however, creates challenges because of the misalignment between when renewable generation is available and when generation is needed to meet demand. Natural gas will play an important role in filling the gaps created by daily and hourly solar and wind generation intermittency.

For example, significant solar generation output peaks during the middle of the day when electric load is considerably smaller than during late afternoon peak periods. This misalignment limits the ability for renewable generation to serve load during the late afternoon peak. While weather models can predict day-ahead wind and solar generation, sudden weather events such as cloud cover or a change in wind direction can abruptly alter the availability of wind and solar generation, requiring fast ramp generation, such as gas fired generators, to balance the electric grid.

Increasing penetration by renewable generation capacity could reduce the need for other forms of baseload generation. Still, the experience in states with the fastest rates of renewable energy deployment, including California which is discussed further below, has been that fast-ramping natural gas fired generators are crucial when non-dispatchable renewable generation is unavailable.

The flexible nature of natural gas fired generation has allowed ISO New England (NE) to meet the overall regional need for energy despite wind generation’s daily variation. On Figure 8, ISO NE’s daily wind and natural gas fired generation during the winter of 2018 (January through March) indicates a negative correlation between wind generation and natural gas fired generation. On days when wind generation is low, natural gas fired generation is increased to make up for the shortfall.

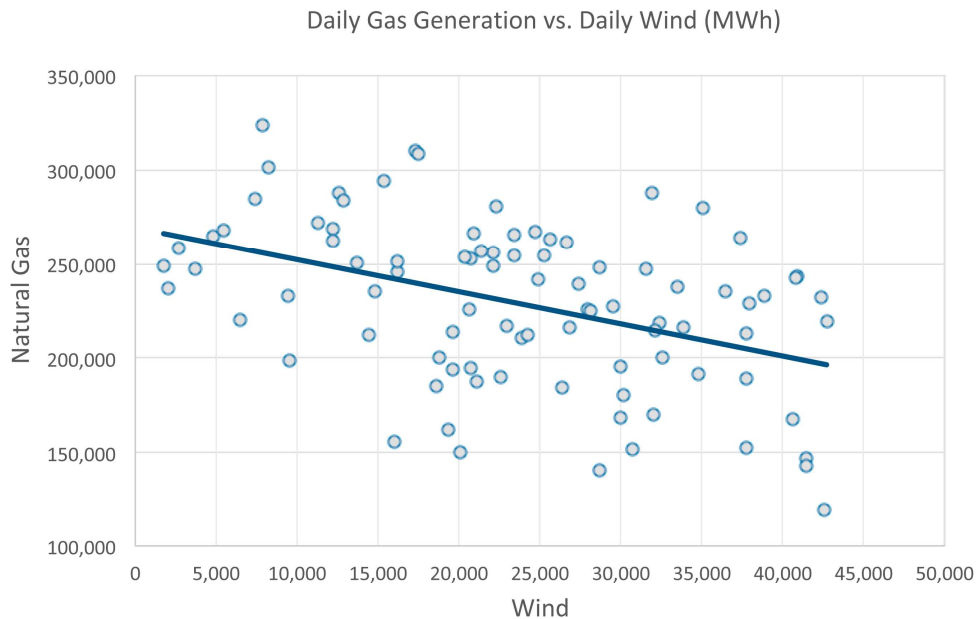


Figure 8. Daily Gas Generation Versus Daily Wind Generation (January through March 2018)

Source: ISO NE

The shortfall reached 15,000 megawatt-hours (MWh), or 5 percent of the daily winter generation load, on one day during this period. As ISO NE experiences increased penetration by wind generation, the demand for natural gas supply and transportation services will become more variable. This increased uncertainty in demand will require system flexibility in the form of additional firm pipeline or storage deliverability. On cold days when natural gas demand from heating houses is high and pipeline capacity becomes constrained, some power generators lacking firm natural gas transportation capacity now resort to burning oil.

We anticipate that natural gas fired generation will play a key role in ensuring electric grid reliability regardless of the amount of renewable penetration. California, with its current and future heavy reliance on solar generation, illustrates this point (Figure 9). Late afternoon ramping requirements already have increased substantially as a result of high electric demand when the availability of solar generation is declining.

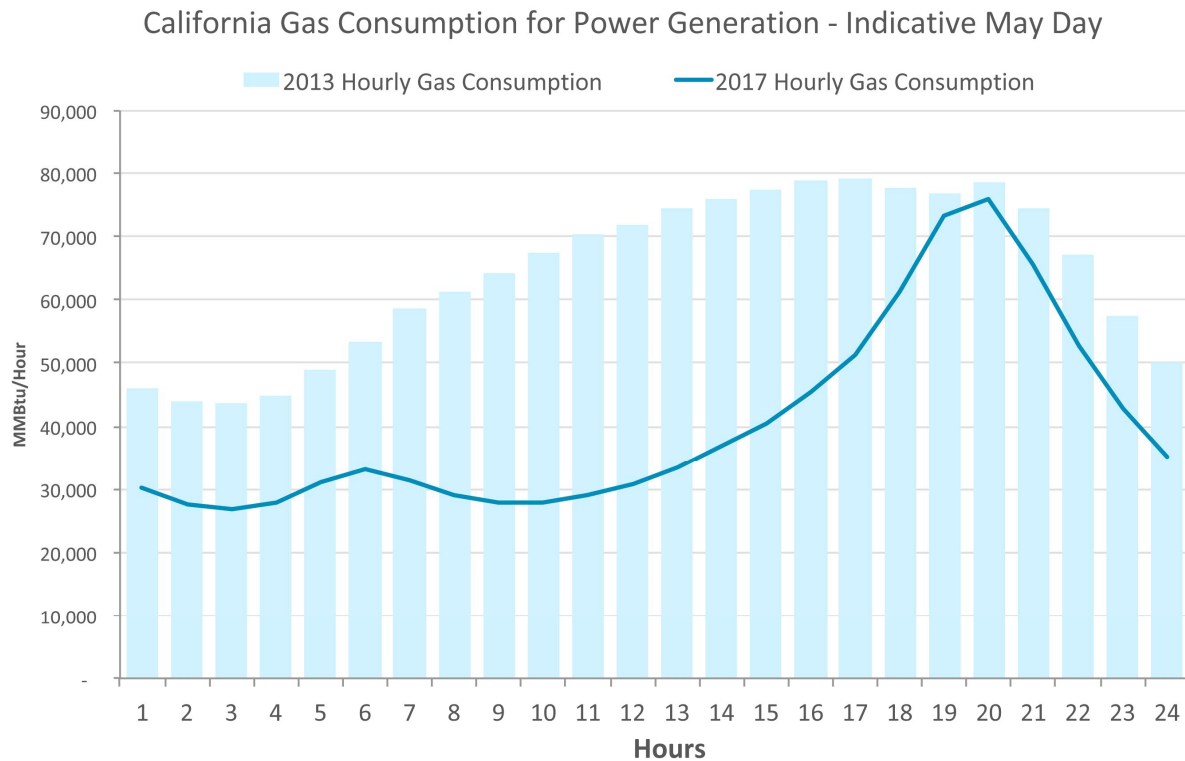


Figure 9. Intraday Gas Needs from the Power Sector in California

Source: Black & Veatch Analysis, California Independent System Operation (CAISO)

Depending on the magnitude of renewables, demand response, and energy efficiency needed, Black & Veatch projects that it is highly difficult for an energy portfolio comprised strictly of renewable resources to provide enough dispatchable energy to displace natural gas fired generation on an annual basis. The variability of renewable generation, especially solar and wind generation, will require flexible, fast-ramping generation. To maintain the reliability of the bulk power system, more resources will be needed that can provide functions such as load and generation profile following, backup power, frequency

regulation, and spinning reserves. Natural gas fired generation can provide the functions that will allow more renewable resources to enter the electric generation portfolio.

3.6 LNG Exports and Pipeline Exports to Mexico

The need for additional North American LNG export capacity is supported by global natural gas demand growth and the continued development of the global LNG market over the 20 year study period. This will create the need for natural gas transmission capacity.

Natural gas will be the primary source of energy to support a transition away from coal and oil in most parts of Asia and Africa. According to the EIA’s International Energy Outlook (IEO) 2017, Asia and Africa natural gas consumption grew to approximately 90 Bcf/d in 2018 and will grow to over 168 Bcf/d by 2040. A large portion of the expected demand growth will be met with North American LNG exports (Figure 10).

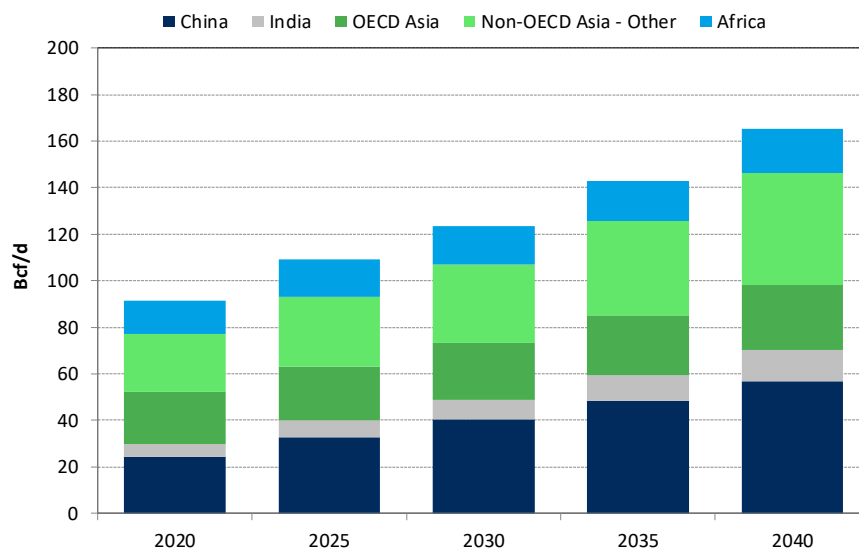


Figure 10. Projected Natural Gas Consumption – Asia and Africa

Source: EIA IEO 2017

US LNG exports will help support the global transition from coal and oil power generation to natural gas and renewables. With steady renewable generation growth in Organization for Economic Co-operation and Development (OECD) Asia and non-OECD Asia⁴, LNG imports to the region will play a complementary role in balancing renewable variability. The combination of natural gas and renewables will reduce overall CO₂ emissions, as shown on Figure 11.

⁴ EIA AEO 2018

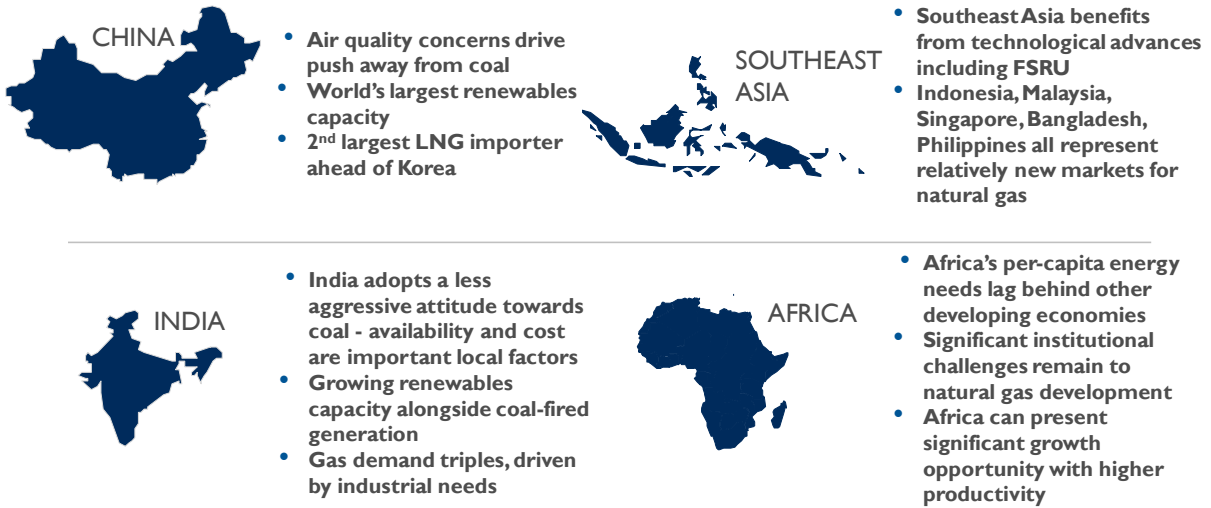


Figure 11. LNG Export Destination Markets - Asia and Africa

Source: Black & Veatch

Energy reforms in Mexico to deregulate oil, natural gas, and electric markets have spurred the evolution of energy markets in that country. This, in turn, has attracted private capital investment in energy infrastructure in Mexico. Natural gas demand growth in Mexico will outpace the expected growth in domestic gas production over the 20-year period considered under the Balanced Future Scenario. Natural gas imports from the United States will grow at 3.1 percent CAGR through 2040 (Figure 32).

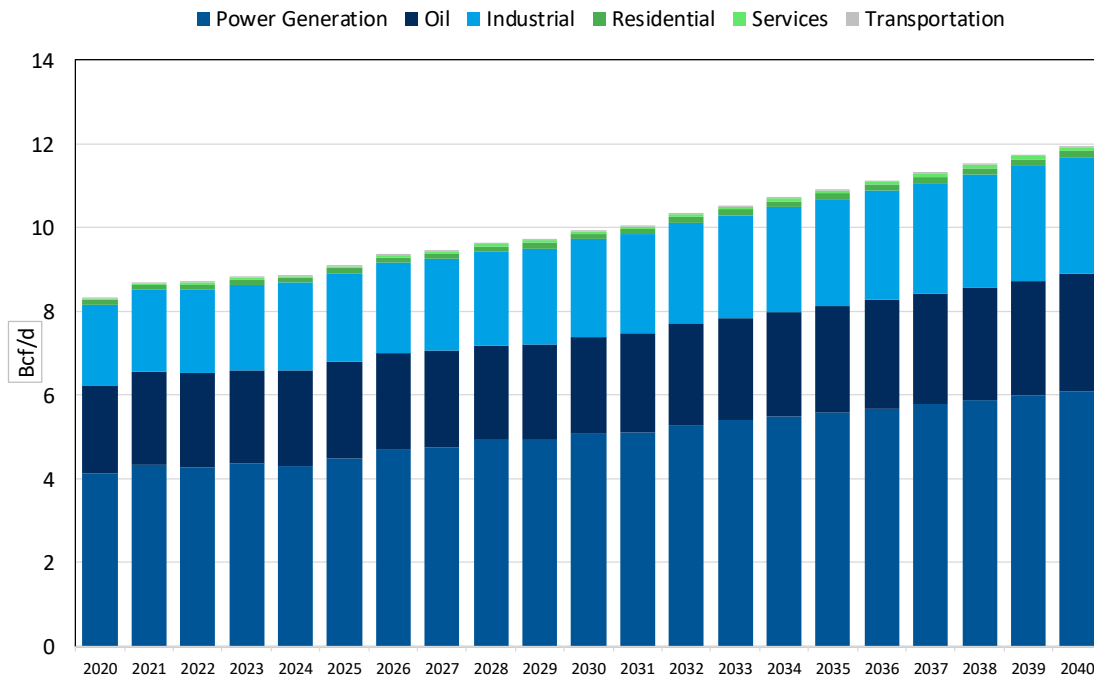


Figure 12. Projected Demand for Natural Gas in Mexico from 2020 to 2040

Source: SENER Prospectiva de Gas Natural (2020-2040), Black & Veatch Analysis

A significant portion of United States natural gas pipeline exports to Mexico will rely upon supplies originating in Texas, which accounted for 84 percent of export volumes to Mexico in 2018. We expect that 2 Bcf/d of incremental US pipeline export capacity to Mexico will be needed between 2020 and 2040 (Figure 13).

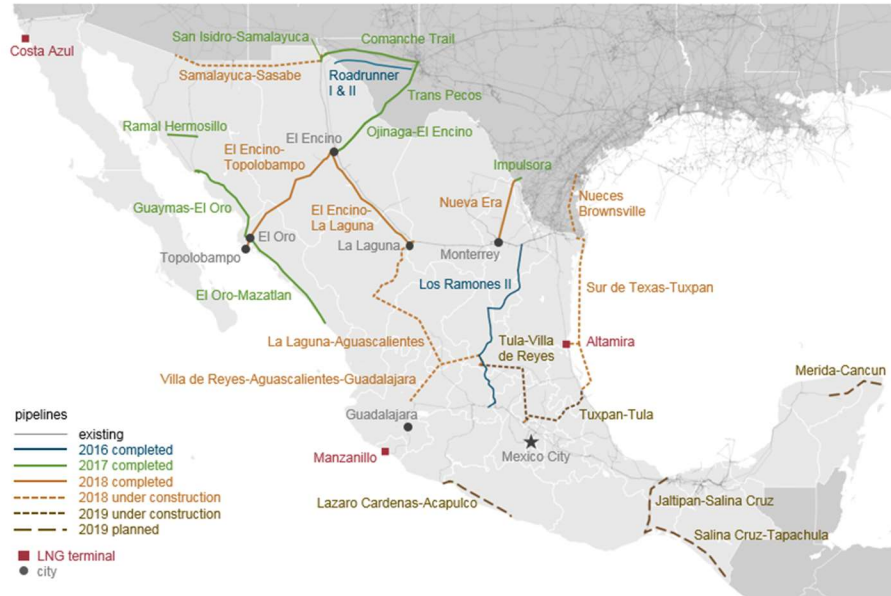


Figure 13. Existing and Proposed Mexican Natural Gas Infrastructure

Source: EIA

Natural gas demand growth in Mexico will be driven primarily by the industrial and power sectors. Natural gas fired generation is expected to replace coal and oil-fired generation in Mexico. Like the United States, Mexico is transitioning to more solar and wind generation in its future energy portfolio, with the goal of obtaining 35 percent of its energy from clean sources (including nuclear) by 2024, and 50 percent by 2050. The primary drivers of industrial natural gas demand will be iron and steel manufacturing, chemicals, and mining. We anticipate that natural gas consumption by this sector of Mexico’s industrial output will grow at a 2 percent CAGR over the 20-year study period.

Mexico’s domestic natural gas production has steadily declined over the past decade, falling from 6.9 Bcf/d in 2008 to 5.1 Bcf/d by 2017. As of January 2018, Mexico has 10.6 trillion cubic feet (Tcf) of proven reserves, 9.4 Tcf of probable reserves, and 10.6 Tcf of possible reserves. A large portion of these reserves is onshore (58.6 percent), and in shallow water (34.9 percent), with the remainder in deep water (6.7 percent). Continued development opportunities in onshore and offshore shallow water will be a primary driver of domestic Mexican production, which can partially offset the volume of US pipeline gas needed to meet the country’s domestic demand.



ANALYSIS AND RESULTS

4



4 Analysis and Results

The energy trends previously discussed provide the starting place for exploring the future role of natural gas and natural gas infrastructure in the United States. In this study, we explore two future paths that model different levels of renewable penetration and examine the effect on natural gas demand. One path reflects a result driven by a balance of policy initiatives and market economics (the Balanced Future); an alternative path is driven heavily by policy initiatives intended to accelerate the penetration of renewables in power generation (Rapid Renewables Transition).

Balanced Future

Sustained/steady transition to a low carbon economy



- RPS goals met on schedule
- Sustained growth of battery storage additions to meet mandates
- Strong second wave of LNG and pipeline exports
- Economic based investment decisions

Rapid Renewables Transition

Global acceleration to carbon reduction



- Minimum 50% RPS targets
- Accelerated battery storage growth
- Operational and under construction LNG terminals only
- Policy or technology driven investment decisions

4.1 Balanced Future Scenario

The Balanced Future Scenario projects the following for natural gas consumption (Figure 14):

- Natural gas demand from the residential and commercial sector will grow at 0.14 percent and 0.29 percent CAGR, respectively. This reflects the efficiency gains in gas appliances and improvements in building codes that will continue to reduce per capita consumption, partially offsetting the growth in total use;
- Industrial demand will grow at 0.6 percent CAGR because of increased demand for petrochemical and ethylene feedstock;
- Four additional LNG export terminals will be constructed in the Gulf Coast over the next 20 years, increasing US LNG exports to 16.4 Bcf/d by 2040; and
- Pipeline exports to Mexico from South Texas, the Permian Basin, and the Southwest will increase to 8 Bcf/d by 2040.

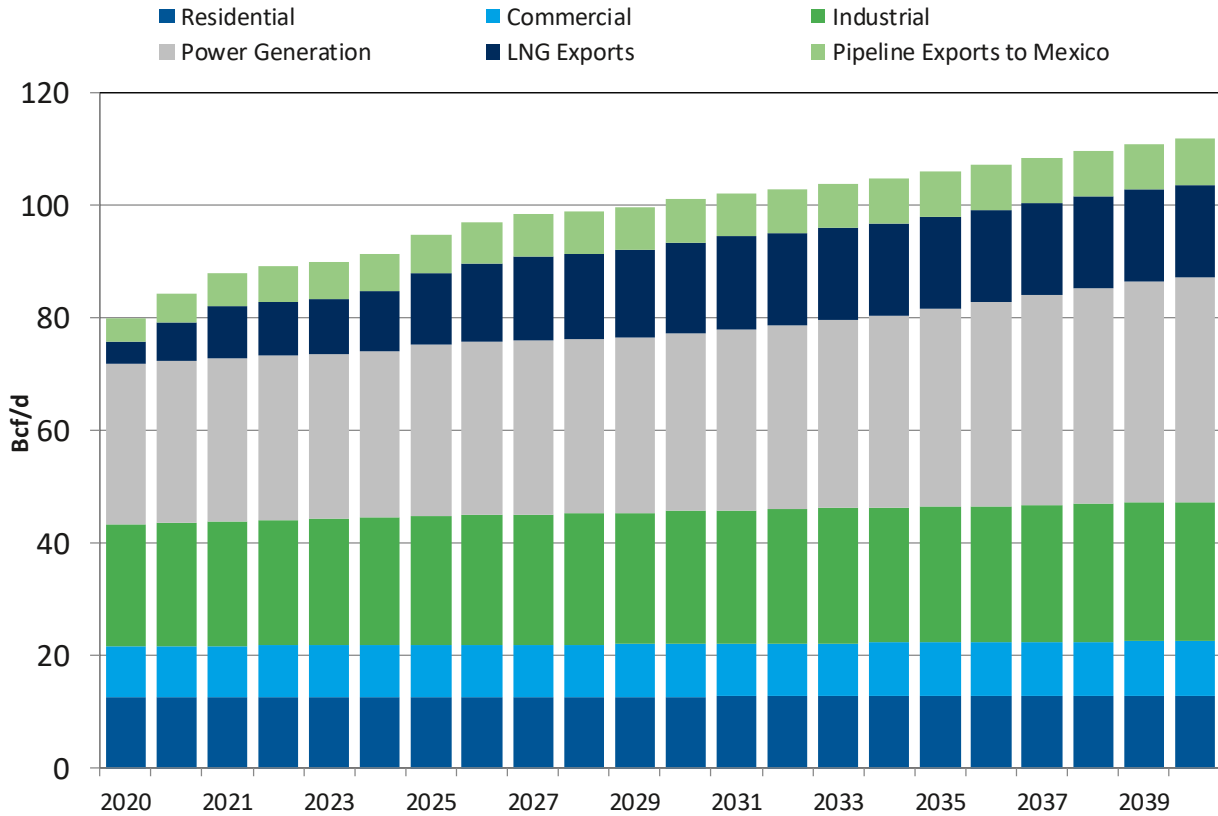


Figure 14. Projected Natural Gas Consumption – Balanced Future Scenario

Source: Black & Veatch Analysis

ELECTRIC MARKET ASSUMPTIONS

Electric sector demand for natural gas will be driven by the following assumptions in the Balanced Future Scenario:

- Load growth will be moderate at 0.7 percent per year;
- Renewable generation capacity growth will increase by approximately 300 GW;
- Environmental policies to reduce carbon emissions will contribute to the retirement of 82 GW of coal capacity, while low commodity prices will contribute to the retirement of 48 GW of nuclear capacity by 2040; and
- Battery storage procurement will reach 12 GW (4-hr battery) by 2040, which equates to 48 GWh of capacity. (assumes 1-charge/discharge cycle per day).

ANALYSIS AND KEY RESULTS

- Under the Balanced Future Scenario, highly efficient natural gas-fired power generation will be an important replacement for retiring baseload capacity, which includes both coal and nuclear generation.

The Balanced Future Scenario forecasts renewable generation capacity to grow at a 5 percent CAGR through 2040. Under this scenario, new renewable energy generation, primarily wind and solar capacity, will be developed to meet current mandatory and voluntary RPS goals on schedule through 2040. Subsequent renewables will be added to maintain the RPS percentage as electric load grows over the 20-year period. In states with no current RPS goals, renewable resources will be added at the recently observed pace for each state. In 2040, wind and solar resources will account for 20 percent of the 4,650 TWh of total electric generation in the United States, compared with 8 percent in 2018.

Under the Balanced Future Scenario, 130 GW of coal and nuclear generation capacity in the US will retire between 2020 and 2040. While renewable generation combined with energy efficiency, demand response, and battery storage could theoretically replace a portion of the retiring baseload capacity, under the Balanced Future Scenario, it is assumed that there will not be enough economically viable renewable resources to fill the generation void created by retiring capacity units. Natural gas fired generation remains a cost-effective baseload resource. Consequently, under this scenario, the need for additional gas fired generation translates into an additional 11 Bcf/d of natural gas demand through 2040.

- **Under the Balanced Future Scenario, US natural gas demand is expected to grow significantly from LNG exports and exports to Mexico.**

Under the Balanced Future Scenario, natural gas exports from LNG terminals and pipeline exports to Mexico will grow by approximately 15.7 Bcf/d between 2020 and 2040 to a total of nearly 24.5 Bcf/d. The LNG terminals currently in operation or under construction will be highly utilized through 2040. An additional 3.0 Bcf/d of export capacity is expected from the US Gulf Coast and East Coast regions during the 2020-2040 time frame. The Gulf Coast LNG terminals will primarily export natural gas supplies from the Marcellus/Utica Shale and the Permian Basin—two of the largest and fastest growing production regions. These basins will be competitive against other global natural gas supply sources and are expected to help meet the 63 Bcf/d expected increase in global LNG demand over the next 20 years.

- **Under the Balanced Future Scenario, existing natural gas pipeline infrastructure will continue to experience increased utilization, and incremental infrastructure will be needed regionally to meet the demand growth over the next 20 years.**

More than half of the production growth from the continental United States will come from the Marcellus/Utica Shale in the Northeast and the Permian Basin in West Texas and New Mexico. Up to 13 Bcf/d of take-away capacity from the Marcellus/Utica and 8 Bcf/d from the Permian Basin will be needed to transport this production to markets in the Gulf Coast, Florida, the Southeast, and New England.

Based on the demand growth projections in the consuming markets and current contracting practices, we expect shippers from the following categories will decide to enter long-term firm transportation contracts to support the development of new pipeline capacity:

- **Natural Gas Producers**--Gas producers consider the balance of regional demand, production, infrastructure, and market liquidity to maximize the value of their gas production and avoid shutting-in production. They subscribe to new infrastructure when it is necessary to move their production out of the production area to markets.

- LNG Export Terminal Operators/Tollers--These entities seek firm access to large low-cost gas production basins to supply gas to an LNG terminal.
- LDCs--LDCs are obligated to supply their firm customers' gas requirements under winter (and summer) design day⁵ operating conditions.
- Industrial Customers--Industrial customers need firm access to natural gas to generate heat in industrial processes and to generate steam or feedstock to make end use products.
- Vertically Integrated Electric Utilities--Utilities are responsible for meeting their customers' electric load requirements; therefore, they will need to secure firm gas supplies to fuel the gas fired powerplants within their fleet of generators.

Utilization of existing and planned pipelines will continue to rise as gas consumption grows and gas supply increases. Still, pipeline utilization could remain stable or decline moderately over time in California, the Pacific Northwest, and the Desert Southwest.

- **Under the Balanced Future Scenario, natural gas pipelines that can provide flexible services to LNG terminals and power generators will create growth opportunities to the natural gas industry.**

Under the Balanced Future Scenario, eight LNG export terminals will be in operation in the Gulf Coast by 2040, with close to 9.2 Bcf/d of demand for incremental feed gas by 2020 and another 4.1 Bcf/d by 2040. The Atlantic Coast LNG terminals, at Cove Point and Elba Island, will add 1.0 Bcf/d of feed gas demand by 2021 and remain flat through 2040. This incremental gas demand will significantly affect the daily and seasonal utilization of pipelines along the eastern seaboard and the service offerings needed to meet the requirements of these LNG terminals.

Ambient temperature can have an impact on the efficiency of the gas turbines used to liquefy natural gas and, can consequently, affect the feed gas rate necessary to produce LNG throughout the day. Higher ambient temperatures will require more feed gas to produce the same amount of LNG. The variation of daily feed gas could approach 12 percent during the peak summer months, which will translate into over 2 Bcf/d extra feed gas demand on certain days.

Operators of LNG liquefaction terminals prefer liquefying and shipping LNG cargos on a steady-state schedule. However, they will likely need emergency market outlets for excess gas when a liquefaction train trips⁶ or short notice supplies when that train ramps back to normal operations. Additional gas storage or pipeline no-notice services will be needed to help mitigate the types of intra-day swings that already have been observed at existing LNG liquefaction terminals.

The destination markets for the LNG terminals currently under construction are in Asia and Europe. Because of significant seasonal demand variability in both markets, the volume of US LNG exports could vary significantly. High US demand for natural gas during the peak winter months to serve residential and

⁵ LDCs generally define design day as either a 1-in-30-year or 1-in-10-year cold weather condition that has the highest requirement for natural gas supplies to meet the residential and commercial customers' heating needs.

⁶ LNG Train is an LNG plant's purification and liquefaction facility wherein natural gas is converted to LNG in a series of processes. An LNG train trip is an outage on the LNG train that can occur due to a liquefaction unit gas turbine being taken offline or a maintenance event for any of the pumps and filters.

commercial load could place additional stress on the existing natural gas infrastructure, requiring new infrastructure to serve LNG exports for the global market. LNG export terminals have supported numerous dedicated pipeline projects to ensure that capacity will be available year round.

IMPLICATION FOR THE ROLE OF NATURAL GAS

- Economic baseload gas fired capacity additions will reach 35 GW over the 20-year period, increasing gas demand from the power generation sector by 11.4 Bcf/d over the analysis period.
- Natural gas’ current role supporting renewable generation will grow because of the needs created by renewable variability.
- Steady demand and supply growth will require additional pipeline infrastructure (refer to Section 5) primarily from the Marcellus/Utica Shales and Permian Basin to serve growing natural gas demand in the Gulf Coast and in other regions.
- Projected global LNG demand growth and the continued competitiveness of North American LNG exports will support the development of additional terminal and pipeline capacity from producing basins.

EVALUATION OF THE PIPELINE INFRASTRUCTURE

The Balanced Future Scenario represents a world in which the transition to greater renewable penetration is supported by a combination of policy mandates and economic drivers. This scenario provides a basis for examining the role of natural gas in achieving a lower-carbon economy and the need for natural gas infrastructure during the 20-year study horizon.

In the Balanced Future Scenario, growing demand and supply will increase regional pipeline utilization and drive regional needs for incremental infrastructure. Detailed regional analyses using a fundamental gas market model indicates that additional pipeline infrastructure will be needed in the Southeast, Florida, Gulf Coast, Appalachian, and New England markets to provide take-away capacity from growing production basins and to serve emerging demand centers (Figure 15).

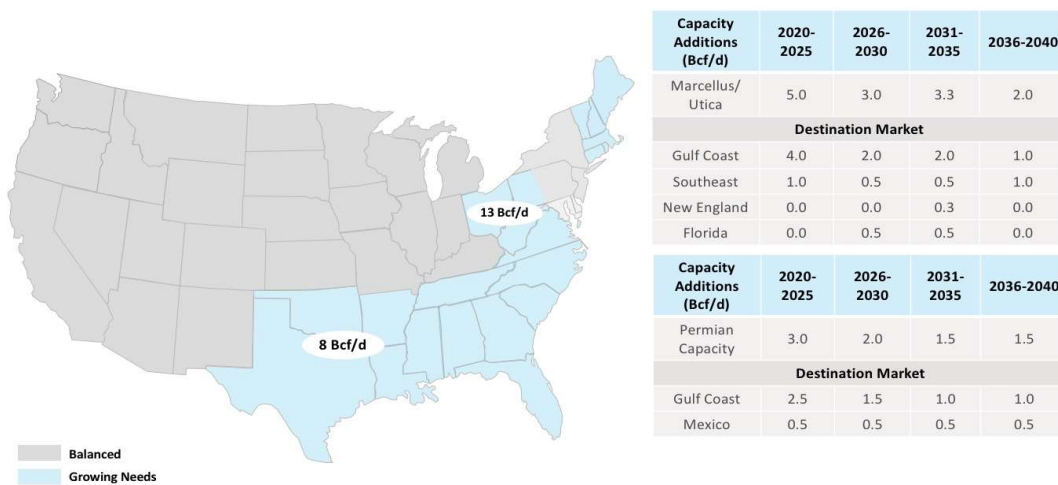


Figure 15. Balanced Future Scenario Infrastructure Needs

Source: Black & Veatch Analysis

Appalachian shale production is expected to remain one of the lowest cost sources of natural gas in North America and will contribute to meeting growing natural gas demand in other regions. In the Balanced Future Scenario, we project Appalachian natural gas production will reach 45 Bcf/d by 2040, as shown on Figure 16, and require 13 Bcf/d of additional pipeline capacity by 2040 to move supply to the Gulf Coast, Southeast, New England, and Florida.

Associated gas production from the Permian Basin will be closely tied to oil production. Based on Black & Veatch’s projections of commodity prices, Permian Basin production is expected to reach 18 Bcf/d and require 8 Bcf/d of additional take-away pipeline capacity. The Permian Basin’s proximity to the growing demand centers on the Gulf Coast and the Mexican export market makes it an ideal source for meeting their needs.

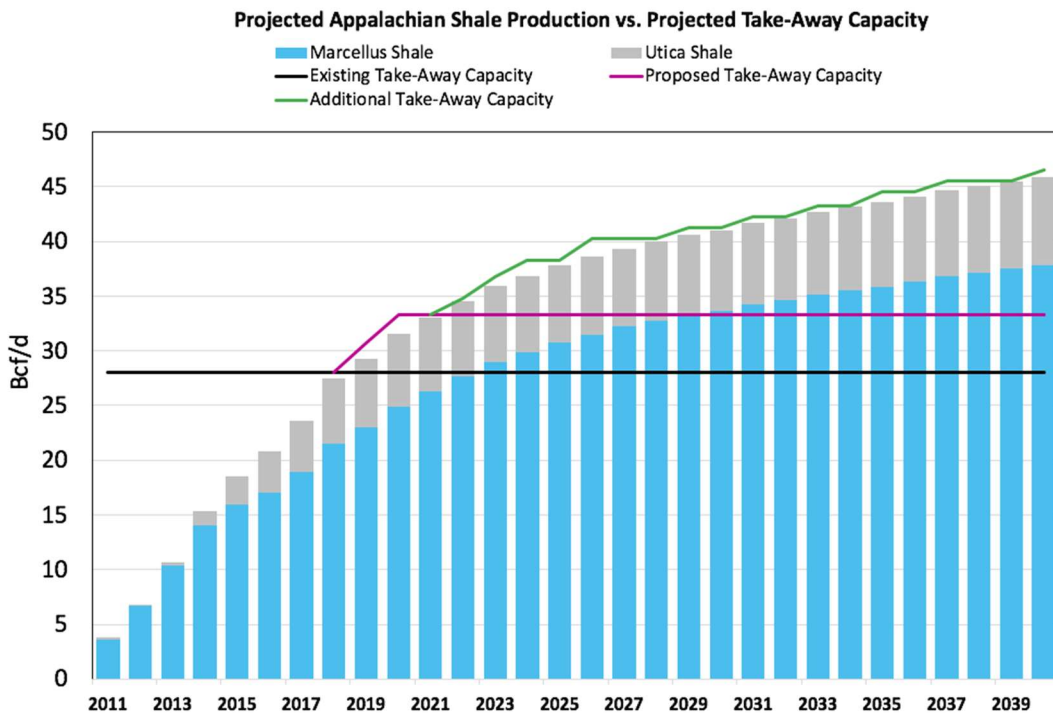


Figure 16. Balanced Future Scenario Appalachian Pipeline Needs

Source: Black & Veatch Analysis

Balanced growth in gas demand and production will continue to alter regional pipeline flows and the utilization of interstate pipelines. As shown on Figure 17, gas demand growth in the Gulf Coast from LNG exports and pipeline exports to Mexico will attract gas supplies from the Marcellus/Utica Shales as well as from the Permian Basin. Over the analysis period, the Marcellus/Utica Shales and Permian Basin are expected to remain the lowest-cost production basins in North America, and the preferred origination point for incremental gas supplies.

In Western markets, the transition to zero-carbon emissions in the power sector will reduce pipeline flows from the Rockies and San Juan to end use markets. Higher levels of renewable energy across the

western markets will create the need for gas fired generation when solar and wind resources are unavailable, thereby increasing pipeline capacity needs because of higher hourly flows.

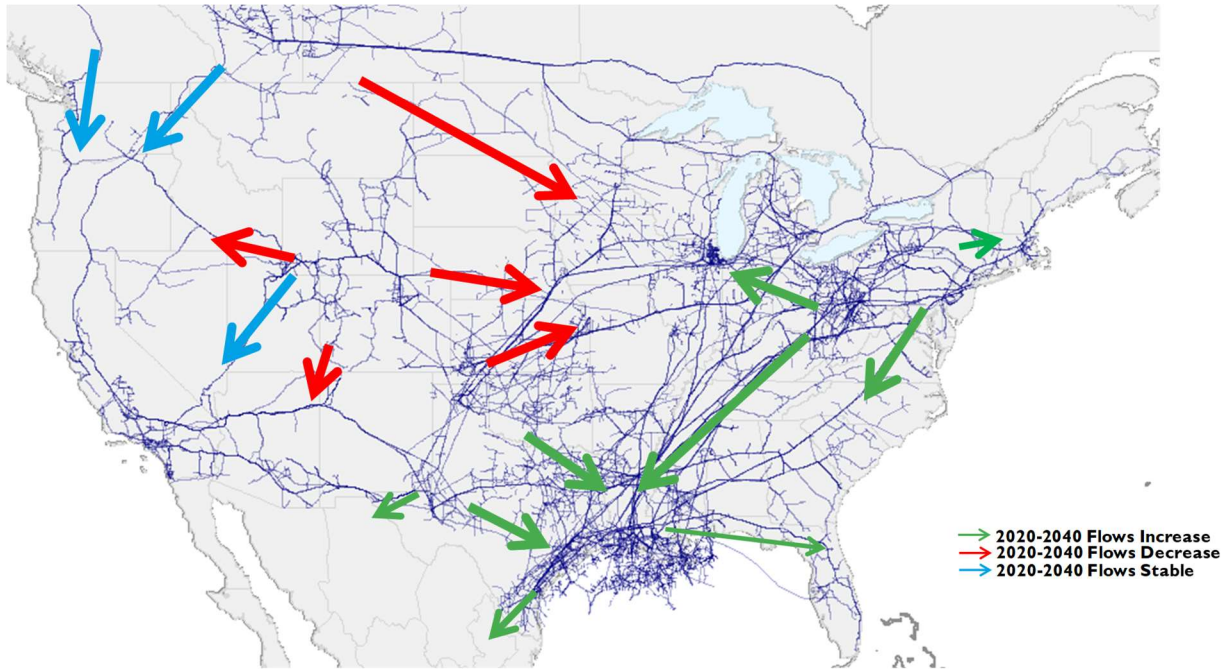


Figure 17. Balanced Future Scenario – Annual Average Flow Pattern Changes (2020 vs. 2040)

Source: Black & Veatch Analysis

4.2 Rapid Renewables Transition Scenario

The Rapid Renewables Transition Scenario assumes the following:

- Federal and state “green laws” will be enacted to accelerate sustainability and environmental agendas;
- States with RPS goals will build renewable generation resources so that at least 50 percent of their electric load is met with renewable generation by 2040;
- Approximately 15 percent of the nuclear generation capacity in the United States with licenses expiring before 2040 will be renewed for an additional 20 years, thereby deferring the need for additional baseload natural gas fired generation capacity; and
- US LNG export growth will be muted between 2020 and 2040, limiting LNG exports to 10 Bcf/d.

The Rapid Renewables Transition Scenario projects the following for natural gas consumption (Figure 18):

- Natural gas demand from the residential and commercial sector will decline by 0.3 percent per year. Residential and commercial customer growth will decline as state policy makers encourage electrification to reduce GHG emissions from those sources.
- Industrial demand will decline by 0.2 percent per year as global feedstock prices decline. Trade policy (i.e., tariffs) will reduce the number of potential petrochemical facilities developed during the 20 year period.

- Global LNG demand growth will decline because of renewables growth and the resurgence of nuclear power in Asian markets. Asian LNG buyers will be less likely to contract for long-term capacity, which would reduce the number of terminals that reach financial investment decision (FID). Only 10 Bcf/d of LNG exports are expected from the United States under this scenario.
- Domestic Mexican production growth combined with aggressive renewable targets will dampen Mexican demand for US pipeline exports. In this scenario, pipeline exports to Mexico plateau at 6 Bcf/d by 2040.

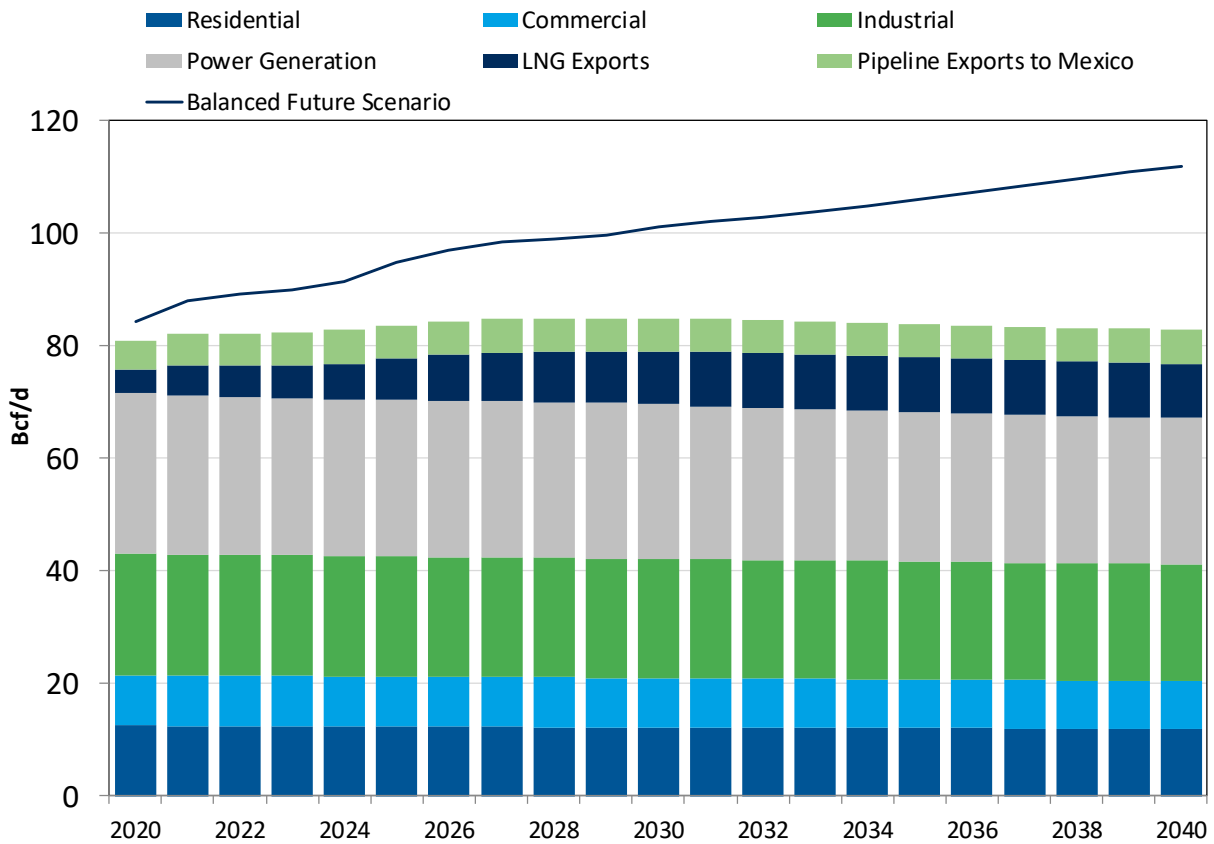


Figure 18. Projected US Natural Gas Consumption – Rapid Renewables Transition Scenario

Source: Black & Veatch Analysis

Electric Market Assumptions

The Rapid Renewables Transition Scenario projects the following regarding electric sector demand for natural gas:

- Electric load growth will be restrained to 0.4 percent per year because of accelerated energy efficiency programs and behind-the-meter renewable energy.
- Renewable generation capacity will grow by approximately 450 GW
- Over 30 GW (four-hour battery storage) will be procured throughout the United States, equating to 120 GWh of capacity with an assumed one-charge/discharge cycle per day.

ANALYSIS AND RESULTS

- **Under the Rapid Renewables Transition Scenario, natural gas demand will remain close to current consumption levels. Existing natural gas infrastructure will continue to be utilized, and limited new infrastructure will be needed.**

The Rapid Renewables Transition Scenario reflects a future in which policy mandates for carbon reduction and dramatic technology breakthroughs result in wide adoption of renewable energy generation resources and battery storage at scale. While the United States is not now aligned with this scenario, we will assume for purposes of modeling that the necessary technological, political, and financial resources will be available and accessible by 2020. This includes the continuation of the production tax credit and investment tax credit for renewable energy products, which are currently slated to be eliminated by 2020 and 2021, respectively.

The Rapid Renewables Transition Scenario will result in slower growth in new gas generation capacity in the United States, as solar and wind generation replaces retiring coal and nuclear generation. US demand for natural gas from the power sector will remain steady or will decline over this 20 year period. LNG export terminals that have not reached FID or are not currently under construction will be deferred because of lower global LNG demand expectations.

Despite the strong global and national push to lower carbon emissions, the projection that natural gas demand will remain at today's level of approximately 82 Bcf/d would indicate that overall gas pipeline utilization would remain comparable to today. Yet, regional growth in infrastructure still will be required to meet changing supply-demand dynamics in the Rapid Renewables Transition Scenario, including connecting new or additional shale formations to the existing interstate gas pipeline network. Although average throughput would decline under this scenario, capacity reservation could increase to supply rapid hourly changes in demand to serve peaking generation. As such, the amount of new infrastructure capacity needed reaches 8 Bcf/d by 2040.

- **Under the Rapid Renewables Transition Scenario, the electric generation resource mix will be more uncertain on a day-to-day basis.**

The Rapid Renewables Transition Scenario incorporates over 450 GW of wind and solar generation capacity to reach higher RPS goals, which creates more uncertainty in the daily electric generation resource mix. Battery storage at scale can partially offset some of the uncertainty, when renewable energy generation exceeds the electric load requirements for a given hour; however, gas fired generation can provide the most flexible hourly balancing service assuming the availability of deliverable gas supply.

- **Under the Rapid Renewables Transition Scenario, LNG exports and pipeline exports to Mexico will continue to utilize the existing gas pipeline transportation network at high load factors.**

US LNG export terminals are expected to remain highly utilized in this scenario despite the dampening of global LNG demand resulting from the shift to renewables in Europe and Asia. As compared to the Balanced Future Scenario, lower gas demand will lead to lower gas prices and make US LNG exports even more competitive in the global market. As with the US transition to renewables, nations around the world will need to balance wind and solar generation with gas fired generation and battery storage.

- Under the Rapid Renewables Transition Scenario, residential, commercial, and industrial demand will remain close to 50 percent of the total US consumption by 2040.

Natural gas infrastructure will remain important to meeting residential, commercial, and industrial demand in the United States. These traditional natural gas end users have limited economically viable alternatives to natural gas and will continue using natural gas for the foreseeable future, even with a public policy mandate to support a transition toward electrification. Gas pipelines and gas storage will remain highly utilized and critically needed to meet winter peak day gas demand from traditional residential, commercial, and industrial gas consumers.

EVALUATION OF THE PIPELINE INFRASTRUCTURE

The Rapid Renewables Transition Scenario was designed to demonstrate the implications of an aggressive shift toward renewables driven by policy mandates within the 20-year study horizon. By design, the scenario enforces a layering of multiple factors that negatively affect natural gas consumption across every demand sector. The scenario is helpful to understand whether natural gas assets will become redundant in a world where renewable generation is aggressively promoted without regard for economics and potential technological challenges. Black & Veatch chose this scenario as a book end to show the most extreme impact on the role of natural gas and natural gas demand during the time period examined.

In the Rapid Renewables Transition Scenario, as shown on Figure 19, overall lower gas demand and production growth will require less pipeline infrastructure than under the Balanced Future Scenario. Notwithstanding aggressive assumptions about the suppression of natural gas demand, regional pipeline utilization is expected to remain relatively flat, except for pipelines serving Florida and the Appalachian Basin, which actually experience an increase in utilization between 2020 and 2040.

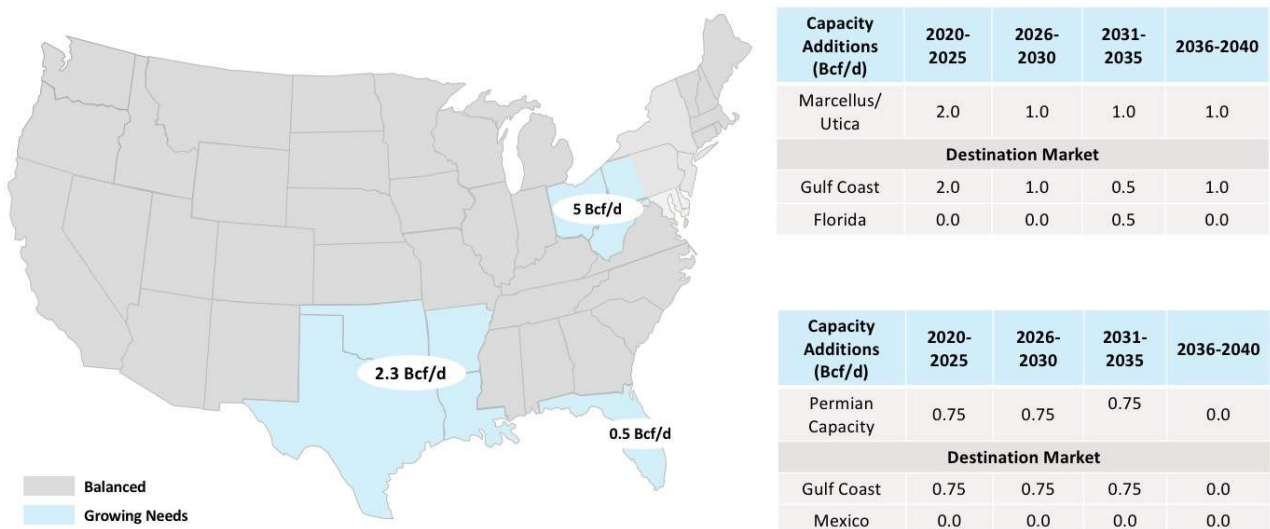


Figure 19. Rapid Renewables Transition Scenario Infrastructure Needs

Source: Black & Veatch Analysis

Even in the Rapid Renewables Transition Scenario, 5 Bcf/d of incremental pipeline infrastructure will be needed to move gas supplies from the Appalachian Basin by 2040, as shown on Figure 20.

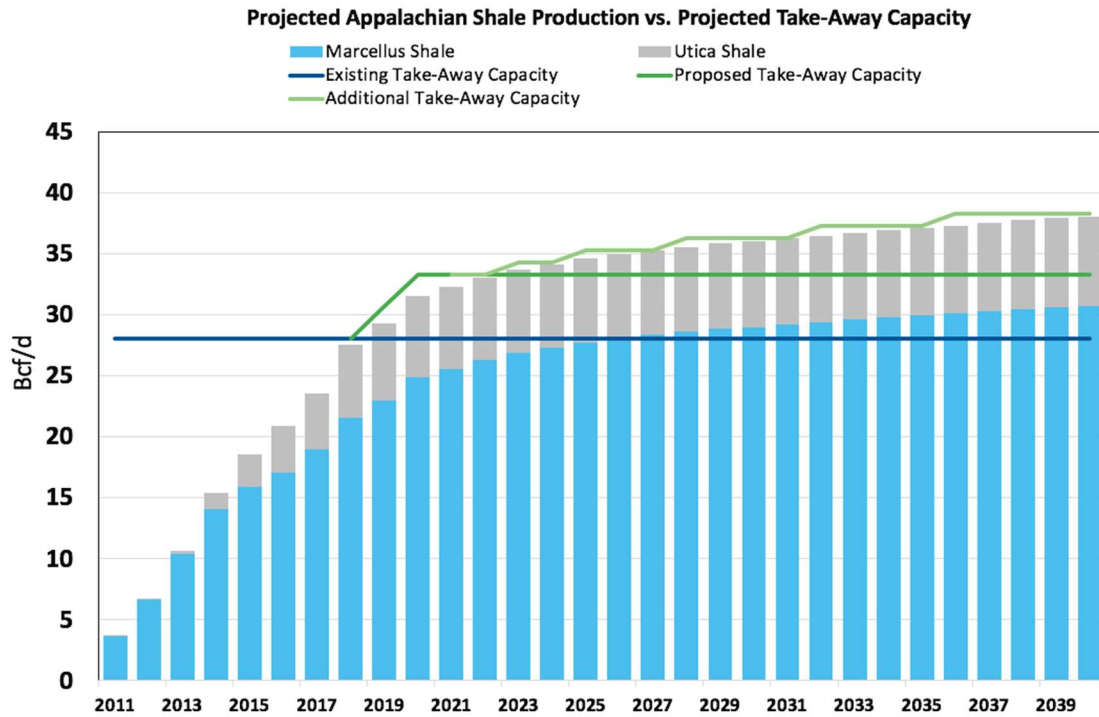


Figure 20. Rapid Renewables Transition Scenario Appalachian Pipeline Needs

Source: Black & Veatch Analysis

In the Rapid Renewables Transition Scenario, global natural gas demand growth is diminished, reducing LNG exports and pipeline exports to Mexico and the need for incremental pipeline capacity associated with that demand. Incremental infrastructure from the Marcellus/Utica Shales and Permian Basin is still needed, even in the Rapid Renewables Transition Scenario, albeit at reduced volumes. As shown on Figure 21, pipeline utilization in western markets is expected to decline, while eastern markets remain generally stable, except for increased north-to-south flows from the Marcellus/Utica shale plays.

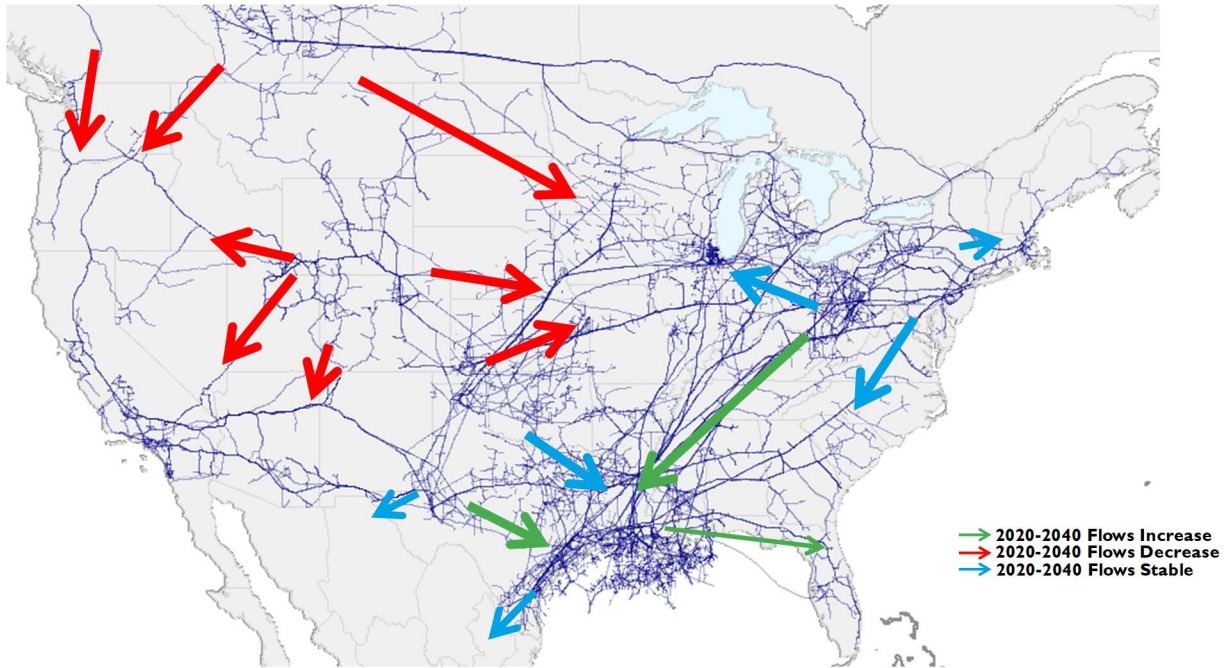


Figure 21. Rapid Renewables Transition Scenario – Annual Average Flow Pattern Changes (2020 vs. 2040)

Source: Black & Veatch Analysis

4.3 Comparison of Two Scenarios

The analysis demonstrates that natural gas infrastructure will remain crucial to meeting residential, commercial, industrial, and power generation demand in the United States as well as export needs. Regional infrastructure growth will remain needed to meet changing supply-demand dynamics in the Balanced Future Scenario and, notably, even in the Rapid Renewables Transition Scenario.

Power Market

Under both scenarios, natural gas and natural gas infrastructure remains an efficient means to address the variability inherent with renewable power generation, even in markets with high renewable resource penetration.

The intermittent nature (seasonal, intraday, and interday variations) of solar and wind generation resources have significantly increased the need for flexible, fast ramp generation supplied by natural gas to maintain the reliability of the electric grid in the United States. The rapid rate of renewable generation growth has displaced some gas fired power generation. However, variation and unpredictability in renewable generation creates challenges because of the misalignment between when renewable generation is available and when it is needed to meet demand.

An example of this variability can be seen during peak winter months in New England. In our analysis, daily wind generation in ISO NE varied between 3,000 and 42,000 MWh between December 2017 and February 2018, while gas generation fluctuated between 120,000 to 320,000 MWh partly to compensate for the variability of wind generation. It is noteworthy that some natural gas fired generators may have been unable to run because of inadequate pipeline capacity in New England. New England LDCs and

industrial customers that hold firm capacity would be utilizing the available pipeline capacity, further limiting the ability of gas fired generators to support renewable generation.

Under the Balanced Future Scenario, for example, with all New England states achieving their ambitious renewable generation goals by 2040, wind generation alone could meet as much as 35 percent of New England's electric generation needs in winter, with a daily variation of approximately 10,000 MWh. Today, wind generation averages approximately 9,000 MWh in New England, with an average daily variation of 5,300 MWh. In the example above, wind met only 4 percent of the region's demand during the three-month winter period. This variability highlights the need for fast-dispatch generation to make up the difference when low output hours or days occur. Natural gas provides an efficient option to managing peak generation needs.

Electric battery storage will allow energy generated when load is low to be discharged back to the grid when needed to manage the renewable variation. Under the Rapid Renewables Transition Scenario, we assume that battery storage has advanced substantially, and that the assumed 30 GW of battery storage capacity installed by 2040 can help meet some of the increasing need for fast ramping capacity. Even under this scenario, however, gas fired generation will continue to play a prominent role in meeting US energy demand, especially for needs that battery storage cannot meet. In California, for example, a large amount of solar capacity in the generation resource mix exacerbates the seasonal and intraday misalignment of generation capability and load requirements. Significant excess generation occurs in April and May, and there are large generation deficits in December and January. In addition, solar generation peaks during the middle of the day, while daily peak electric demand occurs in the late afternoon and early evening.

The seasonal misalignment between renewable generation and load can be solved only with long-term seasonal storage capacity, such as pumped storage or hydrogen storage. Pumped hydro requires access to two different water reservoirs at different elevations which would limit the potential number of sites that could be developed. Hydrogen storage technology has not been widely adopted in the United States and would not be expected to be ready for large scale deployment in the next 20 years. Battery storage is more suitable for short-term capacity, because current technology allows for 0.5-4.0 hours of storage, after which the stored electricity must be discharged back to the grid. Thus, current battery storage technology cannot address the seasonal misalignment.

Electric Load

Electric load growth remains a primary driver for investments in thermal and renewable generation capacity, transmission lines, and energy storage. In the Balanced Future Scenario, overall electric load growth is expected to be 0.7 percent per year over the 20-year analysis period, which reflects moderate growth in the electrification of the transportation sector as well as the impacts of today's energy efficiency programs. In the Rapid Renewables Transition Scenario, electric load is expected to grow at only 0.4 percent per year because of additional behind-the-meter generation and reduced heavy industrial demand, as shown on Figure 22.

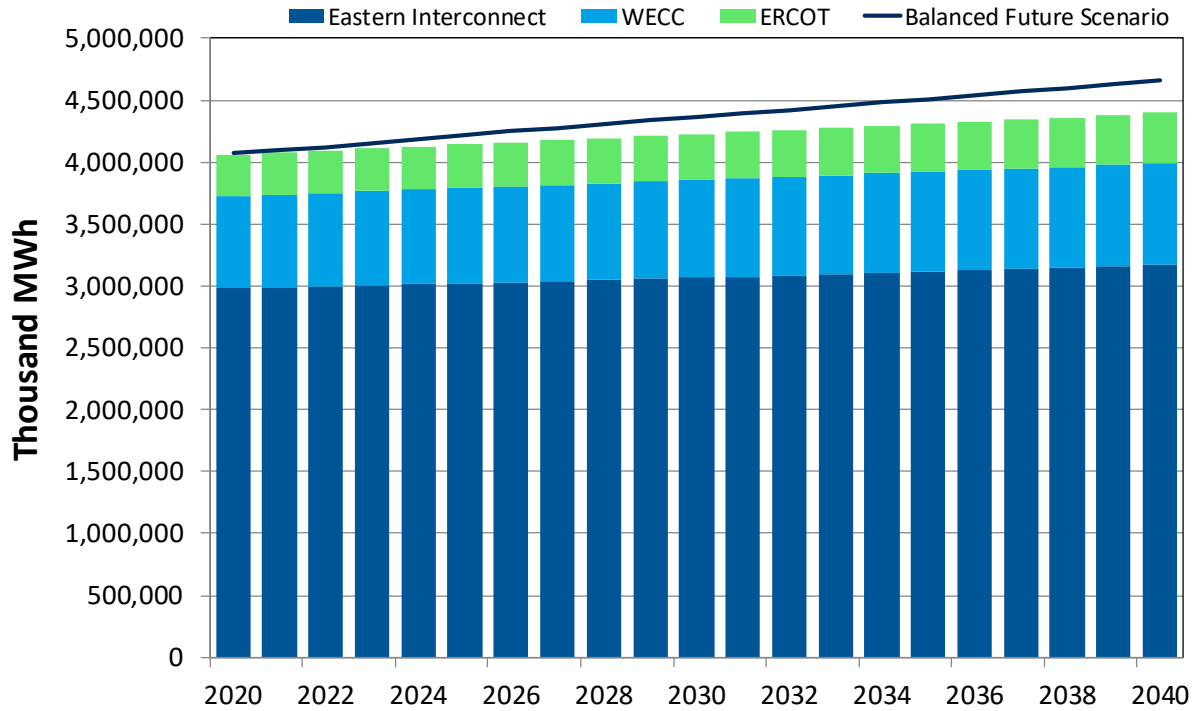


Figure 22. Projected Electric Load Under the Rapid Renewables Transition Versus the Balanced Future Scenarios

Source: Black & Veatch Analysis

Coal and Nuclear Retirements

Under the Balanced Future Scenario, we project natural gas consumption for power generation will grow at a 1.6 percent CAGR through 2040. This projection reflects our expectation that 82 GW of coal and 48 GW of nuclear capacity will be retired (Figure 23). These expected retirements are based on the following key assumptions:

- A shift in economic feasibility will occur if gas prices remain low;
- Coal generation units that are not economically dispatched for three consecutive years will retire; and
- Nuclear licenses on four nuclear plants will expire without a second renewal period being sought.

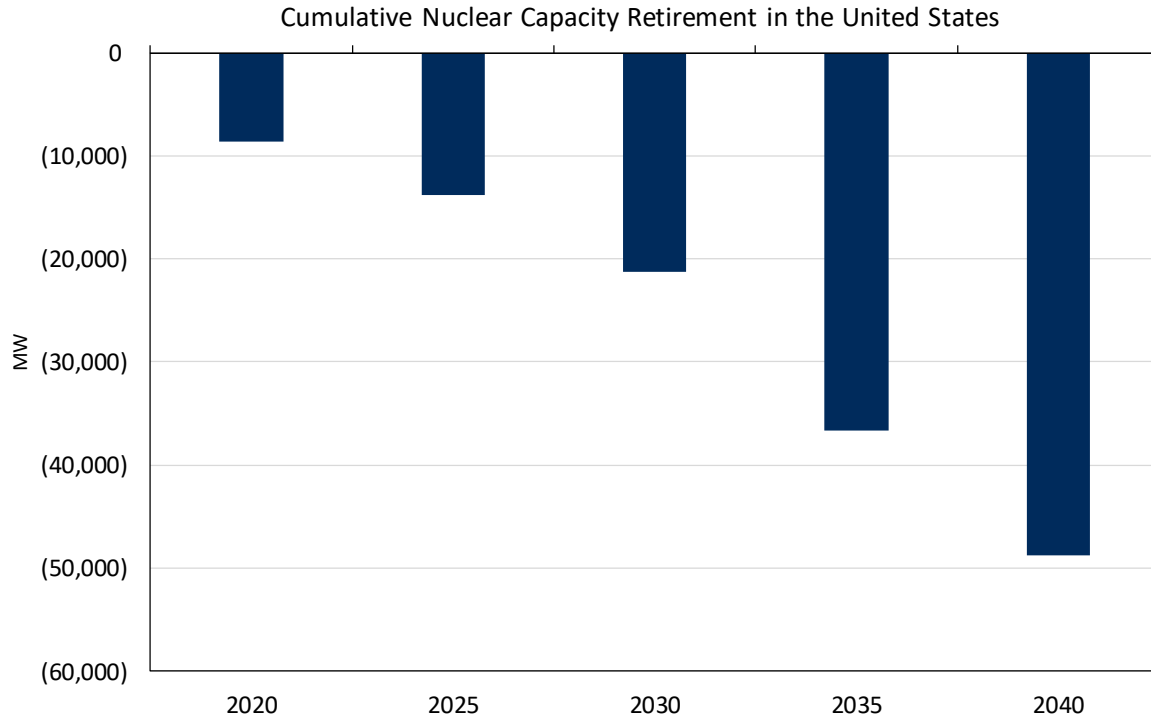



Figure 23. Projected US Nuclear Capacity Retirements

Source: 2018 Black & Veatch Energy Market Perspective



There was 336 GW of coal fired power generation capacity in 2007 and this number dropped to 279 GW in 2017.

Coal produced the majority of US electricity over the past 30 years. In the last 10 years, however, natural gas became more competitive with coal generation in the United States. As a result of low-cost gas setting the market clearing price, wholesale power prices are too low for coal generators to be profitable as baseload generation. Coal plant owners have retired a significant amount of coal

capacity. Total coal generation capacity in the United States has not increased since 2011. Some electric generators with large coal portfolios have announced the strategy of replacing all of the coal generation capacity in their portfolio, reflecting the economic reality faced by these generators and will contribute to the reduction of the carbon footprint of the electric sector.

US nuclear generators initially were designed and licensed to operate for 40 years. Most nuclear generators renewed their operating licenses for an additional 20 years between the mid-1990s to early 2000s. In the last decade, low natural gas prices have made nuclear generators less profitable. Nuclear capacity has decreased by 2 percent in the last 10 years, and we anticipate it will decrease by another 10 percent by 2030.

New York, Illinois, New Jersey, and Connecticut have implemented financial subsidies to postpone the retirement of certain “at-risk” nuclear generators. If natural gas and power prices still are low when the

subsidies expire, these generators will face even bigger challenges to compete as operating costs of aging nuclear reactors increase over time.

Over 40 GW of nuclear generator licenses are set to expire before 2040. By the end of 2018, Dominion, Florida Power & Light, and Exelon filed or planned to file for license extensions to operate four nuclear facilities: Turkey Point Units 3 and 4, Peach Bottom Units 2 and 3, Surry Units 1 and 2, and North Anna Units 1 and 2. If the extensions are granted, there will be increased challenges associated with managing these aging facilities.⁷ The license renewal process is lengthy and could cost up to \$2.5 billion per facility.⁸ At this time, we assume that no additional nuclear generators will apply for renewal between 2020 and 2040.

Renewables and RPS Targets

As shown previously on Figure 6, more than 30 states have established RPS requirements or voluntary RPS goals that stimulate the development of renewable generation resources. The Balanced Future Scenario assumes that all US states will meet the required or voluntary RPS goals on schedule. The scenario assumes that additional wind and solar capacity will be added to maintain the RPS percentage with electric load growth. For states that do not yet have any RPS goals, the Balanced Future Scenario assumes renewable resources will be added at a rate reflecting the most recent history. Between 2020 and 2040, 300 GW of renewable resources are assumed to be added in the United States (180 GW of wind and 120 GW of solar). All existing and incremental wind and solar capacity is assumed to be capable of generating electricity without technical updates over the 20-year period. In 2040, 20 percent of total electric generation in the United States is assumed to derive from wind and solar renewable resources, compared to 8 percent in 2018.

Under the Rapid Renewables Transition Scenario, all of the states with RPS goals are assumed to meet a 50 percent minimum target by their scheduled date, driven by policy mandates or technological breakthroughs. For states currently with no RPS goals, renewable resources are assumed to be added at a rate reflecting recent history, similar to the Balanced Future Scenario. It is assumed that both the production tax credit and investment tax credit, which were heavily responsible for the rapid growth in renewable capacity additions, will be extended as part of the rapid transition. As a result, it is assumed that 450 GW of renewable capacity will be added to the generation fleet. By 2040, approximately 40 percent of electricity in the United State is assumed to be generated from wind and solar resources.

Implications for the Future Role of Natural Gas in the Power Sector

- **New Gas Fired Generation Capacity and Projected Gas Demand**

In the Balanced Future Scenario, additional gas fired generation capacity will be needed for both baseload and to mitigate renewable intermittency. As a result of the assumed need for 35 GW of gas fired generation capacity, gas demand for power generation will increase by 11.4 Bcf/d over the analysis

⁷ <http://www.beyondnuclear.org/home/2018/11/28/beyond-nuclear-opposing-second-license-renewal-for-peach-bot.html>

⁸ https://www.richmond.com/business/dominion-wants-nuclear-reactors-to-last-years/article_c400e2f8-4409-5054-8f6a-c8c79b940f6d.html

period. This will contribute to the need for incremental pipeline capacity from supply basins to markets in the Southeast and Gulf Coast.

In the Rapid Renewables Transition Scenario (Figure 24), slower electric load growth combined with renewable capacity additions and delayed nuclear capacity retirements will reduce the need for additional gas fired generation capacity. In this scenario, only 16 GW of additional gas fired generation capacity is needed, reducing total gas demand by approximately 3 Bcf/d.

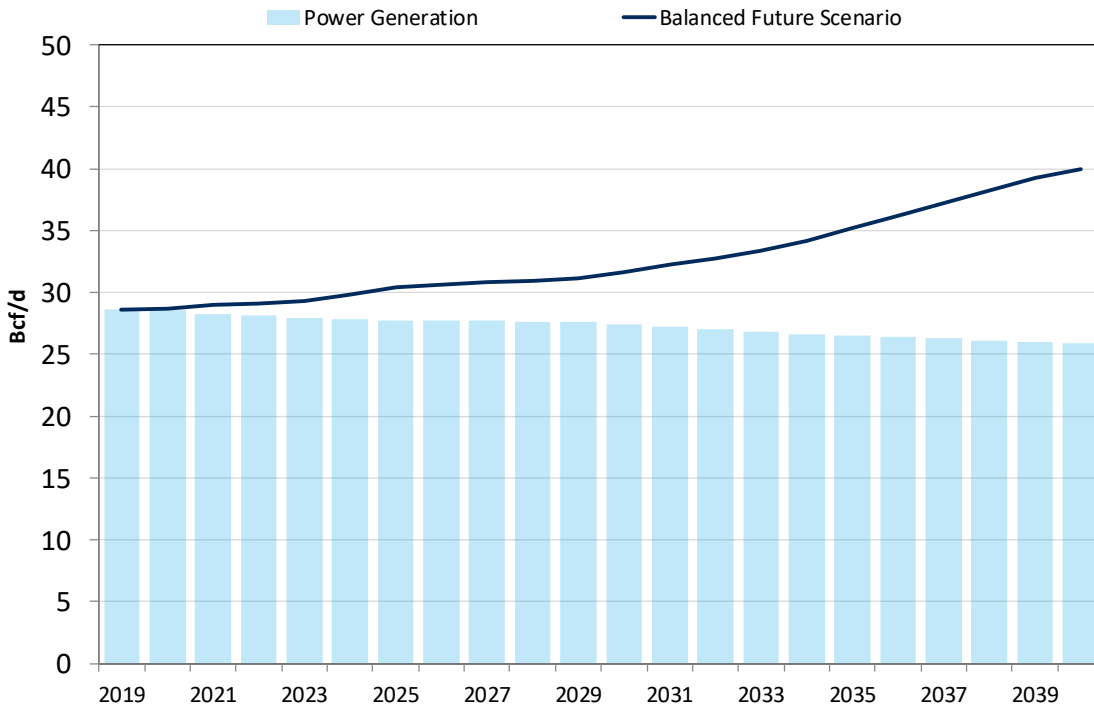


Figure 24. Projected Gas Demand for Power Generation Under the Rapid Renewables Transition Scenario

Source: Black & Veatch Analysis

- **Continued Support to Mitigate Renewable Intermittency Renewable Generation and Energy Storage**

As more renewables are integrated into the electric grid, the day-to-day variation and the intraday patterns already evident in California and New England will be exacerbated, as previously discussed. The impacts of this variability will emerge in other regions with high renewable goals, such as the Pacific Northwest.

Electric storage is a flexible resource that can provide the functions needed to compensate for renewable variability under both scenarios. As shown on Figure 25, a variety of types of electric storage with different storage media and characteristics are available. There was 708 MW of large-scale battery storage capacity in operation in the United States by the end of 2017. More than 80 percent of the capacity is lithium ion battery storage, which is capable of discharging between 0.5 and 4.0 hours. We expect that battery storage capacity will grow by 9 percent per year through 2040, which will result in overall growth of approximately 12 GW over the 20-year period.

Longer duration energy storage alternatives, such as compressed air, pumped hydro, power-to-gas hydrogen, and power-to-gas methane, currently are not widely available in all markets, and will have limited impacts on the 20 year view presented in this study.

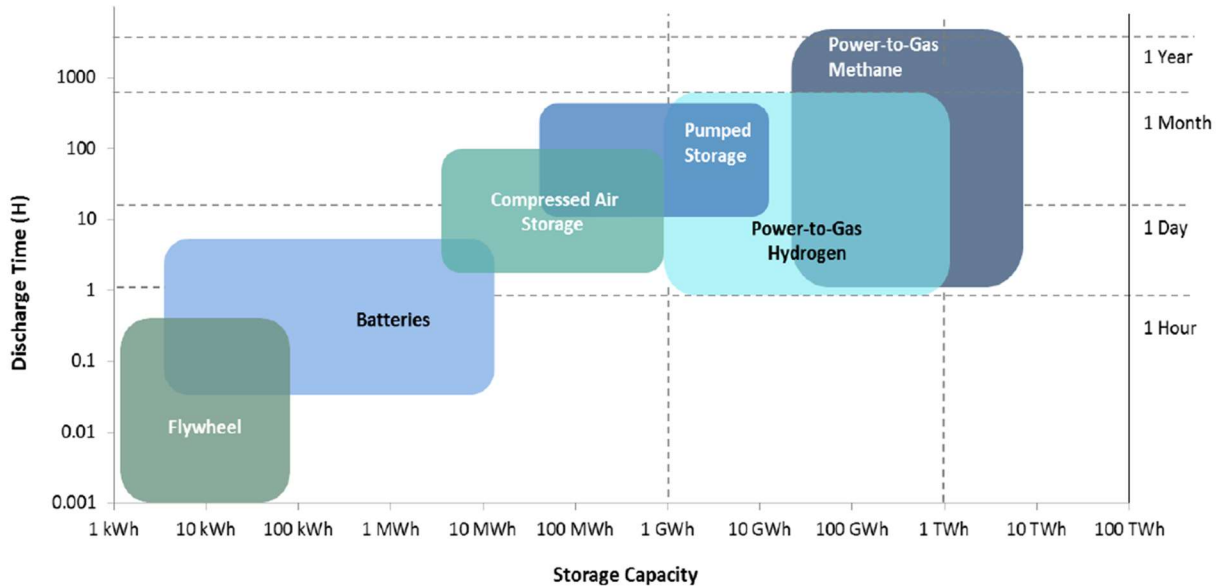


Figure 25. Energy Storage Capacity and Discharge Characteristics⁹

Source: California Hydrogen and Business Council 2015, National Renewable Energy Laboratory 2013b, Fuel Cells and Hydrogen Joint Undertaking 2015

Wholesale power market rules and state mandates already are spurring the development of battery storage capacity. In California, investors and municipal utilities own the battery storage capacity developed in response to a policy mandate. In the Pennsylvania-New Jersey-Maryland (PJM) Interconnection¹⁰, independent power producers built battery storage to take advantage of the frequency regulation market product created in 2012. Currently, California and New York are requiring 1,325 MW and 1,500 MW of battery storage, respectively, by 2020. Under the Balanced Future Scenario, we anticipate these states will be able to support close to 10 GW of battery storage by 2040. This scenario also assumes that other states will mandate some level of battery storage. We expect this will be achieved on time and that additional storage will be installed at the same rate after the mandate is met.

⁹ Flywheel – A mechanical battery that has a mass rotating about an axis, where energy is stored in a kinetic energy
 Compressed Air Storage - Compress and store air in an underground geologic structure during off-peak hours and run air through a gas turbine to generate electricity during peak periods

Pumped Storage – Two water reservoirs at different elevations, where water moving down a turbine generates power when needed, and is pumped back up during off-peak periods

Power to Gas Hydrogen – Use electrolysis to generate hydrogen with off-peak energy that can be stored, and burn hydrogen when power is needed.

Power to Gas Methane – Similar to Power to Gas Hydrogen, using hydrogen to create renewable methane, than can then be stored in traditional gas storage fields, and burned at a gas turbine or combined cycle unit.

¹⁰ The PJM Interconnect is the regional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of DE, IL, IN, KY, MD, MI, NJ, NC, OH, PA, TN, VA, WV and DC.

In addition, FERC Order No. 841, issued in February 2018, requires system operators to remove barriers for electric storage capacity to participate in the capacity, energy, and ancillary service markets. We expect that independent investors will construct battery storage to take advantage of potential revenue opportunities.

Overall, 12 GW of lithium-ion battery storage will be installed in the United States by 2040 under the Balanced Future Scenario. Under the Rapid Renewables Transition Scenario, over 30 GW of battery storage will be installed by 2040. Still, battery storage alone is not expected to completely mitigate the day-to-day variation and intraday ramp requirements created by large amounts of renewable generation for the following reasons:

- Seasonal variability will make it infeasible for battery storage to completely mitigate the variability of renewable generation. Significant excess electric supply exists in March through June, while large shortages occur in peak summer and winter months. (Figure 26) This seasonal charging and discharging in California alone (Figure 27) would require approximately 50 GW of lithium-ion capacity, or 300 GWh of storage to balance load and generation. (Figure 27.)

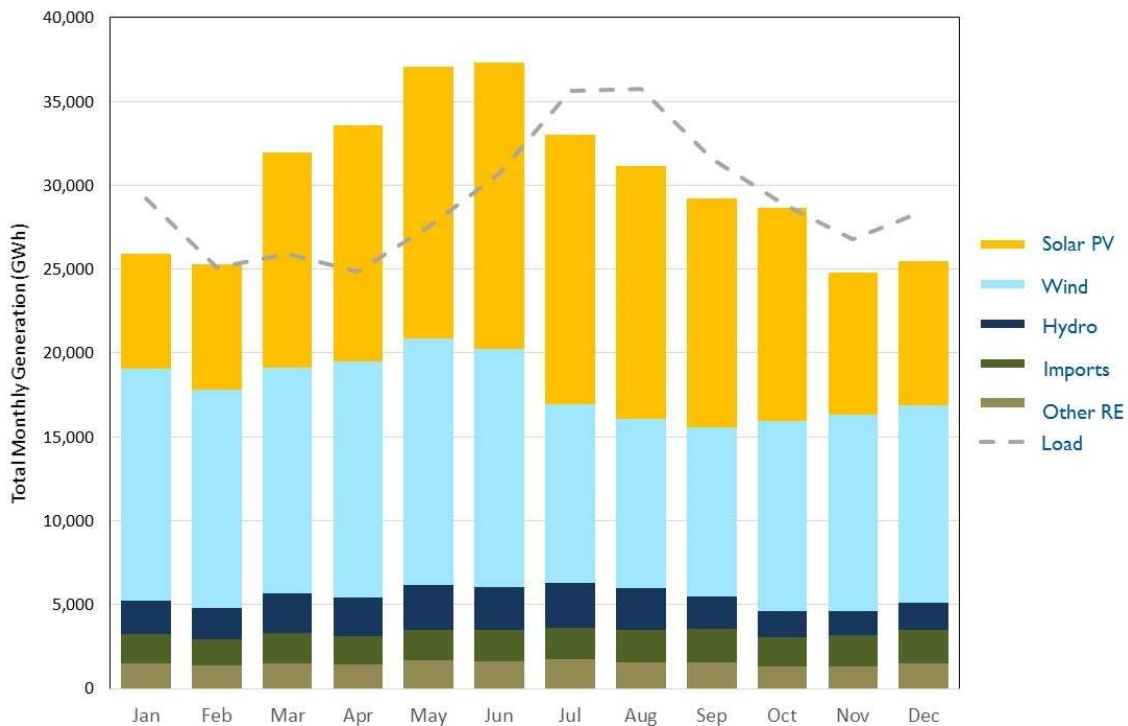


Figure 26. Projected Renewable Generation Versus Electric Load in California

Source: Black & Veatch Analysis

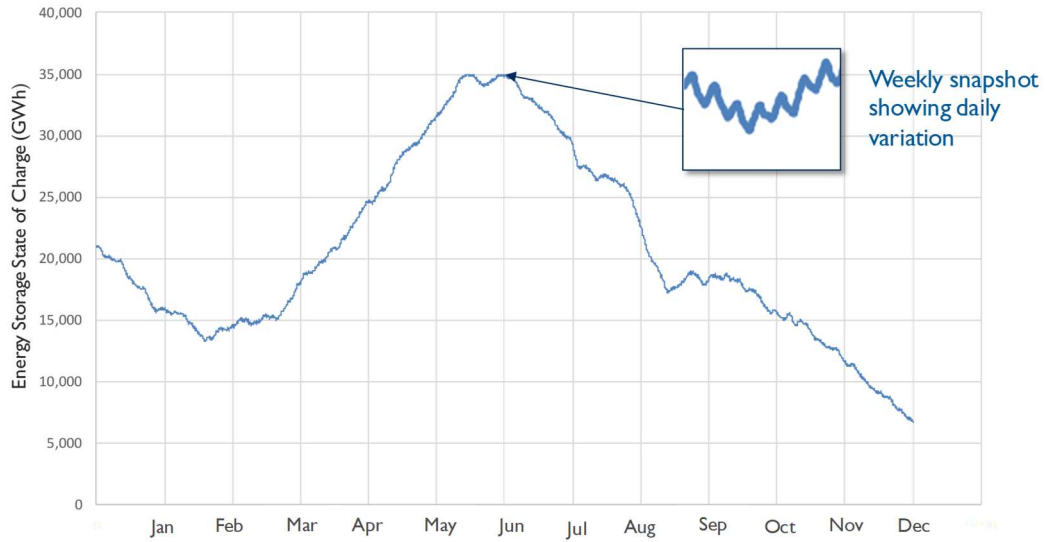


Figure 27. Projected Energy Storage Charging and Discharging During the Year

Source: Black & Veatch Analysis

- Electric storage will remain more expensive than gas peaking capacity. The cost of lithium-ion battery storage has dropped significantly over the last several years. Nonetheless, the current levelized cost of energy storage ranges from \$330 to \$780/MWh¹¹, compared to a \$71 to \$101/MWh range for gas peaking generation at 30 percent load factor.¹²
- Capacity degradation must be considered. A battery installation will generally experience cycling degradation after 3,000 hours of full depth discharge. Cycling degradation would cause the installed energy storage capacity to decline to approximately 80 percent (typically the guaranteed capacity) of original capacity. At this point, the battery system would still be operational albeit at below the original nameplate rating. According to some suppliers, a battery can continue to operate down to below 50 percent of its original installed capacity. To maintain storage capacity levels, battery capacity would need to be overbuilt or replaced after degradation. Either option would create additional costs to the consumer.



If a battery is discharged for 4 hours once-per-day to compensate for the after ramp caused by solar in California, the battery would be below its guaranteed nameplate capacity after 3000 discharges, approximately 10 years of operation.

¹¹ EIA May 2018 Battery Storage Trends page 2

¹² EIA Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2019 page 10

- The realization of battery storage revenue remains uncertain, and the participation rules and compensation mechanisms for battery storage projects have not been clearly defined. We expect that these rules and compensation mechanisms will become better defined over the course of the 20-year study period. The investment community will wait for clarification before large scale investments begins. PJM provides an example of the risk for potential investors. When new, faster responding “Reg-D” assets displaced slower, older, costlier “Reg-A” assets that previously provided flexibility on the dispatch curve in the PJM market, lost revenues were only partially recovered.¹³



PJM plateaued after the initial wave of taking advantage of the new frequency regulation market product, “Reg-D” . The market for the new product became saturated and some installations failed to realize revenue targets.

Role of Natural Gas Generation

Natural gas fired generation will continue to play an important role in supporting renewable generation and maintaining electric system reliability under both scenarios.

We use the New York ISO (NYISO) as an example to illustrate the need for natural gas to support the ever-higher percentage of renewable generation needed to meet electric load. In NYISO, wind generated an average 10.7 GWh of electricity during December 2017 to March 2018, representing 3 percent of the daily electricity generated. The day-to-day variation of the wind electricity output was great, from 0.5 GWh to 33 GWh. By 2040, average daily wind generation could reach 138 GWh during the same peak winter months, representing over 40 percent of electricity generated for the day. The day-to-day output could easily range from 70 GWh to 210 GWh. The dispatch of natural gas fired generation will vary inversely depending on whether wind output is high or low. This will require access to significant amounts of natural gas and natural gas transportation capacity to ensure electric grid reliability.

Figure 28 illustrates the range of daily wind generation range in NYISO for the winter of 2017-2018 and 2039-2040.

¹³ PJM provides market-based compensation to resources that can adjust output or consumption in response to an automated signal, to help match a control area’s generation and demand. Regulation D or “Reg-D” is a fast, dynamic signal that requires resources to respond instantaneously (i.e. energy storage). Regulation A or “Reg-A” is a slower signal that current existing generators (i.e. combustion turbines, steam turbines) can serve. (<https://learn.pjm.com/three-priorities/buying-and-selling-energy/ancillary-services-market/regulation-market.aspx>)

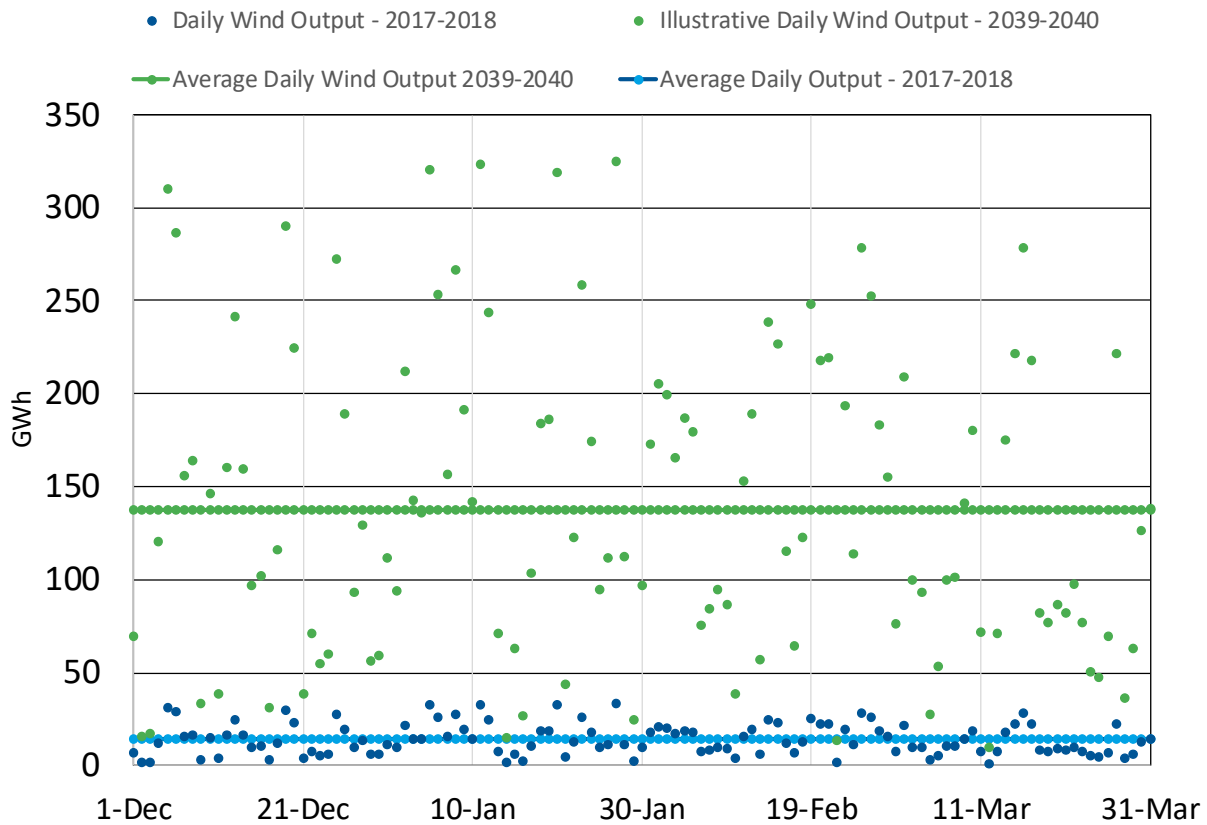


Figure 28. December to March Daily Wind Electricity Output at NYISO (2017-2018 versus 2039-2040)

Source: NYISO, Black & Veatch Analysis

By 2040, we expect there will be enough wind generation in the United States to meet close to 15 percent of average daily load under the Balanced Future Scenario. On days when the wind is not blowing, natural gas fired generation will be needed to manage the need and ensure electric grid reliability. Our model assumes an average wind capacity factor that derives the amount of gas fired generation needed on an average basis.

Using a statistical examination of the daily wind fluctuation in US regions, we estimate that up to 1.0 Bcf/d of natural gas will be needed to compensate for low daily output from wind power four to five days every month during the peak winter period in NYISO. Natural gas demand will be concentrated during the daily hours when electric demand is high. To meet this demand under the Balanced Future Scenario, battery storage will need to play a significant role. We expect that by 2040, storage costs will decrease by two-thirds from today’s levels. Nonetheless, a \$4.8 billion capital investment in battery storage will be needed.


Interstate pipelines currently accommodate generators’ need for natural gas supply and non-ratable hourly offtakes from their systems for short periods using their hydraulic line pack when possible. As increasing demand from gas fired power generation exacerbates hourly flow fluctuations, pipelines are

less likely to have operational flexibility to provide non-ratable flow for all shippers during high demand periods under both scenarios.

Unless a shipper subscribes to a pipeline service that provides for non-ratable flow service on a firm basis, pipeline flexibility to offer gas flow non-ratably, through the use of line pack, is not guaranteed. Even when a pipeline can provide non-ratable flow service on a best-efforts basis, line pack is finite and location-specific. A pipeline cannot exhaust its line pack, because this would impede its ability to meet its firm delivery obligations and prevent it from being able to set up for and deliver the following gas day.

Today, such flexibility may be available because other customers are not fully utilizing the pipeline capacity that they have reserved. However, it cannot be assumed that such flexibility will remain available if historical patterns of pipeline capacity utilization continue. For example, increased demand from gas fired generators could alter pipeline capacity utilization and the availability of flexibility. Thus, continued reliance on flexibility in pipeline capacity cannot be ensured as fast ramping generation increases to keep pace with increased renewable penetration without additional infrastructure or modification to commercial agreements.

Under the Rapid Renewables Transition Scenario, even though demand for natural gas fired generation will decline due to additional renewables and energy storage capacity, natural gas fired generation will remain a cost-effective way to mitigate the variability of some forms of renewable energy. Under the Balanced Future Scenario, there will be an increased demand for gas generation during the peak hours.



The utilization of pipeline capacity to transport gas for export (either as LNG or as pipeline gas to Mexico) at high load factors may affect the ability to utilize such capacity flexibly for other purposes.

It is important for US policymakers to address the economic imperatives in the wholesale restructured electric market created by the increased demand for flexible, fast ramping generation that will accompany increased renewable penetration to ensure that generators have access to the necessary quality of pipeline services. Natural gas fired generators and gas pipelines have the demonstrated ability to fulfill this role. It cannot be guaranteed, however, unless there is the ability to invest in the natural gas transmission infrastructure enhancements that may be needed.

Traditional and Non-Traditional End Use Sectors

RESIDENTIAL, COMMERCIAL, AND INDUSTRIAL DEMAND

Residential, commercial, and industrial gas consumption in aggregate made up 63 percent of the overall gas consumption in the United States in 2017. Residential and commercial natural gas demand is expected to grow by 1 Bcf/d over the 20-year study period according to Black & Veatch's 2018 EMP. The high costs to convert households from gas to electricity will limit the conversion rates in the United States over the analysis period, absent significant public policy incentives. Other factors, such as the cost and siting of electric transmission and distribution grid upgrades required to serve incremental residential heating loads, could be impediments to electrification. Still, in the Rapid Renewables Transition Scenario, public policies such as economic incentives for electric utilities to implement electrification and higher

energy efficiency standards could reduce the overall residential and commercial natural gas consumption in the United States by 1.2 Bcf/d over the 20 year study period (Figure 29).

Gas demand could be diminished due to the electrification of residential homes and commercial buildings for purposes of reducing GHG emissions. While the economics of gas appliances versus electric appliances currently favor natural gas, policy makers may choose to offer the substantial subsidies that would be necessary to encourage switching. Similarly, commercial buildings could be provided incentives to convert to dual electric and gas heating and cooling to reduce gas consumption during peak periods.

Industrial sector demand has grown steadily in recent years in response to lower gas prices. Over 10.3 million tons of processing capacity for ethane, ethylene, and other petrochemical facilities are under construction or have been recently placed into service in the US Gulf Coast and Appalachian regions. We expect the US petrochemical sector to remain competitive globally and sustain demand growth for natural gas in the United States.

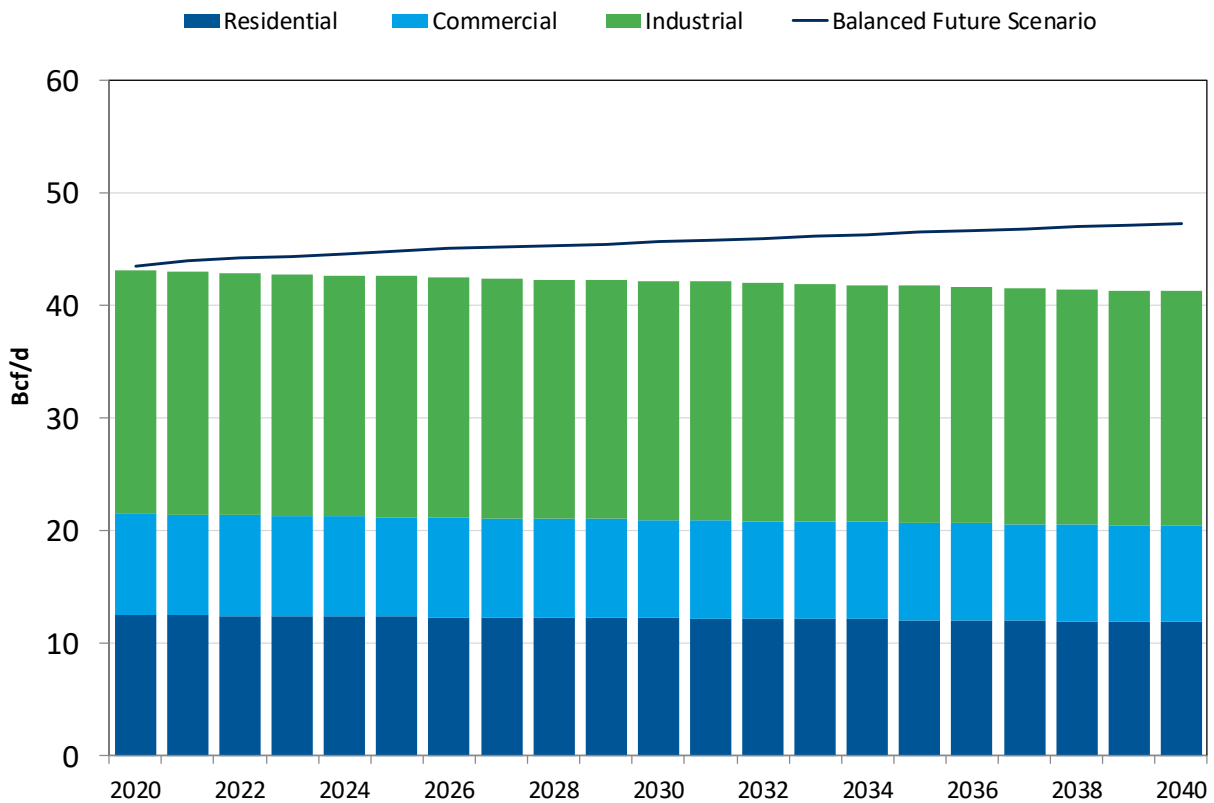


Figure 29. Projected Residential, Commercial and Industrial Natural Gas Consumption – Balanced Future Versus Rapid Renewables Transition Scenarios

Source: Black & Veatch Analysis

NORTH AMERICAN LNG EXPORTS

As previously discussed, the need for additional North American LNG export capacity will be supported by global natural gas demand growth and the continued development of the global LNG market over the 20-year period. This will create the need for natural gas transmission capacity to supply export terminals.

Under the Balanced Future Scenario, North American LNG exports are projected to remain cost competitive with other global LNG supply sources. As shown on Figure 30, global LNG demand is projected to grow at 4.5 percent CAGR, with potential supply and capacity shortfalls starting in 2022. As gas supplies connected to existing LNG export terminals located elsewhere in the world continue to decline, new terminals tied to low-cost supplies will be needed. Declines in LNG exports due to technical or upstream issues in Malaysia, Indonesia and Algeria could provide additional opportunities for new LNG export terminals that will commence operation in the next few decades.¹⁴

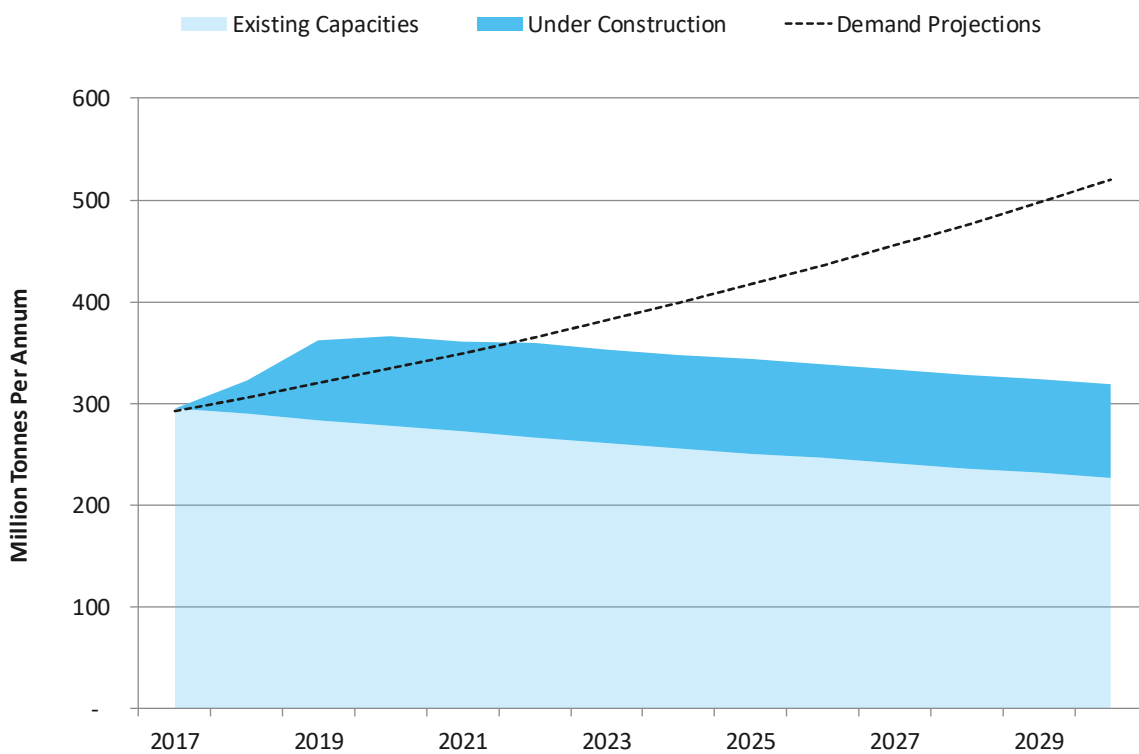


Figure 30. Global LNG Demand and Supply Balance

Source: Black & Veatch Energy Market Perspective 2018

North American LNG is poised to fill this gap given the low production costs, high market liquidity, and robust existing natural gas transmission and storage infrastructure that can be expanded to meet demand. In addition, Asian and European LNG purchasers favor the relatively lower risk in the United States compared to proposed projects in other locations that have higher perceived risk. Consequently,

¹⁴ International Gas Union World Gas LNG Report 2016, 2018, and 2019.

the natural gas transmission infrastructure constructed in the United States to satisfy demand created by LNG export terminals is expected to remain highly utilized.

In the Balanced Future Scenario, US LNG exports are projected to exceed 10 Bcf/d by 2023 and increase further to 16 Bcf/d by 2030 with the second wave of US LNG export terminal development. It should be noted that the terms of the LNG export agreements are based on economic risk models and return on investment decisions and are not perfectly correlated to the useful life of an asset, facility, or production basin. In other words, the term of the initial contract for capacity at an LNG export facility is by no means indicative of the ultimate duration of the demand for service from that facility and its supporting infrastructure. For example, Cheniere’s Sabine Pass LNG export facility has 20-year agreements to provide LNG to global customers. Other export facilities in operation or under construction in the lower US 48 states (i.e., Cameron, Freeport, and Cove Point) have similar agreements with LNG capacity holders and have received Department of Energy (DOE) approvals for the period covering those agreement terms. Black & Veatch anticipates that the renewal of the DOE export license would be followed by the renewal of the LNG sale and purchase agreements similar in length to those that exist today. Thus, interstate pipeline infrastructure serving LNG export facilities will be needed beyond the term of the initial service agreements.

In the Rapid Renewables Transition Scenario, diminished global demand growth slows US LNG export terminal development, limiting exports to approximately 10 Bcf/d by 2040. (Refer to Figure 31.)

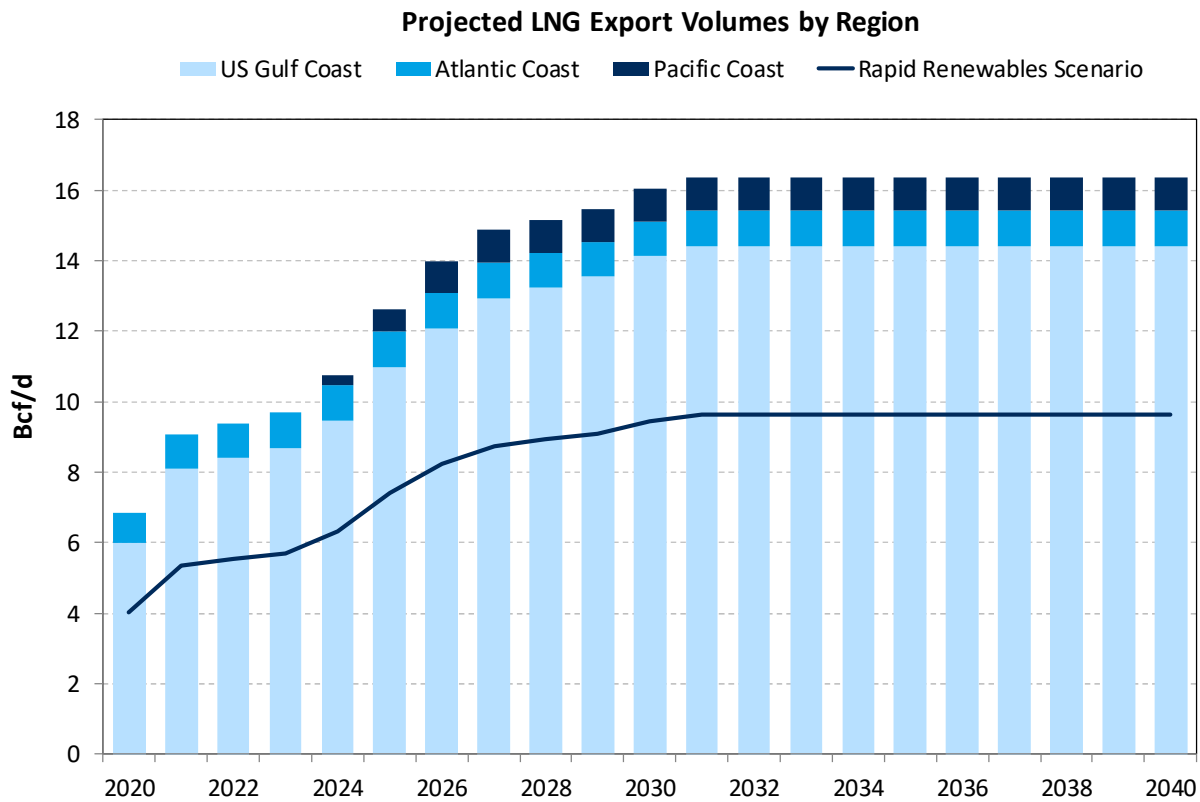


Figure 31. Projected LNG Export Volumes – Balanced Future Versus Rapid Renewables Transition Scenarios

US PIPELINE EXPORTS TO MEXICO

In the Balanced Future Scenario, US pipeline exports to Mexico will grow to as much as 8 Bcf/d by 2040. Mexico’s domestic natural gas production will continue to decline and domestic demand growth will drive the need for greater pipeline imports from the United States. In the Rapid Renewables Transition Scenario, US pipeline exports will reach only 6 Bcf/d by 2040 because of greater domestic natural gas production in Mexico, where an additional 2 Bcf/d of domestic production will displace US pipeline exports. (Refer to Figure 32.)

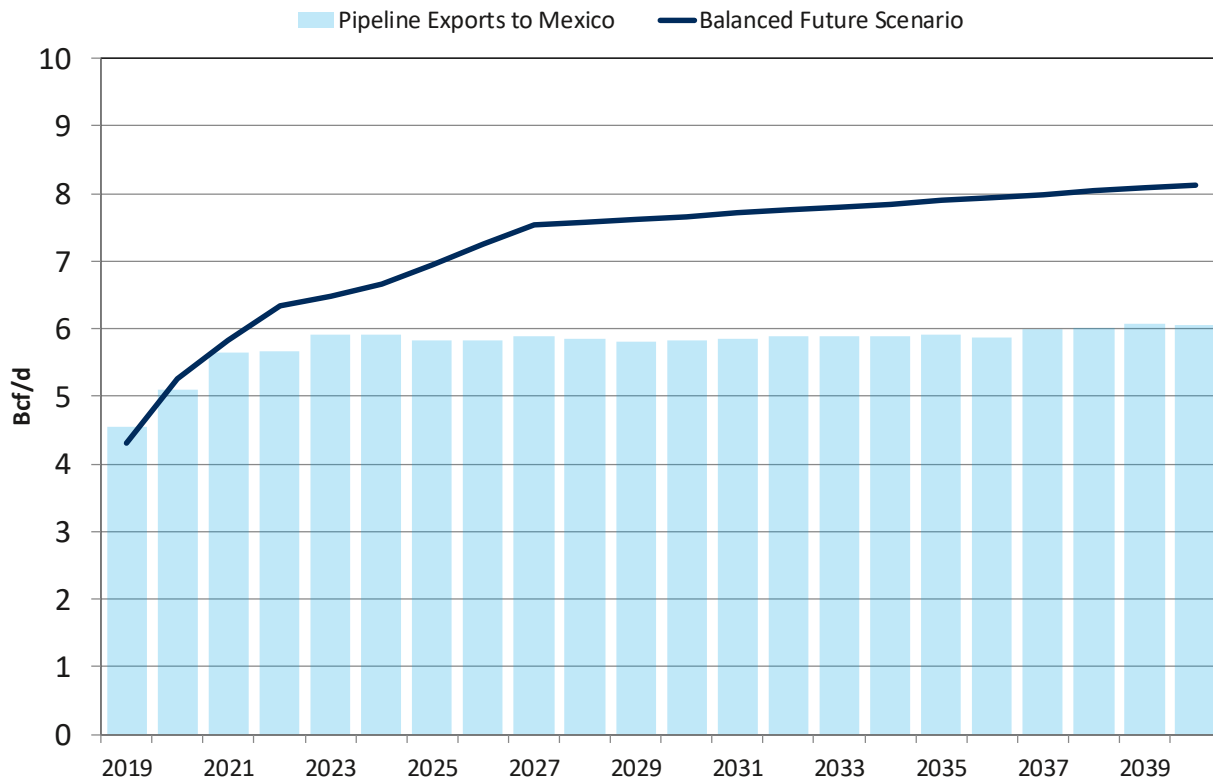


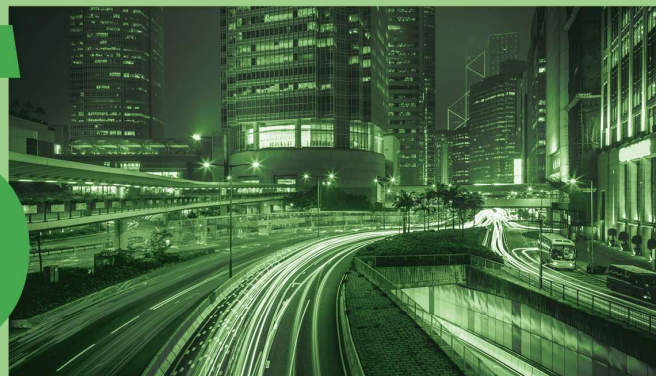
Figure 32. Projected Pipeline Exports to Mexico from 2020 Through 2040 Under the Balanced Future and Rapid Renewables Transition Scenario

Source: Black & Veatch Analysis



CHALLENGES AND OPPORTUNITIES FOR THE INDUSTRY

5



5 Challenges and Opportunities for the Industry

We have identified several primary factors that could shift future US natural gas demand growth and create distinct challenges and opportunities for the natural gas pipeline industry. As discussed, the Balanced Future and Rapid Renewables Transition Scenarios separately examined how each primary factor could affect US natural gas demand growth and the need for natural gas infrastructure (Figure 33).

The primary factors that could reduce US natural gas consumption will present challenges for the industry. Still, diminished baseload utilization of pipeline and storage assets in certain regions due to stagnant demand growth can lead to opportunities to provide additional non-ratable services that pipeline operators may not have had the flexibility to provide previously. The evolution of when gas supplies will be needed on an hourly basis to serve electric loads could create pressure for pipeline operators to refine nomination cycles to provide shippers the ability to change nominations intra-hour. Understanding how gas loads on a pipeline system can shift from hour to hour will provide a basis for pipeline operators to develop new services and capabilities that can address customers’ needs. Of course, there also may need to be some evolution of wholesale power market rules and perhaps pipeline ratemaking to ensure that pipeline operators are compensated for the cost of providing the flexibility sought by generators.

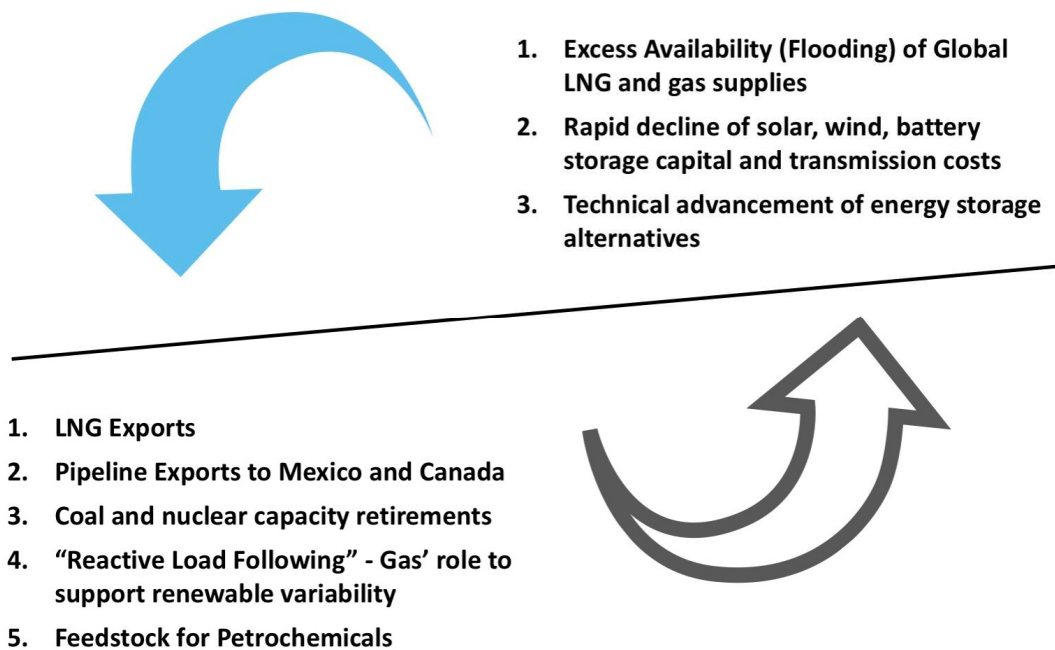


Figure 33. Primary Factors of US Gas Demand Growth

Source: Black & Veatch Analysis

The following discussion was developed through a workshop with representatives of the complete natural gas infrastructure supply chain. These ideas are presented to further illustrate the resilience and adaptability of the natural gas infrastructure sector. While all are technically viable, implementation could require significant commercial and regulatory reform.

5.1 Incremental Opportunities for the Natural Gas Industry

Under both scenarios, the natural gas pipeline industry has the opportunity to provide incremental services to support renewable resources over the next 20 years. It will be essential to build upon the services already offered by natural gas transmission pipeline operators (Table 1).

Table 1. Summary of Incremental Opportunities

INCREMENTAL OPPORTUNITIES	WHY SHOULD IT BE EXPLORED?
Small Scale Gas Transportation Services: LNG Trucking Distributed Generation/Microgrids Non-Utility Customers	New potential customers or value chain to serve may result from trends favoring distributed generation and transportation
LNG Hourly/Daily Balancing or Supply Put Option	LNG terminals will require additional midstream services to handle train trips, weather, or other factors impacting feed gas to the terminal
Hourly Rate Structure to Account for Variability and Time of Use	Hourly rate structure that will allow pipelines to allocate costs based on when customers need gas supply the most and to the customers who need it the most. Alternatively, pipelines should be permitted to price based on the value of the service instead of the cost to provide the service.
Renewable Reliability Service	Gas generation remains a competitive solution to manage renewable variability Pricing options for differentiated, high-value reactive load following products can be explored

Opportunities with Small Scale Transportation Customers

New small-scale gas transportation customers will emerge with the growth of small-scale LNG facilities, microgrids, and distributed generation facilities. Low and stable natural gas prices will spur the use of natural gas in ways that could require incremental pipeline capacity.

Microgrids and distributed generation facilities will also need access to firm natural gas supplies for primary generation purposes as well as a backstop to renewable generation. These small scale (1 to 5 MW) microgrids and distributed generation facilities will use natural gas combined with renewable resources to provide a clean energy option with high reliability and resilience. Small-scale transportation customers will choose to interconnect with an interstate pipeline for economic and reliability purposes to ensure access to firm natural gas during critical peak conditions.

In addition to constructing new laterals to serve these small-scale customers, additional hourly no-notice or balancing services will be needed to meet the peak hour needs of microgrids and distributed generation resources.

Opportunities to Support LNG Exports

- **Daily diurnal LNG feed gas requirements will create new opportunities through 2040.**

With several LNG export terminals being commissioned by 2020, there will be growing daily balancing needs associated with feed gas deliveries to these facilities. While each LNG terminal may have different

operational characteristics because of its choice of technology and configuration, the demand for hourly balancing will grow commensurate with overall LNG volume growth.

Ambient temperature can affect the efficiency of gas turbines used to liquefy natural gas and, consequently, affect the feed gas rate for producing LNG throughout the day. Daily swings in Gulf Coast ambient temperatures vary monthly and can create a daily feed gas rate variance that approaches 12 percent during peak summer months. While lower temperatures do not affect feed gas needs greatly, higher temperatures create the largest variations in hourly needs.

For a Gulf Coast LNG liquefaction train, the feed gas rate can fluctuate throughout the day and seasonally. LNG liquefaction operators or tollers will need daily balancing services on pipelines and/or use instantaneous, no-notice storage services to mitigate diurnal feed gas rate swings in both directions.

Pipeline imbalance tolerances will allow a shipper to flow typically within +/-2.5 percent of daily variation; however, the daily swings for LNG liquefaction feed gas rates are expected to far exceed those thresholds during summer months. Even if pipelines allowed a 5 percent nomination tolerance, the average daily variation would exceed that limit seven months of the year.

The Balanced Future Scenario assumes that eight terminals will be operational on the Gulf Coast, with LNG export feed gas demand reaching 14.4 Bcf/d by 2040. As shown on Figure 34, the total daily variance would potentially require close to 1.3 Bcf/d of daily injection and withdrawal balancing among the pipeline and storage assets supporting LNG liquefaction export terminals. Even after factoring in the potential 2.5 percent daily nomination tolerance level, the total LNG-related injection and withdrawal variability could still approach 1.0 Bcf/d.

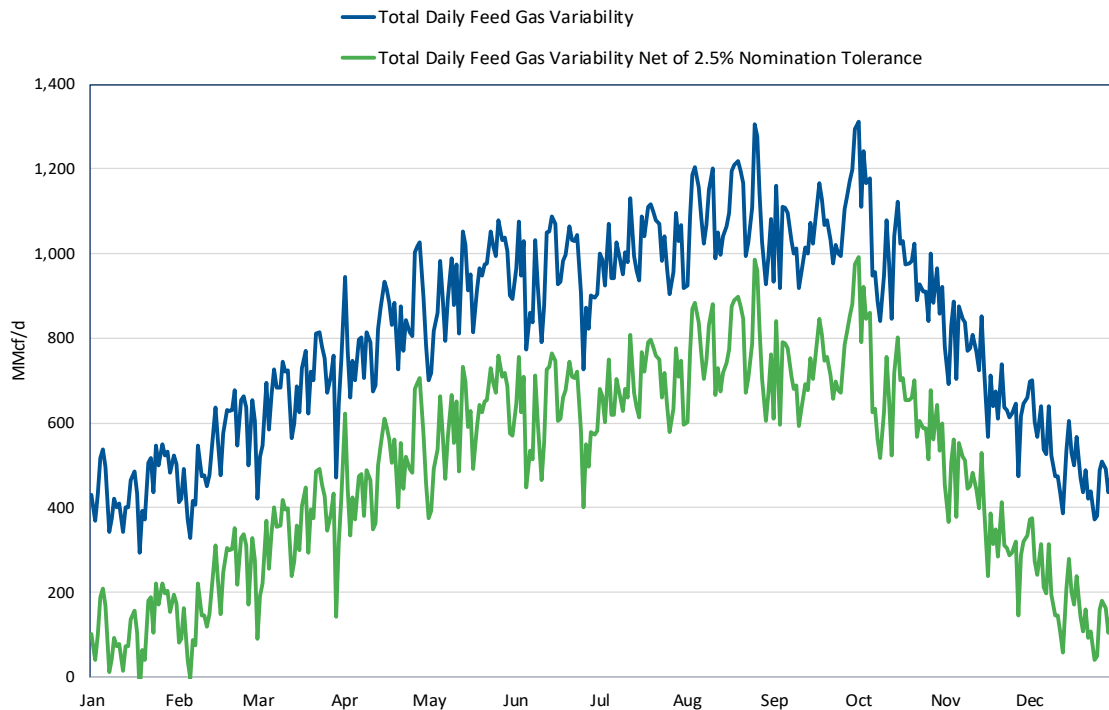


Figure 34. Total Gulf Coast LNG Daily Feed Gas Rate Variance in 2040

Source: Black & Veatch Analysis

- LNG operational train trips will drive the need for intraday pipeline services.

LNG liquefaction terminal operators and customers prefer liquefying and shipping LNG cargos on a steady-state schedule. Nonetheless, the operational history of the Sabine Pass Liquefaction Project and Black & Veatch’s engineering procurement and construction experience indicate that outlets for excess gas will likely be needed when a train trips and short-notice supplies will be needed when a train returns to normal operations. Without the physical sink for excess gas supply or short-notice supply sources, the LNG liquefaction plant operators, or their tollers, could be forced to sell or buy the gas supplies in the intraday spot market at a significant financial loss. (Figure 35.)

In addition to the terminal’s base gas supply portfolio, there will be a demand for additional pipeline and storage deliverability to help manage train trips and restarts.

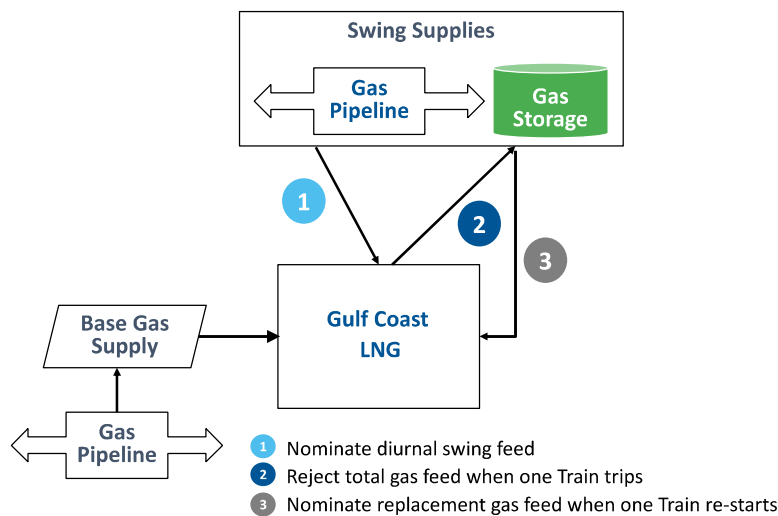


Figure 35. Base and Swing Supply Options for LNG

Source: Black & Veatch Analysis

In 2017, Hurricane Harvey affected Sabine Pass operations for approximately 10 days from August 30 through September 8. During such prolonged downtime, storage is a cost-effective alternative to pipeline imbalance costs or monetization of supplies at the nearest liquid hub. (Figure 36)

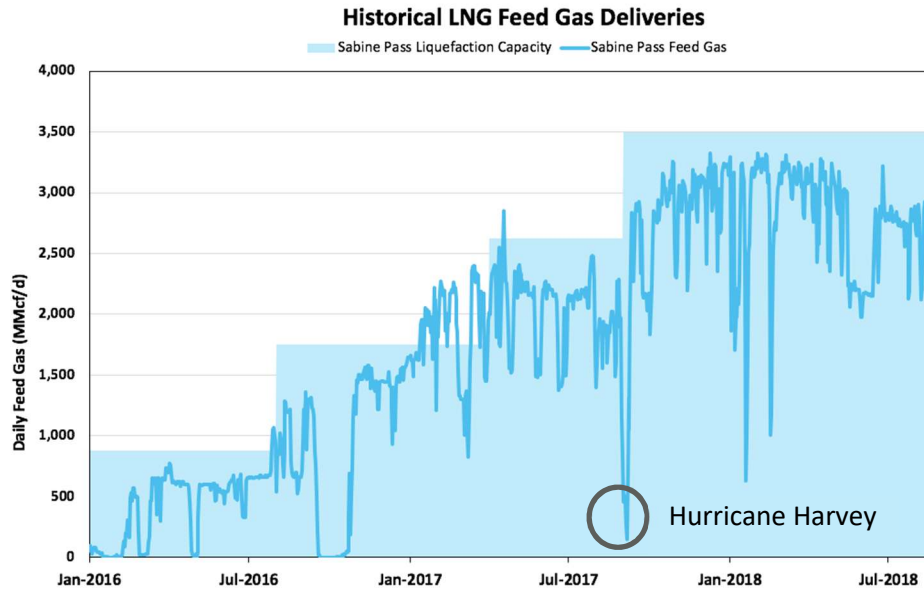


Figure 36. Historical Feed Gas Deliveries to Sabine Pass

Source: Energy Velocity, Black & Veatch Analysis

Opportunities in Renewables

Growth in renewable generation will continue to require support from natural gas fired generation and gas transmission pipelines. Generators wishing to provide services to mitigate renewable variability must have access to natural gas. Pipeline services in support of such gas-fired generators could include the following:

- No-notice or short-notice transportation for gas fired generators called to dispatch to offset renewable variability; and
- Non-ratable flow pipeline tariff service.

The need for fast ramping electric generation resources will continue to grow with the transition to a lower-carbon economy. Developing no-notice or short-notice transportation rates that reflect the time of use element of the delivered gas volumes will be an important step to allocate the appropriate level of costs to each shipper on the system. A shipper that can avoid using gas deliveries on those specific hours, like LDCs or industrial customers can capture some cost savings by allowing the pipeline to offer no-notice services to these electric resources and sharing the incremental revenue with its existing shippers.



CONCLUSIONS



6 Conclusions

Uncertainty about the energy future is nothing new for natural gas or any other energy source. Market dynamics can change because of any number of factors, including a sudden technological breakthrough or federal or state energy policy decisions. Over the next two decades, global market forces and US regional policy initiatives may change how we think about the role of natural gas. In the mid-2000s, the United States was positioning itself to import LNG from around the globe and perhaps pipeline gas from the Arctic, as domestic conventional natural gas supplies were steadily declining. This changed rapidly when the shale revolution made domestic natural gas abundant and affordable. Today, we know that there is both a domestic and a global impetus for reducing carbon emissions and transitioning to a lower-carbon economy. Natural gas will play a key role in supporting this initiative by providing a safe and reliable low-cost source of energy.

Across both scenarios examined, natural gas will continue to serve both traditional (residential, commercial, and industrial customers) and emerging sectors (e.g., LNG exports and pipeline exports to Mexico) while playing a greater role in complementing renewable generation growth. Gas fired generators with the help of pipeline and electric grid operators have been able to ensure a stable and balanced electric grid. Higher levels of renewable generation over the next two decades will create new challenges in the electric transmission sector that the natural gas industry can help overcome. Gas fired generation will require additional flexible transmission services to balance the growth in renewable generation and support electric grid reliability.

LNG exports and pipeline exports to Mexico support the US trade balance and work to reduce global emissions by replacing coal and other fossil fuels with clean burning natural gas. With renewable generation growth in emerging markets, natural gas in the form of LNG will be needed to mitigate hourly and seasonal renewable variation. In both scenarios, US LNG export terminals will be utilized at high capacity factors because US gas supplies will remain competitive with global LNG alternatives.

Existing and new natural gas infrastructure will continue to play a critical role in facilitating future natural gas consumption. Across both scenarios, natural gas infrastructure allows reliable, low-cost gas supplies to be produced and transported to meet critical needs and support the transition to a lower-carbon economy.



GLOSSARY

7



Glossary of Terms

Bcf	Billion Cubic Feet
Bcf/d	Billion Cubic Feet per Day
CAGR	Compounded Annual Growth Rate
CAISO	California Independent System Operator
CFE	Comisión Federal de Electricidad
CO ₂	Carbon Dioxide
DOE	Department of Energy
DSIRE	Database of State Incentives for Renewables & Efficiency
EIA	United States Energy Information Administration
EMP	Energy Market Perspective
FERC	Federal Energy Regulatory Commission
FID	Financial Investment Decision
GHG	Greenhouse Gas
GW	Gigawatt
GWh	Gigawatt-hour
IEO	International Energy Outlook
INGAA	Interstate Natural Gas Association of America
ISO NE	ISO New England
LDC	Local Distribution Company
Line Pack	Volume of Gas That Can Be Stored in the Pipeline Itself as Inventory
LNG	Liquefied Natural Gas
MMMT	Million Metric Tons
MW	Megawatt
MWh	Megawatt-Hours
NO _x	Nitrogen Oxide
NYISO	New York Independent System Operator
OECD	Organization for Economic Co-operation and Development
PJM	Pennsylvania-New Jersey-Maryland Interconnection
RPS	Renewable Portfolio Standard
SO ₂	Sulfur Dioxide
Tcf	Trillion Cubic Feet
TWh	Terawatt-hours