American Gas FOUNDATION

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Enhancing and Maintaining Gas and Energy System Resiliency

Areas of Focus and Change

An American Gas Foundation Study Prepared by:

Guidehouse

Background and Methodology

This study was conducted to investigate the resilience of the US gas system and the necessary changes required to the regulatory framework to support gas resilience investments. It builds off the prior report published by the American Gas Foundation and Guidehouse in January 2021: *Building a Resilient Energy Future: How the Gas System Contributes to US Energy System Resilience.* This work was directed to ask and answer four key questions:

- What characteristics of the current regulatory framework enable or disable gas resilience?
- How can resilience be valued and measured to better qualify gas infrastructure investments?
- What recommended changes are needed to fully enable gas system resilience?
- Through what modified regulatory frameworks can the recommended changes be implemented?

These questions were explored through a qualitative assessment conducted by Guidehouse, including discussions and interviews with many energy industry subject matter experts and Commissioners across the US and Canada. Case studies and examples of resilience were identified as a part of these discussions. Guidehouse used these studies and examples to develop methods to properly value resilience infrastructure and implement gas resilience within the energy system, including through proposed regulatory changes. The findings presented in this work identify issues that merit consideration and further exploration when developing future energy policy and regulation to ensure a resilient, reliable, and clean future energy system in all regions and jurisdictions.

American Gas Foundation

Founded in 1989, the American Gas Foundation (AGF) is a 501(c)(3) organization focused on being an independent source of information research and programs on energy and environmental issues that affect public policy, with a particular emphasis on natural gas. When it comes to issues that impact public policy on energy, the AGF is committed to making sure the right questions are being asked and answered. With oversight from its board of trustees, the foundation funds independent, critical research that can be used by policy experts, government officials, the media, and others to help formulate fact-based energy policies that will serve this country well in the future.

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Abbreviations

Abbreviation	Definition
AGF	American Gas Foundation
BERF	Building a Resilient Energy Future report
CAIDI	Customer Average Interruption Duration Index
CCUS	Carbon Capture Utilization and Storage
CDP	Carbon Disclosure Project
CDF	Customer Damage Function
DER	Distributed Energy Resource
DOE	US Department of Energy
EU	European Union
FERC	Federal Energy Regulatory Commission
IIJA	Infrastructure Investment and Jobs Act (2021)
ICE	Interruption Cost Estimator
IPCC	Intergovernmental Panel on Climate Change
ISO	Independent Service Operator
LDC	Local Distribution Company
LNG	Liquified Natural Gas
LMI	Low and Middle Income
MEA	Maryland Energy Administration
NARUC	National Association of Regulatory Utility Commissioners
NERC	North American Electric Reliability Corporation
NIAC	National Infrastructure Advisory Council
NGO	Non-Governmental Organization
POET	Power Outage Economics Tool
PSC	Public Service Commission
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
STRIDE	Maryland Strategic Infrastructure Development and Enhancement Plan
UK	United Kingdom
US	United States

Executive Summary

Resilience is an inherent and crucial component of a dependable energy system, which is obtained through diverse and redundant energy sources. The ability of the gas system to meet seasonal and peak day demands represents an important and valuable resource that must be considered when designing future energy systems and building pathways to a low-carbon future. This report examines gas system resilience attributes, focusing on how it enables overall energy system resilience, changes to the regulatory framework to support gas resilience investments, and the infrastructure improvements necessary to support broader energy system resilience. This report also examines opportunities to enhance the resilience of the entire "energy system" and how future investments in the gas system that support the resilience of other parts of the energy system can also support a low-carbon future and the increased integration of renewables in both the gas and electric grids. A focus on the evolution of electric and gas grids as a complete energy system which includes additions of renewable supply is needed.

As recent significant weather events have increased in severity, those events illustrate the need for enhanced energy system resilience has become demonstrable. The resilience of the overall energy system rests upon gas system resilience since natural gas accounts for one-third of primary energy consumption across all principal sectors of the economy and is the primary fuel for the generation of electric power in the US. There is broad recognition that gas system resilience is critical to overall energy system resilience. As the use of natural gas has become the primary fuel for the generation of electric power, the importance of natural gas has increased beyond its role as a fuel for homes and businesses. Recent weather events have shown the value and necessity of a resilient gas system and the inextricable linkage between fuel delivery, the supply of electricity, and peak energy management across the gas and electric system.

This report provides the technical, commercial, and regulatory analysis associated with the resilience of the US gas system with the goal of identifying the necessary changes to the policy and regulatory framework for the energy industry to support gas resilience investments. It builds off the prior report published by the American Gas Foundation and Guidehouse in January 2021: Building a Resilient Energy Future: How the Gas System Contributes to US Energy System Resilience.

The American Gas Foundation (AGF) is a 501(c)(3) organization focused on being an independent source of information research and programs on energy and environmental issues that affect public policy, with a particular emphasis on natural gas. When it comes to issues that impact public policy on energy, the AGF is committed to making sure the right questions are being asked and answered. With oversight from its board of trustees, the foundation funds independent, critical research that can be used by policy experts, government officials, the media, and others to help formulate fact-based energy policies that will serve this country well in the future.

The study set out to address the following four key questions:

- What characteristics of the current regulatory framework enable or hinder gas resilience?

- What recommended changes are needed to fully enable gas system resilience?
- How can resilience be valued and measured to better qualify gas infrastructure investments?
- Through what modified regulatory frameworks can the recommended changes be implemented?

Resilience attributes of the gas system are examined in this study focusing on how it enables overall energy system resilience, the changes to the regulatory framework which may support future gas resilience investments, and the infrastructure improvements necessary to support broader energy system resilience into the future. This report was developed and assembled using data and inputs from a diverse array of sources including interviews with industry recognized state regulators, detailed review of available studies and assessments of the impact of severe weather events upon energy infrastructure and broader regional economies, regulatory initiatives to address resiliency implemented in the US and overseas, reliability studies and analyses performed by the University of California at San Diego (UCSD). Also, discussions with representatives of local distribution companies (LDCs) active in addressing issues associated with resiliency and independent analytics of key features of the energy system including the deployment of distributed energy resources was undertaken.

High-Level Recommendations

There are a number of recommendations that should be considered to achieve enhanced energy system resiliency:

Recommendation: State Commission Analysis into Value of Gas Infrastructure

Commissions may explore methodologies that look beyond used and useful analysis to understand the true value gas infrastructure provides to the resilience of the entire energy system - relying on traditional regulatory criteria may not cover the future benefits of resiliency or weather-related system improvements.

Recommendation: Emphasize Safety and Renewable Integration When Seeking Approval

When seeking approval for resilience infrastructure investments and stakeholder support, gas companies should emphasize the investment's value to ensure safety and the future integration of renewables in both the gas and electric systems.

Recommendation: Focus on Enabling Mechanisms Emphasizing Resiliency and a Low-Carbon Future

To achieve current and future resilience, regulatory and financial supportive mechanisms should be considered that emphasize the gas system's long-term role in a low-carbon energy system

Downstream and Upstream of the City Gate Recommendations

Investments downstream of the city gate address the risk of upstream supply chain disruptions today, but greater investment may provide greater contingency planning.

Key **downstream** investment recommendations include:

- Increase investments in the weatherization of pipelines and storage distribution infrastructure.
- Continue improving downstream of city gate pipeline interconnections.
- Develop additional storage facilities on the gas distribution system to enhance the resilience of the overall pipeline distribution system.
- Introduce and expand the integration of alternative fuels (e.g., hydrogen or RNG) or LNG produced and stored behind the city gate.
- Continue to modernize infrastructure, including distribution pipelines to help enhance safety, reliability, resiliency, and affordability while in turn driving down emissions and delivering ever more low-carbon gas supply solutions over time.

Key **upstream** investment recommendations include:

- Increase investments in the weatherization of well-heads, gathering, and processing systems, gas transmission networks, and storage facilities to ensure they are prepared for extreme weather events and potential duration changes.
- Continue to modernize aging pipelines and interconnections with long lived assets that support broader energy system resilience.
- Design systems to accommodate low-carbon fuels such that future system operations can continue to provide resilience benefits while supporting mid-century decarbonization emission reduction goals.

Federal and State Recommendations

Recommendations: Federal and state intervention and approval to implement resilience measures

At both the federal (e.g., US House of Representatives, Senate, and federal agencies) and the state (e.g., state legislative or regulatory commission) levels hearings may be held on the impacts and consequences of extreme weather events on the US or state, including the risks of prolonged outages to customers, utilities, and state economies.

Federal

From the findings, Congress may consider issuing formal documentation notating the critical importance of enhancing energy system resilience, including the pipeline network and electric grid, to meet the challenges associated with climate change.

State

At the state level, legislators may request utilities to develop plans that describe the resilience investments necessary to mitigate against the impacts of extreme weather events. Resilience is important for forward looking plans required by regulatory agencies or submitted to reduce carbon going forward. For example, New York recently passed legislation which allows utilities to recover their climate resilience plan costs through a specific cost recovery clause.[1]

Recommendations: Implement resilience regulatory requirements

Both state and federal regulators may incorporate resilience into updated regulatory frameworks that govern the broader energy system.

Federal

By the means of legislation or other federal directives, the Federal Energy Regulatory Commission (FERC) can address this issue by establishing baseline resilience requirements for jurisdictional energy systems, possibly via the North American Electric Reliability Corporation (NERC). In addition, they can develop rules that require electric generators operating in regulated power markets in FERC's jurisdiction to engage with fuel suppliers that adhere to resilience requirements.

State

While FERC resiliency requirements or related rules may be adopted by some states and utilities, supportive policies in the state and regulatory arenas should recognize regional differences and state-specific requirements. State regulators will also need legislative support to expand the principle of "used and useful" to include the approval of resilience asset investments that may have very low utilization through their targeted response to high-impact, low-probability events.

Recommendations: Enable federal and state funding support for resilience investments for all energy sources.

Federal

Federal legislation could provide federal funding avenues for resilience investments, including both upstream and downstream of the city gate. Congress can also consider either amending the Infrastructure Investment and Jobs Act (IIJA) or producing new legislation to provide energy system infrastructure resilience investment avenues.

State

A template tariff for natural gas distributed energy resources may be developed to compensate LDCs for resilience investments. This would help address supply during peak demand periods (e.g., winter heating season) and help allocate a portion of the revenues earned by distributed energy resources (DERs) from participation in wholesale capacity markets and demand response programs.

States can also consider innovative regulatory constructs to manage the costs from energy system resilience investments and extreme weather impacts.

[1] New York State Senate. January 26, 2021. "Assembly Bill A3360A." New York State.

Recommendations: Improve the interdependencies and coordination between the electric and natural gas industries

Federal

FERC and the Department of Energy (DOE) may consider policy and rules that recognize the importance and interdependencies and coordination of the natural gas and electric energy systems to ensure the points raised above are recognized and implemented at the federal level.

State

In parallel, state commissions can establish workshops and/or dockets that (i) establish policy and rules that recognize the importance and interdependencies of the natural gas and electric energy systems to ensure the points raised above are recognized and implemented at the federal level, (ii) recognize electric service to pipeline and distribution infrastructure as critical load so they are excluded from load shedding by utilities during extreme weather events; and (iii) establish broader state energy system dockets which review electric and natural gas initiatives that support overall energy system resilience.

1. Introduction

Resilience is an inherent component of a dependable energy system.[2] As extreme weather events have increased in frequency and severity, the need for enhanced energy system resilience has become demonstrable. In large measure, the resilience of the overall energy system rests upon gas system resilience since natural gas accounts for one-third of primary energy consumption across all principal sectors of the economy and is the primary fuel for the generation of electric power in the US.

There are additional opportunities for policymakers and regulators to account for and prioritize gas system resiliency within utility investment considerations. The gas system can address the challenges of severe winter weather events. However, enhanced resiliency planning and investment are critically important as we move forward into the 2020s and beyond.

An antecedent report to this study was published in January 2021 by the American Gas Foundation and Guidehouse. *Building a Resilient Energy Future: How the Gas System Contributes to US Energy System Resilience* (BREF[3]) highlights the gas system's ability to support resilience through its inherent, physical, and operational capabilities. Unique attributes of the gas system enable it to address the challenges associated with increased gas demand and supply constraints during severe winter events. The BREF report analyzed the current state of the natural gas regulatory system, including its restraints in supporting resilience investments, and identified issues that merit further consideration when developing future energy policy and regulation to ensure a resilient, reliable, and clean future energy system. Key findings from that report include:

1. There is inadequate political and regulatory support for resilience in the gas system;
2. There is no regulatory initiative that specifically addresses gas system resilience at the state level;
3. Resilience is often indirectly referenced and embedded within reliability and safety standards, though resilience has been and will continue to be a priority for the industry; and
4. In the electric sector, regulators have approved various mechanisms for compensating value chain participants for resilience investments. However, notwithstanding that gas system resiliency is core to most electric resiliency projects, gas utilities are typically not appropriately compensated for resilience services in many circumstances.

Building off the prior BREF report, this report further examines the resilience attributes of the gas system, focusing on how it enables overall energy system resilience, the changes required to the regulatory framework to support gas resilience investments, and the infrastructure improvements necessary to support broader energy system resilience. Under the traditional regulatory regime, the value of resilience to customers would need to be demonstrated before incremental investments can be made. The regulatory, industry, and political support system needs enhancements to ensure present and long-term resilience of the energy system, including natural gas.

[2] This report focuses on the entire "energy system" as well as the "gas system", these terms are used throughout – the gas system has an overall impact and benefit for the broader energy system and the terms used in the report intend to focus on gas specifically and how it benefits and impact the energy system.

This report was directed to ask and answer four key questions:

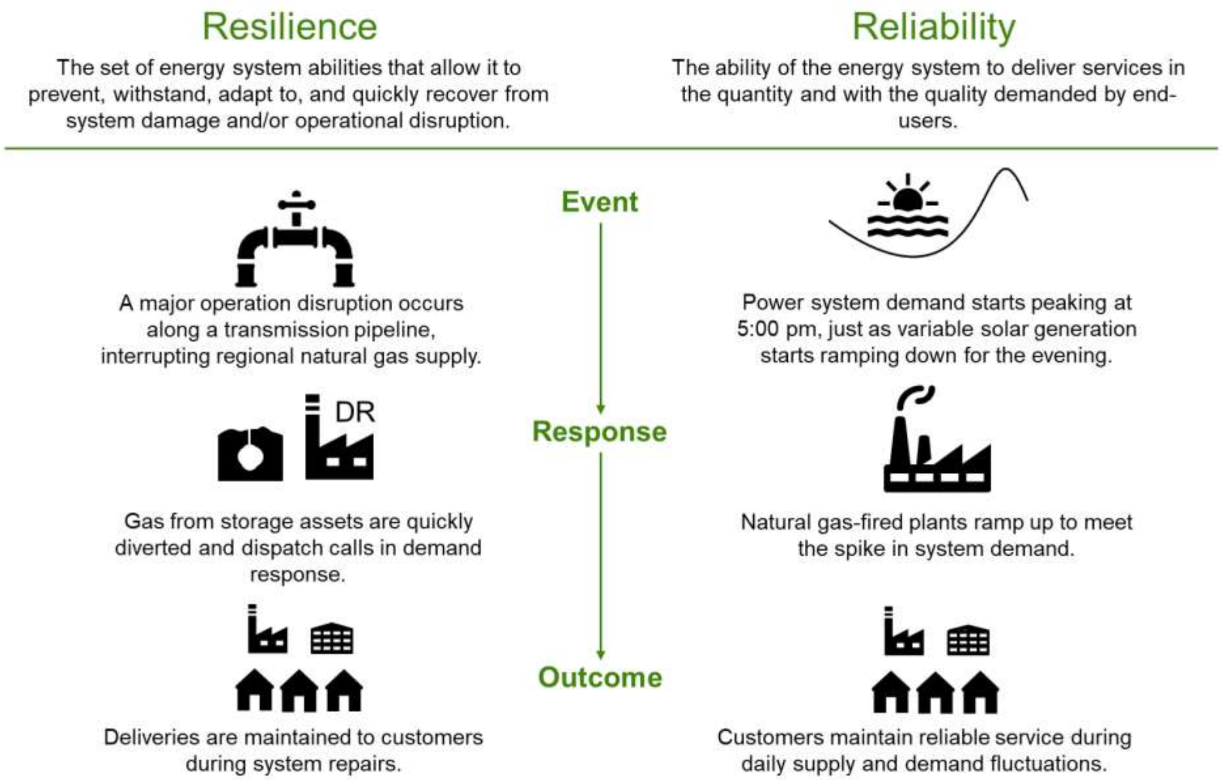
1. What characteristics of the current regulatory framework enable or disable gas resilience?
2. What recommended modifications are needed to fully enable the gas system to support energy system resilience?
3. How can resilience be valued and measured to support gas infrastructure investments? How can avoided cost analysis be used to value resilience?
4. Through what modified regulatory frameworks can the recommended changes be implemented?

Detailed recommendations for the analysis in this report are outlined in the text below and compiled in 4.Appendix A

1.1 The Importance of Resilience and Reliability

Integral to this report is the difference between reliability and resilience, a fundamental principle previously established in the BREF report and shown in Figure 1-1. **Resilience** is the ability of the energy system to prevent, withstand, adapt, and recover from a system disruption. In contrast, **reliability** focuses on the ability of the energy system to deliver services in the quantity and with the quality demanded by end-users. Resilience is attributed to high-impact, low-probability events that can create an unforeseen operational disruption, while reliability occurs during standard operating conditions, including from low-impact, high-probability events. While reliability has been central to energy regulations and frameworks for many years, increased focus on resilience is required to enable the investments necessary to address stressors and manage emerging challenges on the energy system.

Figure 1-1. Comparison of Resilience and Reliability



Source: Guidehouse

Over the past years, natural gas demand has grown broadly across geographies and market segments. According to the International Energy Agency (IEA), global natural gas demand is expected to grow at an annual rate of 1.5%[4] from 2019 to 2025. As this trend occurs, some states and localities are increasingly focused on climate change and its impact on the energy system. Such climate policies may have placed little consideration or importance on energy system resilience and the role of natural gas and the natural gas infrastructure in maintaining energy system resilience. US response to climate change should include a focus on gas system adaptation which includes resiliency enhancements to strengthen the US energy system,

Gas system resilience is essential to overall energy system resilience because:

1. Natural gas pipeline and storage infrastructure are critical in supporting energy grid resilience by reliably delivering natural gas, even during short and long-term duration needs (e.g., including extreme weather).
2. Low-carbon fuels, including natural gas, will remain a core element of the US energy system for decades to come and natural gas fuel electric generation is critical to scaling the integration of renewables.
3. Local distribution companies (LDCs) can integrate zero-carbon fuels (e.g., hydrogen) with existing natural gas infrastructure to help accelerate a long-term sustainable energy future.

[4] IEA (2020), Gas 2020, IEA, Paris https://www.iea.org/reports/gas-2020

The impacts of extreme weather events have demonstrated the necessity of significant enhancements in grid resilience across the entire value chain, including generation, transmission, and distribution, to maintain electric grid reliability. Utility-scale power generators and customers downstream of the city gate rely on the resilience of natural gas infrastructure to deliver natural gas for power generation and fuel. As a result, all stakeholders have a vested interest in ensuring investments in infrastructure that ensures energy system resilience obtain expedited regulatory approval across federal and state jurisdictions.

For energy companies to prepare for the energy system's ability to recover from and adapt to extreme weather events, resilience investments need to be publicly recognized as critical to mitigating risks associated with these events. Public recognition will enable the necessary policies at the federal and state levels, including the implementation of regulatory initiatives that permit the natural gas industry to incorporate enhanced resilience as a key element of business and infrastructure planning. In addition, it will enable the industry to develop investment programs to enhance the resilience of natural gas delivery to gas distribution customers and utility-scale power generators located upstream of the city gate.

Effective resilience solutions must be dependable, equitable, and forward-looking. The following sections will examine these design principles in greater detail.

Table 1-1. **Improving How We Measure Reliability and Resilience**[5]
As this report has emphasized, the natural gas network is part of a large, interconnected energy system. Particularly important are the interdependencies between gas and electricity. A growing number of utilities and governments agree on the need to reduce emissions economy-wide. Nearly all modeling and policy studies show that decarbonization implies much greater electrification alongside a shift to more renewable sources of electric power. What's not so clear is the right roles for gas in these future energy systems. Depending on the emission goals and other policy and commercial factors, the role for gas could expand or contract. It is common to model resilience using N-1 and N-2 conditions. For example, model the system reliability using three scenarios: 1. Model the system and assume the largest capacity resource becomes unusable – how soon does the system collapse and what does the model use to solve? 2. Model the system and assume the two largest capacity resources become unusable – how soon does the system collapse and what does the model use to solve? 3. Model the system and assume NO new generation comes in – how long until the system fails. All three can be modeled under a low, high, and peak demand forecast. This is straightforward and produces a set of outcomes that probabilities can be assigned. A key factor is reliability. There have been many studies comparing technology costs and emissions of transitions toward or away from gas. But far less is known about how such transitions may affect

[5] This detail is provided by researchers at the University of California San Diego who have been generous with their input and detail for this report; Carlton, E., Smillie, S., Bagaria, D., Hanna, R., Apt, J., Victor D.G., 2022. How well do we know the reliability-value of natural gas in a decarbonizing, decentralizing energy system?

reliability. In the absence of such information, state commissions have struggled to make and support decisions on how to properly value gas assets and the role of gas not just in today's energy system but also future systems where electric systems have become both more central to modern energy and economic systems and more dependent on variable renewables.

In a new working study, a team of researchers from UC San Diego (UCSD) and Carnegie Mellon (CMU) review the current reliability of the natural gas transmission and distribution networks. The study finds that frameworks for measuring reliability drawn from electric power, such as SAIDI and SAIFI, could be adapted in ways that would allow much more useful characterization of gas system reliability; as this report makes clear, these concepts can't be used blindly but need to be adjusted to suit the specific organization of the gas system. While there are conceptual advances that could add more value, the key problem today is data. The UCSD and CMU study finds that public documentation of gas service interruptions is too sparse and opaque to allow for more than a very coarse estimate of reliability, especially on the distribution side. This is a stark contrast with the electric system, where a history of outages has led to mandated, systematic reliability reporting across the US.

This kind of study shows the high value of collaboration between academics and industry around questions of measuring and valuing complex system traits like reliability or resilience. In the case of the UCSD and CMU study, a series of conversations with SoCalGas employees and other industry representatives helped provide important context around the data that were available publicly. The next phase of work involves using customer data to make a more comprehensive assessment of service interruption estimates—something that academics have not yet done and which requires collaborations behind a confidential NDA. Better understanding the current system is an essential condition to modeling future evolution of gas and electric infrastructures—including possible roles of gas infrastructures with non-fossil molecules—so that missions such as decarbonization can be understood in the context of reliability and affordability. With a clearer vision tradeoffs and contours of the future energy system, such work can contribute not just to better forecasting of future energy systems but also improved regulatory decisions that affect gas infrastructure investments.

1.1.1 Dependable Power

Not only do customers expect 24/7 access to resilient energy, but power outages can also give rise to health and safety concerns, particularly for vulnerable populations. Energy disruptions are more during extreme weather events and can lead to severe impacts of people and economies (e.g., Winter Storm Uri, Hurricane Ida). Winter Storm Uri resulted in 246 deaths, two-thirds of which were attributed to hypothermia.[6] Understanding the costs of Uri provides a deeper understanding of potential benefits and avoided costs of implementing a more resilient gas system which would also improve the energy system.

In response to disruptions in energy supply from extreme weather events, customers have increasingly sought alternative methods to ensure reliable and resilient energy. Customers have installed backup generators, batteries, and solar arrays to provide power in the event the power companies are unable to deliver. Generac, a manufacturer of residential standby generators, reported a 40% increase in net sales for their residential products in a presentation to investors in February 2022. Generac noted that "natural gas generators [are] driving superior growth" and their

[6] P. Svitek. January 2, 2022. "Texas puts final estimate of winter storm death toll at 246." *The Texas Tribune.*

targeted growth markets are Texas, due to demand driven by Winter Storm Uri, and California, where grid reliability has been challenged by increasing wildfires.[7]

1.1.2 Equitable Access to Power

Unlike customers who have the means and capital to invest in backup energy sources, low and middle-income (LMI) customers are often unable to purchase standby electric generation, making them disproportionally vulnerable to supply disruptions and the significant increase in the cost of energy associated with these interruptions. In addition, LMI households may be unable to pay the costs of evacuation in the event of extreme storms or recover after the disruption, let alone pay the cost of backup energy sources. Equitable access to power is an increasingly glaring issue after various hurricanes and other storms have left many LMI customers without power for weeks.

During Winter Storm Uri, underserved and LMI communities were some of the first to lose power.[8] Historically, underserved and LMI communities have been the last to be reconnected.[9] Extreme weather events have a greater impact on LMI customers compared to other customers and energy system resilience should be enhanced in these areas.

Recent efforts in quantifying and valuing resilience have attempted to capture equitable considerations. The Social Burden Method, developed by Sandia National Laboratories and the University at Buffalo (State University of NY), calculates the social burden of power outages. Other methodologies that rely on surveys tend to reflect a customer's ability to pay rather than their willingness to pay. The Social Burden Method aims to incorporate wealth disparities and the importance of a reliable energy system to human health and safety.[10] Methodologies and frameworks that aim to capture the societal cost of power outages, such as the Social Burden Method, should be utilized to value the true impact of resilience investments on LMI communities. Benefits of resilience can also be measured through calculating avoided costs.

Resilience investments and infrastructure improvements need to be equitable and available to all customers. Investing in system-wide resilience infrastructure will help to protect communities most vulnerable to the consequences of energy disruptions.

1.1.3 Forward-Looking Design

To appropriately design a resilient energy system, designers and operators also need to consider the future needs of a low-carbon system. The electric industry has come under mounting pressure to increase the share of renewable power generation in its portfolio to achieve ambitious emissions targets. Variable renewables such as solar and wind are intermittent and not dispatchable. Additional dispatchable generation is required to ensure firm energy services and maintain their reliability standards and resilience to extreme events.

In response, low-carbon fuel generation has been identified as a critical component for the energy system to decarbonize while maintaining resilience and reliability. Low-carbon fuels (e.g., RNG and

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[7] A. Jagdfeld, Y. Ragen, M. Harris, and K. Rosemann. February 2022. "Investor Presentation." *Generac.*

[8] J. Dobbins and H. Tabuchi. February 18, 2021. "Texas Blackouts Hit Minority Neighborhoods Especially Hard." *The New York Times.*

[9] S. Jessel, S. Sawyer, and D. Hernandez. December 12, 2019. "Energy, Poverty, and Health in Climate Change: A Comprehensive Review of an Emerging Literature." *Frontiers in Public Health.*

[10] Wilson Rickerson, Kiera Zitelman, and Kelsey Jones. February 2022. "Valuing Resilience for Microgirds: Challenges, innovative Approaches, and State Needs." *National Association of Regulatory Utility Commissioners and the National Association of State Energy Officials.*

hydrogen) and natural gas facilities with carbon capture, utilization, and storage (CCUS) have been identified by the International Energy Agency as a solution to ensuring energy security while simultaneously cutting emissions.[11] Specifically, it should be noted that the natural gas industry can reduce/eliminate, capture, and sequester the GHG emissions associated with the production, gathering, processing, and transport of natural gas. In addition, the production of LNG can be substantially decarbonized today using post-combustion capture and geologic sequestration of CO2. In the US CCUS is supported by Section 45Q federal tax credits. Proposed revisions to Section 45Q will expand the feasibility of CCUS to a larger number of natural gas facilities including combined cycle power plants.

Further, existing natural gas infrastructure can be levered to deliver a range of low-carbon fuels such as hydrogen and renewable natural gas. As a result, the natural gas industry is well positioned to be a significant component of the low carbon energy economy and important investments in natural gas system resiliency will carry the energy system forward for decades to come.

Industry studies have supported the role of gas and its infrastructure in a low-carbon energy future. A recent 2019 study by Gas for Climate, a group of ten leading European gas transport companies and two renewable gas industry associations, analyzed the most cost-optimal path to fully decarbonize the EU energy industry by 2050. This work indicated that the pipelines used in the gas transmission and distribution networks could be re-purposed or otherwise utilized to transmit and distribute hydrogen and renewable methane. The main conclusion of the study was that dispatchable energy generated with gas or hydrogen, is required to meet low-carbon resource goals, and complement the growth in solar PV and wind. In addition, the use of gas through gas infrastructure offered billions in annual savings by 2050 throughout the energy system. In a 2020 follow-up study, the analysis demonstrated the use of dispatchable energy (e.g., gas, hydrogen) enabled increased opportunities for developers to implement intermittent renewables, especially in areas where renewables are unable to meet the full energy demand of the communities they serve.[12] Existing gas infrastructure in the EU will make the energy system more flexible and resilient by providing transportation and storage capacity for renewable energy in the form of hydrogen, ammonia, or other hydrogen carriers.

1.2 The Impact of Extreme Weather Events on the Energy System

The electric and gas energy systems have provided reliable energy supply to customers across the US. Increased frequency and severity of extreme weather events have revealed weaknesses of the energy system –production and delivery have been hampered by extreme events. Significant damage and system disruptions are becoming more of a norm. In 2021, 20 extreme weather events affected the US with losses exceeding $1 billion each, with total losses from all events reaching $145 billion.[13] As seen in Figure 1-2, these extreme weather events included severe storms, tornados, hurricanes, flooding, wildfires, and winter storms, all of which had a different impact on energy infrastructure. The frequency of extreme events with over $1 billion in damage has been growing at a compounded annual growth rate (CAGR) of 4.98% over the decades since1980 as shown in Figure 1-3. As the frequency and severity of each event grow, the political sensitivity to the impacts of severe weather events has risen and regulators have placed a higher

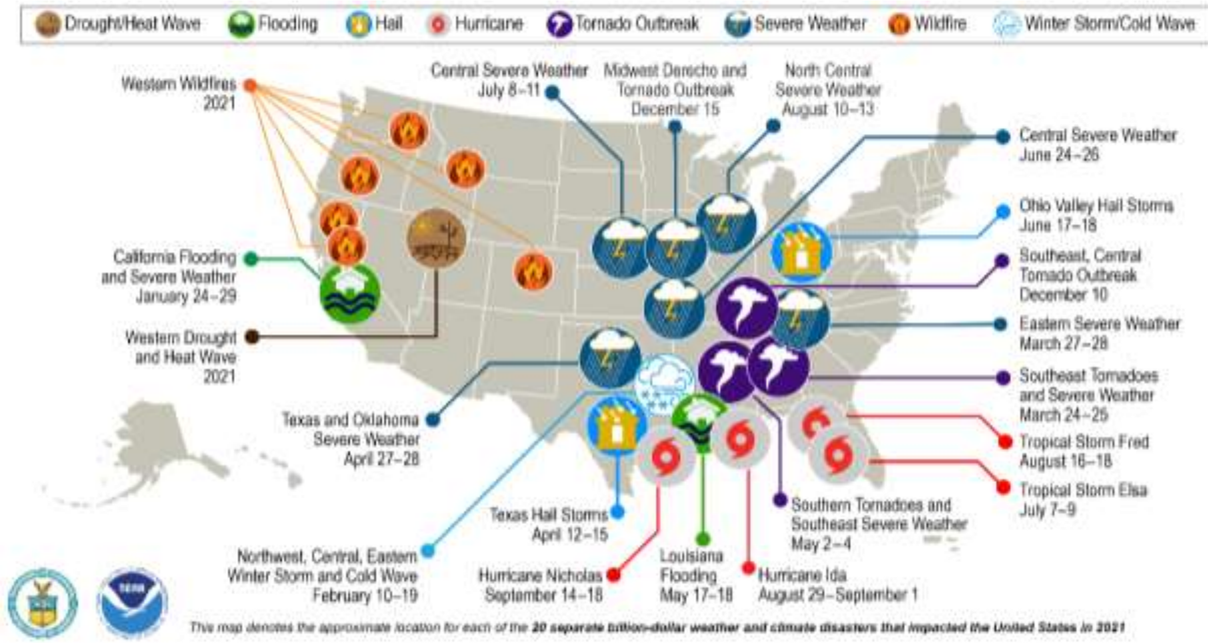
[11] IEA. October 2021. "The Role of Low-Carbon Fuels in the Clean Energy Transitions of the Power Sector." *International Energy Agency.*

[12] Guidehouse. May 2020. "Gas Decarbonization Pathways 2020-2050." *Gas for Climate.*

[13] NOAA National Centers for Environmental Information (NCEI). 2022. "U.S. Billion-Dollar Weather and Climate Disasters." *NOAA.*

priority on enhancing energy system resilience. However, the challenge is to translate this "sensitivity" into tangible regulatory constructs which support LDC investments.

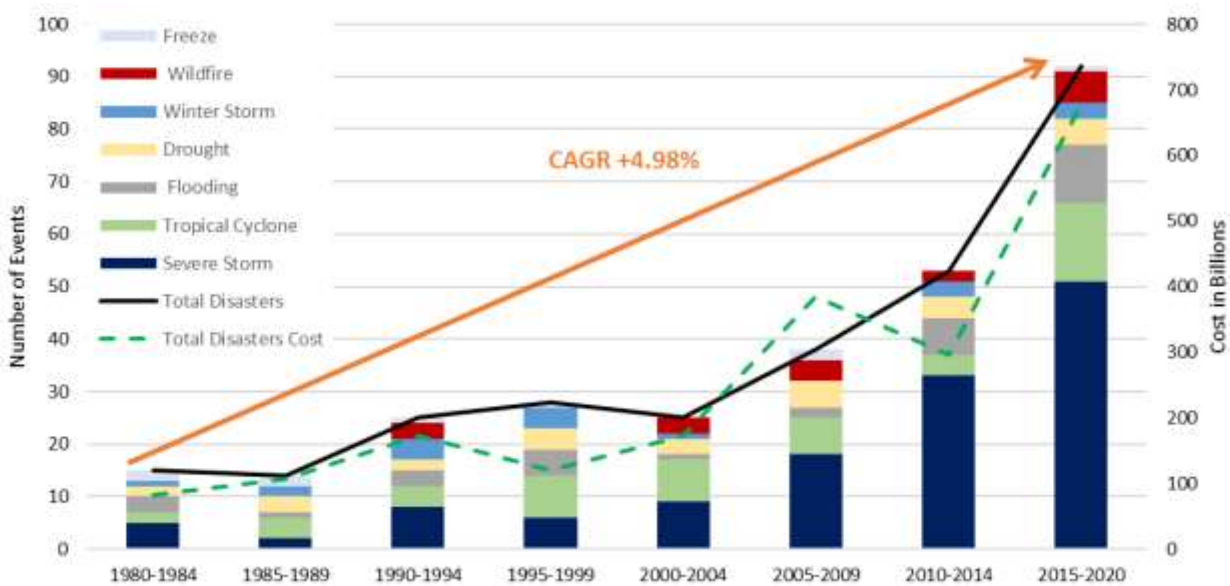
Figure 1-2. US 2021 Billion-Dollar Weather and Climate Disasters



Source: NOAA National Centers for Environmental Information (NCEI)

Figure 1-3 shows growth of weather and climate-related costs by decades.

Figure 1-3. Growth of U.S. Billion-Dollar Weather and Climate Disasters



Source: NOAA National Centers for Environmental Information (NCEI); Dollars are shown in nominal values over time.

There are recent findings from the IPCC Sixth Assessment Report[14] which indicate that weather events, i.e., forest fires and hurricanes, may increase in frequency and severity. Weather events have become more severe and have left millions of people without power and have threatened their health and safety since energy systems collapsed for long periods. In addition to aging energy infrastructure, these events have exposed vulnerabilities in the energy system's ability to respond to and recover from natural disasters. Energy system resilience, including anticipating and preparing for extreme weather events, is essential to reduce overall system risk and to safeguard the energy system from extreme weather events. Recent events have intensified calls for increased gas system resilience, such as:

1. Winter Storm Uri (February 2021), a storm that impacted states such as Texas, resulted in approximately $10 billion in economic losses to investor-owned utilities.[15]
2. Hurricane Ida (August 2021) caused Entergy Corp 948,000 outages and nearly $2.6 billion in restoration costs.[16]
3. California wildfires cost PG&E an estimated $20 billion between 2017-18.[17] PG&E announced a plan to bury 10% of their distribution and transmission lines in 2021, at an additional $15-30 billion, to mitigate future wildfire risks.[18]
4. 2019 Polar Vortex, a severe winter storm that impacted most of the US, resulted in estimated permanent losses of about $5 billion.[19]

The BREF report described several additional extreme weather case studies, including the 2019 Polar Vortex, the 2014 Polar Vortex, 2020 Hurricane Isaias, and the 2020 season of heat, drought, and wildfires. The case studies illustrate how the gas system and its resilience assets have supported the overall integrity of the energy system during these high stress periods. Addressing resilience in response to these type of events can identify the benefits of avoiding costs related to such events going forward.

More recently, Winter Storm Uri revealed that the absence of certain resilient assets, standards that require evolution, and future investments (e.g., proper winter weatherization) would have mitigated some energy system performance issues during extreme winter conditions. Uri was a record-setting winter storm that particularly impacted Texas in mid-February 2021 and caused ERCOT (Electric Reliability Council of Texas)[20] to lose nearly half its available generating capacity over two days due to two causes: generating units were unprepared and a decline in the production

[14] Working Group II. March 2022. "Climate Change 2022: Impacts, Adaptation and Vulnerability." *Intergovernmental Panel on Climate Change (IPCC)*

[15] Justin Horwath. May 19, 2021. "February storm caused over $10B in losses for investor-owned power companies." *S&P Global Market Intelligence.*

[16] Reuters Staff. September 21, 2021. "Entergy estimates repair costs of up to $2.6 billion from Hurricane Ida." *Reuters.*

[17] Associated Press. November 7, 2019. "PG&E falls deeper into the hole as wildfire costs grow." *Los Angeles Times*.

[18] The Associated Press. July 21, 2021. "PG&E Will Bury 10,000 Miles of Power Lines So They Don't Spark Wildfires." *NPR*.

[19] John Roach. July 8, 2019. "Polar vortex's bitter cold could cost US economy $5 billion, though the worst may be over." *AccuWeather.*

[20] Electric Reliability Council of Texas, Inc. is an American organization that operates Texas's electrical grid, the Texas Transmission Interconnection wires, which supplies power to more than 25 million Texas customers and represents 90 percent of the state's electric load.

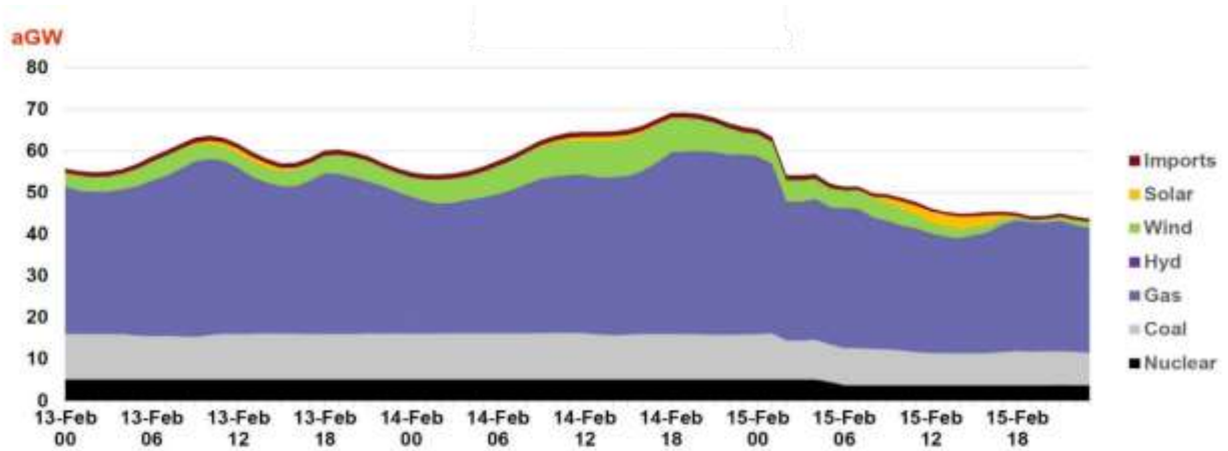
and processing facilities .[21] While the electric gas systems are different and regulated differently, ERCOT is responsible for system reliability in Texas and the Texas Reliability Entity, Inc. serves as the regional entity that enforces NERC's reliability standards in the region.

The interdependence of the electric and gas systems created outages that cascaded into instability and power losses. Load-shedding requirement were issued by independent system operators (ISO) which impacted many electric-driven equipment that supported natural gas supply, which only further crippled the system, and caused additional power outages that could have been prevented.

Figure 1-4 shows the reliance of ERCOT on natural gas for generation during the winter storm event, despite cascading infrastructure and generation failures. Primarily due to the lack of weatherization, the largest declines in ERCOT generation were due to gas-fired unit failures. However, even as the electric grid was stressed from unprecedented demand and generation forced outages, natural gas continued to be the major contributor to electric generation. As a result of Storm Uri sufficient data has now been collected to identify energy system vulnerabilities and associated remedies. However,

If the role of natural gas in the resilience of the electric system were better understood, additional investments could have been warranted to weatherize the assets that failed, lessening the number of failures, reducing the number of customers who lost power, and dramatically shortening the restoration time for those who did lose power.

Figure 1-4. ERCOT Hourly Generation During Winter Storm Uri



Source: S&P Global Platts Analytics, ERCOT

Extreme weather events have shown the value and necessity of a resilient gas system and the inextricable linkage between fuel delivery and the supply of electricity. Research conducted by S&P Global, EIA, NERC, FERC, and other research institutes after extreme weather events have

[21] Federal Energy Regulatory Commission, North American Electric Reliability Corporation, and Regional Entities Staff. November 16, 2021. "The February 2021 cold weather outages in Texas and South Central United States: FERC, NERC and Regional Entity Staff Report." *Federal Energy Regulatory Commission*.

identified a set of common causes for interruptions in energy supply and the ability to recover from high-impact, low-probability events, including:

- The regulation of pipeline and storage infrastructure is separated from electric generation and storage. The asset mix required to provide the resilient service of fuel supply to electric generation is an integrated energy system issue.
- The failure of components across the energy value chain (e.g., well-head equipment, gathering systems, and processing and storage facilities) occurred because they were not designed to address the increasing frequency and intensity of extreme weather events (e.g., sub-freezing temperatures throughout Texas during Winter Storm Uri).
- There is a lack of integrated operational awareness between operators of natural gas infrastructure (e.g., pipelines and storage infrastructure) and electric operators (e.g., ISOs and electric utilities). For example, during Winter Storm Uri, necessary equipment for fuel delivery was shut down due to decisions made by ISOs and electric utilities.
- There is no direct price signal to incentivize resilience specific investments for the integrated system. Today, investments are targeted for reliability improvements for either the gas system or electric system, but not resilience from one system to the other.

1.3 Orientation of this Report

The remaining content in this report is separated into three sections.

- *Section 2 The Current State of Resilience* describes how resilience is embedded within markets and regulations, including the interdependence between gas and electric systems.
- *Section 3 Methods to Increase Gas System Resilience* details the key recommendations that may be taken to improve resilience, how to value resilience, and the methods to implement resilience.
- *Section 4 Conclusions* outlines the steps to implement the findings in this report and how they can be used by utilities and regulators.

2. The Current State of Resilience

This section analyzes the current regulatory approach, market response, and interdependency of the natural gas and electric industries and their relationship to resilience. In addition, international case studies are presented to understand how gas resilience is approached in other jurisdictions. AGF and its researcher, Guidehouse, approached analysis of this topic and determined that regulator interviews were needed to gather the current state of affairs and market view of resilience. The following approach and method were used for the interviews:

- AGF and Guidehouse focused on state regulatory commissioners (Commissioners) across the US engaged with AGF and AGF staff.
- States were chosen based on level of gas use and current engagement on the changing energy system landscape.
- Interview focus was also undertaken on states and commissioners involved with a separate AGF resiliency report analysis.
- Interviews were pursued with a focus on regulatory frameworks and policies and specific state commission resiliency efforts.

2.1.1 Overview of Resilience Frameworks

Currently, there is a lack of robust and standardized resilience frameworks applicable to the natural gas industry, which has led to gas resilience assets being undervalued. Current efforts to value natural gas resilience assets have largely fallen short because they either rely too heavily on reliability standards or focus exclusively on the electric industry. For example, many regulators utilize several indices, such as CAIDI (Customer Average Interruption Duration Index), SAIDI (System Average Interruption Duration Index), and SAIFI (System Average Interruption Frequency Index) to determine the reliability of an energy system. However, reliability indices are often inadequate as resilience metrics because:

1. They focus on normal operating conditions and often undervalue the impact of high-impact, low-probability events.
2. In these models, lost load is priced at a flat rate when the value of lost load compounds over time.
3. Including major events in SAIDI and SAIFI calculations complicates the results and skews the data, as restoration costs are much higher and they inflict longer-term service interruptions, so almost half of utilities exclude them.[22]

Numerous non-governmental organizations (NGOs) and governmental entities have sponsored work to establish a value for resilience assets, though these efforts have largely concentrated on the electric industry. The National Renewable Energy Laboratory conducted several studies of resilience metrics and methodologies. Their initial 2019 report stated that integrating the value of resilience into investment and operation decisions was "challenging due to the context-specific and diffuse nature of benefits, the difficulty of obtaining the data required to accurately determine the

[22] Miles Keogh and Christina Cody. November 2013. "Resilience in Regulated Utilities." Pg. 7. *The National Association of Regulatory Utility Commissioners.*

benefits associated with a given investment, and the lack of universally accepted resilience metrics and analysis approaches."[23] These findings were later confirmed in a 2020 study that found existing tools are currently unable to accurately capture the value of resilience.[24] Despite the challenges, the metrics and analyses studied were specific to the electric system and lacked applicability to the gas system.

In 2019, NARUC published a report that identified methods for valuing resilience based on a bottom-up approach methodology that analyzed the avoided costs associated with disruptions in electric supply.[25] In a follow-up report published in 2022, NARUC identified several specific methodologies to quantify these avoided costs:

- **Interruption Cost Estimator (ICE):** ICE was developed by the Department of Energy (DOE) in 2011 to aid electric reliability planners in estimating interruption costs and benefits for infrastructure investments. ICE utilizes CAIDI, SAIDI, and SAIFI in its calculations and does not differentiate the value of lost kilowatt-hours over time, which may undervalue the economic damage of large outages and make it an inaccurate calculation for resilience investments.[26] A second iteration of ICE is projected to be released in 2023.[27]

- **Customer Damage Function (CDF) Calculator Tool:[28]** The CDF Calculator was developed by the National Renewable Energy Laboratory to help facilities understand the costs incurred at their sites as a result to an electric grid outage. The results help estimate the avoided costs associated with resilience investments. While helpful, the analysis is specific to the electric industry and facility-specific instead of a portfolio-wide analysis.

- **Power Outage Economics Tool (POET):[29]** POET, which was developed by ComEd and Lawrence Berkely National Laboratory, surveys customers within ComEd's service territory to assess the costs faced by customers during longer-duration power outages. The results will be used to develop a model that estimates the direct and indirect costs of power outages and utilize them to justify investments that avoid these added costs. However, the model is region-specific (focuses on ComEd's service territory), specific to the electric industry, and the survey-based results will become outdated quickly, making it an unreliable model to apply to a country-wide system.

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[23] September 2019. "Valuing Resilience in Electricity Systems." *National Renewable Energy Laboratory.*

[24] C. Murphy, E. Hotchkiss, K. Anderson, C. Barrows, S. Cohen, S. Dalvi, N. Laws, J. Maguire, G. Stephen, and E. Wilson. February 2020. "Adapting Existing Energy Planning, Simulation, and Operational Models for Resilience Analysis." *National Renewable Energy Laboratory.*

[25] Converge Strategies. April 2019. "The Value of Resilience for Distributed Energy Resources: An Overview of Current Analytical Practices." *National Association of Regulatory Utility Commissioners*

[26] Miles Keogh and Christina Cody. November 2013. "Resilience in Regulated Utilities." Pgs. 6-7. *The National Association of Regulatory Utility Commissioners.*

[27] Wilson Rickerson, Kiera Zitelman, and Kelsey Jones. February 2022. "Valuing Resilience for Microgirds: Challenges, innovative Approaches, and State Needs." *National Association of Regulatory Utility Commissioners and the National Association of State Energy Officials.*

[28] 2021. "Customer Damage Function Calculator." *National Renewable Energy Laboratory.*

[29] Wilson Rickerson, Kiera Zitelman, and Kelsey Jones. February 2022. "Valuing Resilience for Microgirds: Challenges, innovative Approaches, and State Needs." *National Association of Regulatory Utility Commissioners and the National Association of State Energy Officials.*

In addition, there has been considerable work on economy wide approaches, including the Social Burden Method introduced in Section 1.1, and hybrid approaches based upon a developed understanding of regional economic impacts associated with power supply interruptions.[30]

In many cases, these models fail to provide meaningful resilience valuations for the pipeline industry because they fail in their inherent applicability to gas investments and infrastructure. Whereas the resilience of the electric system is relatively exclusive to that industry, the resilience of the gas system contributes to both the gas and electric systems. In the electric industry, reliability or resilience metrics are typically reported simultaneously for all distribution and transmission-connected customers. This approach is not applicable to the natural gas industry because the metrics lack resolution by customer class and type of supply contract (e.g., firm, or interruptible).

Recommendation: To solve these issues, the models should take into consideration the gas industry's contributions to and interdependence with the electric industry and broaden their applicability to the gas industry.

2.2 Regulator Interviews on Approaches to Natural Gas Resilience

Public utility regulatory agency Commissioners across the US and Canada were interviewed by the research team to identify frameworks, policies, and guiding principles that focus on natural gas resiliency "projects" are discussed below in general terms to identify local and state efforts to improve gas system resiliency. State regulatory agencies and their Commissioners central responsibilities are to review and approve various short- and long-term natural gas asset development project proposals and related policies to ensure affordable and ongoing services are provided to customers by utilities.

The findings from the BREF report are validated through the Commissioner interviews, namely:

1. There are very few regulatory initiatives that specifically address gas system resilience at the state level; and
2. Resilience is often indirectly referenced and embedded within reliability and safety standards, and programs and/or gas infrastructure programs to upgrade old pipe, but resilience is not central to system upgrades or improvements on commission agendas.

Interviews and research could not identify an example where resilience was explicitly used to justify large investments in the US, even in the light of extreme weather events. Despite the awareness of many Commissioners of this need, resilience projects are not viewed as standard, approvable projects because they are more expensive and often do not meet "lower-cost" criteria. Commissioners mentioned there was no concrete methodology or technique to properly value resilience, as resilience is still considered an aspect of reliability. They also stated that resilience projects are difficult to gain approval since conventional ratemaking is based on a cost-benefit analysis and that analysis typically reveals a negative cost-benefit result. Also, the analysis leads to the potential of disallowing resilience assets into the rate base.

a. Many of the Commissioners confirmed that the regulatory "used and useful" standard is relevant to the resilience discussion since utilities typically have trouble recovering the costs and earning a return for resilience asset upgrades. The regulatory asset used and

[30] Wilson Rickerson, Kiera Zitelman, and Kelsey Jones. February 2022. "Valuing Resilience for Microgirds: Challenges, innovative Approaches, and State Needs." *National Association of Regulatory Utility Commissioners and the National Association of State Energy Officials.*

useful standard is a regulatory tool used to determine whether an asset should or should not be placed into a utility's rate base for cost recovery and return on that investment. Once in rate base, consumers pay for an asset that is determined by a commission to be used and useful to the system and consumers. This is standard regulatory practice across the states.[31] Used and useful is employed by regulators and commissions across the country to evaluate and approve new asset investments.[32] Approved resilience costs should be allowed in rate base aligned as a separate item on customer bills for clear designation of those funds.

Resilience projects are typically excluded from a used and useful evaluation, as these projects may not be stand-alone assets. System improvements or upgrades need to be supported by a benefit-cost or similar analysis. Such traditional analysis can be challenging since resiliency projects tend to be high cost and only offer benefits during high-impact, low-probability events (e.g., the benefits occur infrequently, but at significant cost during extreme weather). In circumstances where a high-impact event doesn't occur over the life of the asset, the asset may never be used.

Recommendation: Commissions should consider exploring methodologies that look beyond used and useful analysis to understand the value of gas resilience projects to the energy system - relying on standard regulatory criteria may not cover the future benefits of resiliency or weather-related system improvements. Considerations for commissions include:

- Proper measurements of the potential benefits resilient assets provide to the gas system and to the energy system during low frequency-high impact events, need to be incorporated going forward.
- Standards for including large impact, low-probability events in used, and useful gas system analysis are needed to allow for system upgrades for direct or indirect resilience benefits to be properly evaluated and integrated into the rate base.
- Evolve used and useful analysis that focuses on "normal conditions" and would also add a "resilience" value to the analysis for extreme conditions.

State commissions have approved some resilience project investments, which mainly include the replacement of old pipelines. Because pipelines have a ~70-year useful lifespan, utilities can spread the cost over a long period of time, avoiding a price spike and ensuring gas continues to be affordable for customers Table 2-1. While these approvals do not currently include many large infrastructure investments, they show willingness by the Commissioners to approve some types of resilience projects and invest in projects with lifespans of decades (Table 2-2). These regulations provide a potential avenue to propose and gain approval for larger resilience-based infrastructure projects. For example, an opportunity exists for utilities to rate base interconnection costs associated with gas services that are required to deploy resilience or distributed assets and microgrids for critical facilities (i.e., community centers, hospitals, water utilities, data centers, grocery stores, or facilities requiring continuity for key community services).

[31] See *Smith v. Ames,* 171 U.S. 361 (1898) - US Supreme Court voided a Nebraska railroad tariff law, declaring that it violated the 14th Amendment's due process clause and established the concept of used and usefulness of properly.

[32] There is no standard definition for "used and useful" across jurisdictions, but generally refers to assets that are in use and are adequately designed to provide safe, reliable utility service to consumers. Of note, resilience is rarely, if ever, a part of the used and useful discussion.

Table 2-1. **Example 1: Pathways for Resilience Investment Approvals**
Maryland STRIDE: The Strategic Infrastructure Development and Enhancement Plan (STRIDE) program authorizes the accelerated replacement of targeted pipelines throughout its Maryland service territory. Specifically, the program has allowed for the replacement of old and leaking pipelines that presented safety, reliability, and resilience concerns. However, the project was largely pitched around safety, rather than long-term resilience. Pipe replacements cover numerous concerns, including resilience and reliability. The law allows the Public Service Commission (PSC) to approve mechanisms that allow gas distribution utilities to recover the costs associated with certain infrastructure replacement projects. These recovered costs are expedited, though subject to a monetary cap. In 2019, the PSC adopted rules which allowed utilities to implement multi-year rate plans that incorporate forward-looking test years. While the project centered around safety considerations, the STRIDE program is an example of a resilience project approval and demonstrates how a utility could communicate the prudence of a resilience investment.

Table 2-2. **Example 2: Illinois Qualifying Infrastructure Plant Rider**
220 ILC 5/9-220.3: The Illinois Public Utilities Act includes a provision (Section 9-220.3) that acts as a recovery mechanism for natural gas utilities to support "modernization investments", including the replacement of "transmission pipelines and associated facilities identified as having a higher risk of leakage or failure."[33] Within this, utilities may make investments to replace outdated infrastructure and enable cost recovery without the expense of filing a rate case. While resilience is not specifically used in the language, the Illinois Commerce Commission has seen utilities make investments under this plan that are necessary and related to resilience.

From the interviews, Commissioners indicated that they may be more willing to approve large resilience investments in the future as several states including Illinois, Massachusetts, and Washington increase research into natural gas resilience and its role in a low-carbon future. Key findings from the interviews with Commissioners on the potential pathway for resilience approvals include:

1. **Gas utilities can leverage and identify the inherent safety benefits of resilience projects to improve regulatory support.**

    a. Projects such as the Maryland STRIDE program (see Example 1) were approved primarily on safety considerations, even though these gas projects contain inherent resilience benefits.

    b. Commissions generally see increased avenues for the approval of resilience-focused gas projects if their business case highlights the project's impact on the safety of the customer and the broader energy system.

[33] "Public Act 098-0057." *Illinois General Assembly*

2. **Utilities should emphasize how resilience projects can support emission reductions and the increased integration of renewables**.

To increase support among commissions, resiliency projects should incorporate low-carbon resource features. As examples, new gas distribution infrastructure primarily for support gas supply to DERs can designed to be hydrogen capable or LNG peaking plants can be powered with decarbonized electrons derived from CCUS equipped natural gas combined cycle power plants.

3. **Resilience projects require support from the public and environmental stakeholders.**

Support for natural gas as a vehicle for carbon emissions reduction has eroded as environmental activists have adopted an elimination of fossil fuels mantra. For the natural gas industry to remain relevant in the future low carbon energy industry it will need to establish that it has a critical role to play in managing the implementing the transition, including providing resilience support to the electric grid.

While the current regulatory constructs do not prioritize or explicitly support resilience investments, there are paths forward to improve the regulatory environment. Commissioners often try to balance the need for investments to address climate change while ensuring service to customers is reliable, resilient, adequate, safe, and equitable. While there can be friction between these principles, regulators and utilities have been successful in balancing these factors while providing service to customers at a reasonable cost. Movement within the regulatory space indicates an increase attention on resilience in the broader energy system, though utilities should work to improve the business case for resilience assets.

Recommendation: When seeking approval for resilience infrastructure investments and stakeholder support, utilities should emphasize the investment's use to ensure safety and the future integration of renewables.

2.3 Market Response

Extreme weather events have caused widespread power outages and led to dramatic increases in natural gas demand as natural gas has become the dominant fuel for both utility scale electric generation and DERs, including standby, Behind the Meter (BTM) generation. In the case of severe cold conditions that were not forecasted, gas utilities often experienced aggregated gas demand that was higher than peak-demand forecasts – this forced utilities to limit or interrupt supply to some customers. Interruptible customers were cut off plus other standard customers. For example, during Winter Storm Uri gas utilities were forced to interrupt supply to firm industrial and commercial customers to maintain supply to residential and critical customers (e.g., hospitals, first responders, schools, and other government facilities). Demand exceeded forecasted extreme weather events. The rise in energy service disruptions for customers has caused many to take resilience into their own hands by installing distributed energy resources (DERs) including standby generators, further increasing the demand for natural gas during extreme weather conditions.

As noted, market demand for standby generators has soared over the past few years due to storm-induced outages and the requirement by customers for dependable electricity, as noted in Section 1.1, Generac saw increased net sales of 122.5% from 2017 to 2021, largely due to a rise in demand for home standby generators and commercial and industrial products.[34] However, the installation of these backup power generation sources exacerbates the impacts of extreme weather

[34] April 29, 2021. "Generac Reports Record First Quarter 2021 Results." *Generac*.

events on the gas system because backup generation increases demand for a limited supply of gas during electric supply interruptions. Current utility planning processes are not designed to assess the impacts of these installations, as these spikes in demand are likely to occur more often and reach higher levels than forecasted peak-demand planning assumptions. In certain cases, growing gas-powered DERs are likely to be concentrated in certain industrial, commercial, and high-end residential sectors, which may be make it more difficult to forecast increases in demand from such high impact climate events.

Recommendation: Utility planning needs to account for the increased use of backup generators and DERS on forecasted demand assumptions to adequately prepare for peak-demand scenarios, such as during high-impact, low-probability events. This increase in gas supply may require expansion of existing gas distribution infrastructure as well as additional sources of gas supply, including behind city gate storage and alternative fuels to meet peak demand.

Table 2-3. Example 3: Market Response – Enchanted Rock Case Study
Enchanted Rock is a leading microgrid developer with over 500 MW of operational microgrid capacity in 2022 and significant growth across the country. Enchanted Rock provides resiliency-as-a-service to large commercial, industrial, and institutional customers utilizing an ultra-clean, natural-gas fired reciprocating engine to power a microgrid, which can provide local resilience for customers in the event of a grid outage and dispatchable, fast ramping grid services in support of conditions that may arise due to natural disasters or surges in demand. Using renewable natural gas offsets, Enchanted Rock can provide fully decarbonized resiliency solutions for long duration outage protection, including most recently for a large data center in northern California. During Texas' Winter Storm Uri, Enchanted Rock's microgrid fleet provided local resiliency services at 143 sites experiencing grid outages as long as 100 consecutive hours, including at grocery stores, assisted living facilities, manufacturers, and water utilities. During the storm Enchanted Rock powered H-E-B stores, a local grocery chain, so they could supply critical supplies and serve as ad hoc community centers despite the widespread outages.[35] The impact was so profound that the chain's ability to operate through the storm was highlighted in a NY Times article.[36] At other sites, Enchanted Rock's microgrids operated throughout the 8-day event to provide grid support services. Even while traditional thermal generation experienced major forced outages, Enchanted Rock's technology was able to support full load operations utilizing LDC gas at pressures down to 5 psi. Distributed Energy Resources (DERs), such as Enchanted Rock microgrids, enable a clean, diversified electrical resiliency strategy by improving local air quality through the displacement of diesel backup generation solutions, reducing GHG emissions through the use of renewable fuels, and deploying dispatchable capacity resources that can help the grid accommodate more intermittent renewable resources cost-effectively.

[35] February 2022. "Did your Texas energy business change after Winter Storm Uri?" *Power Grid International.* <https://www.power-grid.com/distributech/did-your-texas-energy-business-change-after-winter-storm-uri/>

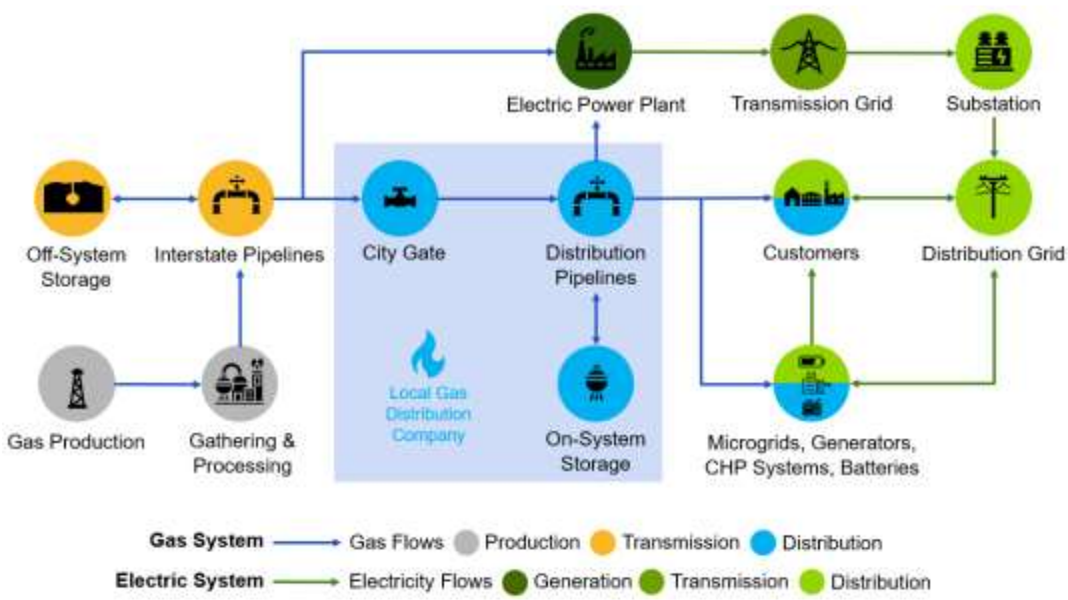
[36] February 22, 2021. "How H-E-B Helped Texans After the Winter Storm." *The New York Times*. <https://www.nytimes.com/2021/02/22/us/texas-heb-winter-storm.html>

2.4 Impacts on the Energy System

Extreme events impacting the natural gas system directly affect the broader energy system. There is sufficient evidence to support immediate resilience planning and investments to mitigate against the impact of extreme weather events, specifically where these impacts occur at the nexus of electric and gas infrastructure. Gas resilience is key to overall energy system resilience due to the increased interconnectivity and reliance on gas during extreme operating conditions (e.g., high-impact, low-probability events).

Natural gas serves the energy system by supplying base load generation for electric systems because of standardized gas plant construction and economical natural gas supplies. The two systems are growing increasingly coupled as natural gas is used to power electric natural gas turbines for baseload electricity production and electricity has been used to power natural gas equipment for onsite commercial and industrial equipment operations. If pumps that extract fossil fuels are powered through electricity, the gas production system can fail when power outages occur. Within the gas transmission section, compressor stations are a key component to help maintain the pressure and flow of gas to the market. In some regions, a lack of coordination between the electric and gas systems can create issues in ensuring electric supply to critical natural gas infrastructure.[37] In addition, a recommendation to require upstream natural gas suppliers and transporters to mitigate electric power outage risks with gas-fired backup power or microgrids at electric compressor stations may be warranted. Figure 2-1 shows the interdependence of the natural gas and electric energy systems and their linkage across production, transmission, and distribution.

Figure 2-1. Interdependencies Between the Gas and Electric Systems



Source: Guidehouse

Elements of gas transmission and local distribution are inherently more resilient than the electric transmission and distribution systems, as underground pipelines are better insulated from extreme weather events than overhead power lines. Transmission and distribution systems can be affected

[37] April 2015. "Quadrennial Energy Review: Energy Transmission, Storage, and Distribution Infrastructure." *US Department of Energy.*

by extreme cold; this was witnessed with Uri where natural gas system related disruptions and well-freeze offs and power outages occurred. Energy outages can occur from damaged wires and outages that impact transformers, switch gear, and other engineered equipment that manages or controls the electric grid. However, some above ground natural gas infrastructure faces the same challenges with extreme weather events as the electric system. Infrastructure not built to withstand extreme weather scenarios can result in forced outages of natural gas infrastructure, as seen during Winter Storm Uri. The lack of similar regulation between the two systems further exposes the bulk power system to vulnerabilities from high-impact, low-likelihood events.

Recommendation: To generate support for increased resilience investments and beneficial regulations, LDCs should consider collecting location and event-specific data that details the impact of extreme weather on their distribution network and capabilities. This would include, among other data, infrastructure failure rates, procedural utility flaws and costs associated with outages and system rebuilds.

In recent years, pressure has mounted to decarbonize electric generation production and electrify heating and transportation. While some have argued the reliance on the gas system should decline in tandem, the value of natural gas and low-carbon fuels in the system becomes even more imperative as more renewables are added to the system. Gas infrastructure will also support a vital role in reducing emissions and supporting lower-carbon fuels, such as hydrogen and renewable natural gas in the energy system.

2.5 Current Policies and Regulations for the Electric System

There is increasing interdependence of the natural gas and electric systems as seen with increasing use of gas for electricity generation, this study includes an in-depth review of the current regulatory structure for the electric industry, particularly the Reliability Standards established by the National Electric Reliability Council (NERC). These standards outline the specific requirements for operators to ensure reliable energy delivery and are analyzed to determine the applicability and inclusion of the gas system.

While the NERC standards incorporate resilience aspects into reliability standards and frameworks[38], they do not adequately reflect resilience needs or support new resilience investments for the bulk energy system. NERC standards were developed with a focus on reliability without a strong emphasis on resiliency. Increased calls for resilience from the federal government have resulted in renewed inquiries into resilience frameworks, but NERC concluded that the existing reliability framework adequately incorporates resilience and does not require additional or specialized regulation.[39] In addition, a 2010 National Infrastructure Advisory Council (NIAC) study on electric industry resilience seemingly dismissed the need for any specific resilience initiatives by observing:

[38] NERC standards: https://www.nerc.com/FilingsOrders/us/NERC%20Filings%20to%20FERC%20DL/Regulatory%20Directives%20Report%202020.pdf

[39] November 8, 2018. "Reliability Issues Steering Committee Report on Resilience." *North American Electric Reliability Corporation.*

"Although we found hundreds of examples of how power utilities mitigate risks in day-to-day operations, many of the practices are so ingrained in the operations and culture of the utility industry that many within the industry do not label them as resilience, and many outside the industry are unaware of the extensive resources expended to minimize all-hazard risks."[40]

Nine Key NERC standards are detailed here in a summary table:[41]

Table 2-4. Example Standards

	Resilience Phase			
NERC Electric Reliability Standards	Prepare	Withstand	Recover	Adapt
(BAL) Resource and Demand Balancing (43)	x	x	x	
(CIP) Critical Infrastructure Protection (95)	x		x	
(COM) Communications (12)	x			
(EOP) Emergency Preparedness and Operations (36)	x	x	x	
(FAC) Facilities Design, Connections, and Maintenance (38)	x			
(INT) Interchange Scheduling and Coordination (35)	x			
(IRO) Interconnection Reliability Operations and Coordination (61)	x	x	x	x
(MOD) Modeling, Data, and Analysis (55)	x			x
(NUC) Nuclear (6)	-			
(PER) Personnel Performance, Training, and Qualifications (13)	x			
(PRC) Protection and Control (99)	x	x	x	x
(TOP) Transmission Operations (44)	x	x		
(TPL) Transmission Planning (35)	x			
(VAR) Voltage and Reactive (26)	x	x	x	

A detailed analysis of the NERC Reliability Standards and associated reliability standards relevant to resilience can be found in Appendix B.

While several entities (e.g., NERC, US Department of Energy, NIAC) have developed frameworks to address resiliency issues, none have yet to be widely enforced. Resilience continues to be lightly regulated under reliability for both the natural gas and electric industries. Because of this, there is not yet a federally mandated or federally accepted framework for resilience outside the context of reliability.

Recent federal policies have ignored natural gas resilience. In November 2021, the US passed the Infrastructure Investment and Jobs Act (IIJA). The law allocated more than $65b to upgrading US power infrastructure.[42] This included $11b in grants to enhance the resilience of the electric infrastructure against extreme weather events, $2.5b to improve and develop national electric

[40] Alfred R. Berkeley III and Mike Wallace. October 19, 2010. "A Framework for Establishing Critical Infrastructure Resilience Goals: Final Report and Recommendations by the Council." Pg. 6. *National Infrastructure Advisory Council.*

[41] https://www.nerc.com/pa/Stand/Pages/ReliabilityStandards.aspx

[42] "President Biden's Bipartisan Infrastructure Deal." *The White House.*

transmission lines (primarily to enable utility-scale renewables), and $3b to improve the flexibility of the grid, including upgrading existing transmission and distribution systems.[43] However, the law excluded funding for enhanced natural gas transmission, storage, or distribution infrastructure to enhance the resilience of the gas and overall energy system. A core question is what specific enhanced natural gas transmission infrastructure would enhance the overall energy system. This question is not completely answered; however, the funds are focused on improving the electric infrastructure resiliency, developing national electric transmission lines, and improving flexibility of the grid for quicker response to severe weather events. Similarly, numerous states have legislative or regulatory demand response requirements for electric utilities to reduce unplanned outages due to stresses on the system, but many ignore the benefits of gas demand reduction in increasing resilience during extreme weather events – benefits are mainly focused on reduced system stress, system failures and outages that bring down the system.[44]

2.6 . Resilience Examples Overseas

The natural gas systems of the United Kingdom (UK) and Australia were analyzed to provide examples of international efforts to either support or fail to support resilience infrastructure investments. Table 2-5 includes the key findings; see Appendix C for more details.

Table 2-5. Summary of the UK and Australia's Resilience Frameworks

	United Kingdom	Australia
Key Challenges	• Declining natural gas domestic production • Rising energy prices for consumers and suppliers • UK does not prioritize natural gas storage as a resilience option • Increased winter gas demand worsening seasonal demand differences	• Declining natural gas domestic production • LNG export contracts cause domestic supply shortages • Segregated transmission and distribution networks exacerbate regional supply/demand differences • Increased frequency and severity of extreme weather
Market Structure	• Wholesale market	• Wholesale market • Spot markets allow short-term trades to meet gaps in supply/demand
Investment Incentives	• Market prices drive private investment • Innovation funding (not awarded to gas) • Capacity Market	• Market prices drive private investment • Gas-Fired Recovery Plan: allocates $38.7m for critical gas infrastructure projects
Resilience Strategy	• Utilize natural gas storage and available linepack • Increase LNG imports	• Utilize natural gas storage • Divert natural gas from export to be used domestically (Australian Domestic Gas Security Mechanism)
Energy Policy	• Focus on decarbonization and cleaner energy sources, such as hydrogen	• Earmarked natural gas as key to economic recovery • Pledge to reduce emissions and promote renewables, including transitioning to hydrogen

Source: Guidehouse

The United States and Australia have undergone similar energy transformations in the past decade with rapid increases in natural gas production. Both rely heavily on natural gas for domestic consumption and as a revenue source from exports. With a gas economy like Australia and decarbonization goals like the UK, US regulators, government, and industry will have to effectively

[43] November 9, 2021. "DOE Fact Sheet: The Bipartisan Infrastructure Deal Will Deliver for American Workers, Families, and Usher in the Clean Energy Future." *US Department of Energy.*
[44] *See* ACEEE Energy Efficiency State Database - https://database.aceee.org/

manage low-carbon resource targets with strategies to develop a more reliable and resilient gas system.

Australia presents a comparative example to the regulatory climate in the US. Like the US, the Australian gas market has grappled with competing demand from both domestic consumers and international markets due to the rise of its liquified natural gas (LNG) production. The government and natural gas industry have looked for avenues to ensure gas system resilience, including increased utilization of storage facilities and expanded pipeline capacity. Government regulations and incentives have created an environment that highlights the importance of natural gas to the Australian energy system. Mechanisms in place permit the reallocation of gas in emergency situations and highlight the cooperation of the electric and gas systems, such as diverting LNG from export to domestic buyers and allotting gas to the National Electricity Market during extreme weather events. [45,46] To incentivize continued investment, the government recently announced a $53 Million Gas-Fired Recovery Plan aimed at securing reliable and resilient natural gas supply in Australia. [47]

Comparatively, despite a sustained demand for natural gas domestically, the UK does not incentivize or fund natural gas infrastructure development and relies on market signals to spur investment. The UK has centered its future energy goals on rapid decarbonization and electrification and, does not prioritize domestic resilience of natural gas in its energy future. Given a focus on reducing natural gas consumption, investment in domestic production infrastructure is not prioritized and, as result, resiliency is not a focus. Instead, it plans to rely on imports and the transition to low-carbon fuels, such as hydrogen, instead of domestic storage. The UK stores under 2% of its annual gas demand compared to 25% on average stored in other European countries.[48] Decreased profitability has forced many natural gas storage facilities to close, decreasing overall UK energy system resilience and reliability.[49]

Four key lessons can be drawn from these case studies and their applicability to the US market:

1. **Oversight must be coupled with active market participation.**
    a. Regulatory and government oversight of the natural gas industry is not enough; active incentives, participation, and moderation are required to ensure natural gas has a role in maintaining a reliable and resilient energy system.
2. **Position natural gas as a strategic low-carbon resource solution.**
    a. In a country with incentives, policies, and regulations geared toward rapid decarbonization and cleaner fuels (such as the UK), the natural gas industry can position itself as a vital component of the energy system by showing the route to aa low-carbon future through natural gas infrastructure, such as:

[45] March 11, 2021. "Stakeholder submissions invited on review of the Gas Supply Guarantee." *Australian Energy Market Commission.*

[46] Commonwealth of Australia. 2021. "State of the energy market 2021." *Australian Energy Regulator*.

[47] Department of Industry, Science, Energy and Resources. "Gas markets." *Australian Government.*

[48] January 25, 2021. "The expense of 'just-in-time' gas imports over gas storage." *Storengy.*

[49] Anita Oluyede, Adam Brown, Angela Cheng, David Tennant, Gemma Dreelan, Rebecca Owen-Howes, and Sam Boileau. "At a glance: natural gas pipeline transportation and storage in United Kingdom." *Lexology*.

    i. Using gas infrastructure to employ renewables and potential hydrogen fuel integration.
    ii. Using natural gas to balance out variable renewable generation.
    iii. Providing a resilient energy supply in times of peak demand or extreme events.

3. **Market signals alone may not be sufficient to spur new gas infrastructure investment.**
    a. If prices are too low, private investment may not be forthcoming (Australia), while if high prices are coupled with a political environment not conducive to future natural gas success (UK), private investments may be hesitant due to higher risk and lack of government support.
4. **Seasonal and daily price volatility enhance the profitability of storage facilities**
    a. For many long-term natural gas storage operations to be economic, suppliers must be able to purchase quantities of natural gas at a cheaper price (i.e., often in the summer) to resell at a higher price when demand is larger (i.e., often in the winter). However, in the US seasonal spreads have materially declined.
    b. Storage facilities can also be utilized to balance out daily supply/demand variances, however price volatility is an important driver, as seen in Australia, as another means to ensure reliable energy and balance variable renewable generation.

Recommendation: To achieve current and future resilience, the US gas system should consider a focus on supportive regulatory and financial mechanisms that emphasize the gas system's long-term role in achieving economy-wide emission reductions, including through the integration of zero-carbon fuels such as hydrogen.

3. Methods to Increase Gas System Resilience

This section explores the recommendations that may be required to improve gas system resilience and how to achieve them. Specifically, the section first identifies critical investments needed for gas resilience based on an analysis of extreme weather event impacts. The value of resilience is explored to enable regulations, incentives, or legislation and defined as the "avoided costs" of implementing mitigation assets (e.g., resilience infrastructure) to reduce the impacts and costs of extreme weather events. Finally, recommendations for implementing resilience actions are outlined, revolving around specific state and federal initiatives. Also, building resilience across the energy system should include coordination with investments in the electric grid (i.e., transmission facilities or distribution system enhancements). Electric transmission and distribution system resilience can likely be enhanced by natural gas and low-carbon fuel distributed resources. This can also be identified as improving the energy system and improving avoided costs (i.e., a benefit).

Identifying Critical Resilience Investments

An integrated set of solutions are required to ensure continued, resilient gas service to LDC customers. The primary driver of enhanced gas system resilience will continue to be the need to reduce electric grid outages. These solutions will rely on pipeline infrastructure both upstream and downstream of the city gate. The key recommendations for both these classes are listed below.

Recommendations: Downstream of the City Gate

Investment downstream of the city gate address the risk of upstream supply chain disruptions today, but greater investment should occur to provide greater contingency planning. Also, extreme events that invoke force majeure may be become more common and utilities and insurance carrier should make this a priority. In the absence of these investments, LDCs will likely manage supply disruptions by either disconnecting interruptible or, in more extreme circumstances, firm customers, starting with commercial and industrial users. If supply can be maintained, extreme weather events can result in significant increases in commodity costs, which create financial challenges for LDCs and customers. An underlying theme is including the cost of resiliency in standard ratemaking and utility rate base. This would help in fortifying infrastructure and possibly build supply redundancy in the system. It's more cost-effective and manageable to include the cost of resilience investments within routine rate increases rather than potentially passing through extraordinary commodity costs that may lead to rate shock during extreme weather events.

Key investment recommendations include:

- Increase investments in the weatherization of pipelines and storage distribution infrastructure.
- Expand or build downstream of the city gate pipeline interconnections.
- Develop additional distributional storage facilities to enhance the resilience of the overall pipeline distribution system.
- Introduce and expand the integration of alternative fuels (e.g., hydrogen or RNG) or LNG produced and stored behind the city gate.
- Continue to modernize infrastructure, including distribution pipelines to help enhance safety, reliability, resiliency, and affordability while in turn driving down emissions and delivering ever more low-carbon gas supply solutions over time.

Recommendations: Upstream of the City Gate

Investments upstream of the city gate should focus on improving natural gas infrastructure to support firm supply to LDCs and natural gas-fired power generation. To provide adequate resilience across the entire energy system, complementary investments should be made in the electric grid, such as the weatherization of transmission facilities or enhancements in distribution. Electric distribution resilience can be enhanced through natural gas and low-carbon fuel DERs, but existing distribution systems may not be designed to account for the increase in peak demand related to gas DERs and support their associated benefits. Significant upgrades would be required to permit increased supply to support demand across customer classes.

Key investment recommendations include:

- Increase investments in the weatherization of well-heads, gathering, and processing systems, gas transmission networks, and storage facilities to ensure they are prepared for extreme weather events and potential duration changes.
- Continue to replace aging pipelines and interconnections with long lived assets that support broader energy system resilience.
- Design systems to accommodate low-carbon fuels such that future system operations can continue to provide resilience benefits while supporting mid-century emission reduction goals.

3.1 Valuing Resilience

The value of resilience should be established to develop regulatory mechanism and public policy support for new investments. Resilience assets are valuable because they mitigate the consequences of high-impact, low-probability events by reducing the risks and costs incurred during climate events. These include physical system, financial, regulatory, environmental, and societal risks and costs which influence all customers and entities impacted by extreme weather effects. Valuing resilience includes:

1. Increased customer, investor and stakeholder reliability and benefits.

2. Benefits resulting from focused infrastructure investments (i.e., less harm to customers, decreased gas and electric system disruptions, decreased insurance premiums, etc.).

3. Avoided costs from energy systems able to adapt, withstand, or recover from major events – reducing social impacts of outages - e.g., the economy doesn't shut down, emergency services maintained, business continuing operating without disruptions, etc.).

4. Extrinsic values such as energy optionality, more connectiveness and access to the market, contingencies for emergencies, on-demand energy supplies, flexibility when planning for future energy scenarios as the system evolves (the gas system can be utilized to delivery natural gas today, can be used for renewable natural gas or hydrogen, utilized for seasonal energy storage, etc.).

For example, insurance companies, acknowledging the rising costs of extreme weather events, are raising premiums to energy companies. There are examples of insurance companies potentially eliminating or reducing utility and consumer coverage for specific events (e.g., wildfires in California). Some insurers are cutting back on coverage of larger homes based on wildfires.[50] Utilities are insured and it's likely that customer insurance premiums have been affected. Improving resilience can reduce potential liabilities for both utilities and customers.

The value of resilience results from the reduction of societal impacts and mitigation of risk associated with these extreme events, which are notoriously hard to predict. With advances in climate science, utilities are increasingly looking at downscaled stochastic climate models overlaid on their assets to quantify this very risk. This quantification gives them an addressable baseline against which to measure the benefits.

Traditionally, resilience assets have been undervalued in the natural gas industry, especially at the nexus of the natural gas and electric industries. As we have seen from recent climate events (e.g., Winter Storm Uri) the costs to the communities served by the energy system are significant. Benefits associated with gas industry resilience assets, including on-demand fuel usage and utilization for electricity generation during extreme weather events, have been undervalued and merit re-examination considering the increasing risk of future climate events. Including avoided cost analysis would improve valuation of resilience investments in the natural gas industry.

As noted, valuing resilience in microgrids and deployment of DERs provide distribution system resilience.[51] The NARUC report explicitly acknowledges the importance of adequate fuel supply (including natural gas) as a key component of a microgrid. The recognition of the resilience benefits of DERs is largely dependent on the resilience of the fuels that generate distributed electricity. For example, combined heat and power (CHP) has been recognized as a resilience solution. However, the resilience benefits CHP provides depend on the resilience of the natural gas value chain since a large percentage (> 70%) are fueled by natural gas.

3.1.1 Resilience Cost Analysis

While currently not applicable to the natural gas industry, the resilience frameworks show the importance of calculating the avoided costs from high-impact, low-probability event impacts to value resilience investments. Including the avoided costs of implementing resilience assets is essential to calculating benefit-costs analyses. Avoided costs are a key variable in benefit-costs tests. In some cases, the avoided cost from implementing mitigation efforts can provide financial benefits to customers, utilities, and regulators while reducing power outages and customer disruptions.

Recommendation: Avoided costs should be properly used in benefit-costs tests so that benefits of resilience asset investments are correctly measured.

In public CDP reports, some utilities and energy providers have outlined their key climate risks, the estimated cost of operations, and the estimated mitigation cost (Table 3-1). While some anticipate mitigation efforts to cost more than the unmitigated impacts of an extreme event (especially for

[50] https://www.wsj.com/articles/wildfire-risk-in-california-drives-insurers-to-pull-policies-for-pricey-homes-11642593601

[51] Wilson Rickerson, Kiera Zitelman, and Kelsey Jones. February 2022. "Valuing Resilience for Microgirds: Challenges, innovative Approaches, and State Needs." *National Association of Regulatory Utility Commissioners and the National Association of State Energy Officials.*

flood and cyclones), utilities have reported avoided costs from mitigation measures. Similar metrics and calculations can be used to justify resilience investments to regulators.

Table 3-1. The Comparative Costs and Mitigation of Extreme Weather, by Utility

Utility	Extreme Climate Event	Cost of Impact ($m)	Cost of Mitigation ($m)	Timeframe (years)	Avoided Cost ($m)
Ameren	Flooding, precipitation	$3,200	$3,200	0-5	$0
Dominion Energy	Floods, cyclones	$1,460	$1,420	15-25	$40
Duke Energy	Floods, cyclones	$11,000	$11,600	0-5	-$600
Exelon	Floods, cyclones	$1-31	$500	0-2	-$469-499
Xcel Energy	Cyclones, floods, extreme weather	$0-40	$13.5	Unknown	-$13.5 to +$36.5
Avangrid	Extreme weather events	$40	$40	0-1	$0
LA Dept. of Water and Power	Wildfires	$350	$94	20-30	$256
Pacific Gas & Electric	Heat waves	$150-300	$46	0-1	$104-254
Pinnacle West	Water scarcity, drought	$4-6	$1.4	1-5	$2.6-4.6

Source: Utility Dive[52]

Recommendation: Entities downstream of the city gate, including LDCs and combined electric and gas pipeline utilities, can utilize similar strategies by providing individualized data for their jurisdictions. This includes distribution level energy outages, proposed mitigation measure costs, and direct and indirect costs to customers and utilities.

3.1.2 An Approach to Funding Resilience

Leveraging historical recovery costs known at the state and utility level can be used as a measure of what should be spent for resilience investments going forward. Today, there are few mechanisms to fund utility resilience investments, and most are implemented on a local scale in specific jurisdictions rather than at a national scale. Table 3-2 below shows the Maryland case where resilience is considered a specific criterion for a state grant program. New York recently passed legislation that allows utilities to recover their climate resilience plan costs through a specific cost recovery clause.[53]

[52] Utility Dive Team. November 18, 2020. “Climate risks are accelerating. Here’s what Duke, PG&E, and 16 other utilities expect to pay.” *Utility Dive.*

[53] New York State Senate. January 26, 2021. “Assembly Bill A3360A.” New York State.

Table 3-2. Example 3: DERs Resilience Grant Program
MEA Resilient Maryland Program: The Maryland Energy Administration (MEA) Resilient Maryland program allocates competitive grants (totaling up to $300,000) to projects around microgrids and DERs and is recommended for "organizations seeking reliable, sustainable, and affordable energy to improve their operations and shield against the negative impacts of power outages."[54] Resilience is recognized as a scoring criteria and allocates 20 percent of an applicant's overall score.[55] The program offers a potential framework and avenue for natural gas resilience projects to gain funding and approval.

Utilities use storm recovery mechanisms to address the added costs of high-impact, low-probability storm events. Utilities could leverage historical recovery costs known at the utility level as a measure of what should be spent for resilience investments. Recovery mechanisms are essentially reserve funds based on historical costs. Such accounts are a good measure of actual costs needed to fix system damage from severe weather. Numerous states have storm recovery mechanisms which include the following shown in Table 3-3. The table provides a summary of states which have approved and supported utility storm recovery mechanisms – this is based on a review of rider recovery, reserve accounts and securitization mechanisms across the states – the mechanisms are defined as follows:

- **Rider Recovery** – allows utilities to recover costs related to restoring service and repairing facilitates as a result of severe storms[56].
- **Reserve Accounts** – provide a type of self-insurance for utilities; funds are collected in advance and help lessen earnings impact from storms[57].
- **Securitization** – issuance of bonds backed by a specific existing revenue stream that has been guaranteed by regulators and/or state legislators[58].

[54] August 18, 2021. "MEA's Resilient Maryland Returns to Push the Envelope on Distributed Energy: FY22 Program Now Accepting Applications." *Maryland Energy Administration.*

[55] Wilson Rickerson, Kiera Zitelman, and Kelsey Jones. February 2022. "Valuing Resilience for Microgirds: Challenges, innovative Approaches, and State Needs." *National Association of Regulatory Utility Commissioners and the National Association of State Energy Officials.*

[56] Ernst, R., & Bellizzi , S. M. (2017, September). *RRA Regulatory Focus Adjustment clauses*. S&P Global Market Intelligence . Retrieved from https://www.spglobal.com/marketintelligence/en/documents/adjustment-clauses-state-by-state-overview.pdf

[57] Johnson , B. (2005, February). *After the disaster: Utility restoration cost recovery - missouri*. Edison Electric Institute . Retrieved from https://www.efis.psc.mo.gov/mpsc/commoncomponents/viewdocument.asp?DocId=4048185

[58] Michael Lustig, L. F. (2022, February 14). *Okla. utilities allowed to securitize February 2021 storm costs*. S&P Global. Retrieved from https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/okla-utilities-allowed-to-securitize-february-2021-storm-costs-68870713

Table 3-3. Storm Recovery Mechanisms

State	Rider Recovery	Reserve Account	Securitization
Alabama	✓	✓	
Arkansas		✓	✓
California		✓	
Connecticut	✓		
Florida	✓	✓	✓
Kansas			✓
Kentucky	✓		
Louisiana		✓	✓
New Orleans	✓	✓	✓
Maine	✓		
Mississippi	✓	✓	✓
Missouri	✓		
New Hampshire	✓	✓	
North Carolina		✓	
Ohio	✓		
Oklahoma	✓		✓
Oregon		✓	
Pennsylvania	✓		
Rhode Island		✓	
Tennessee	✓		
Texas	✓	✓	✓

Source: S&P Global Market Intelligence, S&P Global Ratings[59] The Oklahoman[60], KOAM News[61]

Table 3-4 and Table 3-5 demonstrate utilities that have utilized storm recovery mechanisms to fund recovery efforts following extreme weather events. The cost of repair in these scenarios can be used as an estimate of the value of resilience (i.e., proxy for cost to build resilience into the system) and potential means to encourage resilience investments by regulators. The idea is to use known recovery and rebuild costs as a gauge or a proxy for how to fund resilience construction and asset costs.

Table 3-4. Example 3: Storm Recovery Mechanisms: Reserve Funds and Rider Recovery

Entergy: In 2015, Entergy New Orleans secured low-interest, securitized bonds to fully fund its storm reserve, resulting in a minor cost increase for customers and an estimated customer savings of $32m.[62] However, storm reserves such as these do not fully protect a utility from the financial burdens of a major storm. From 2020 to 2021, Entergy was impacted by several storms, including Hurricanes Laura, Delta, and Zeta, as well as Winter Storm Uri. These high-impact, low-probability events exhausted the company's storm reserves, and the company sustained an estimated $4-4.4bn in damages in Louisiana alone.[63] To secure relief from recovery costs, state regulators approved a special rate treatment for $1bn in debt issues by Entergy.

[59] Gabe Grosberg. November 8, 2018. "Can U.S. Utilities Weather the Storm." *S&P Global.*

[60] Money, J. (2022, February 11). *Divided Corporation Commission supports two additional winter storm cost recovery orders*. The Oklahoman. Retrieved from https://www.oklahoman.com/story/business/2022/02/11/divided-commissioners-advance-two-utilities-storm-cost-recovery-plans/6720892001/

[61] Louque, A. (2022, February 8). *Kansas creates plan to recover deferred energy payments*. KOAM. Retrieved from https://www.koamnewsnow.com/kansas-creates-plan-to-recover-deferred-energy-payments/

[62] August 12, 2015. "Entergy New Orleans Customers to Benefit from Fully Funded Storm Reserve." *Entergy.*

[63] Abbie Bennet. November 18, 2021. "Entergy Louisiana owes $4.4B for storm damages." *S&P Global.*

Table 3-5. Example 4: Storm Recovery Mechanisms: Securitization
Duke Energy: In North Carolina, a series of efforts implemented by the government and regulators saved customers of Duke Energy about $300m in repair costs from severe storms in 2018 and 2019. Senate Bill 559, passed in November 2019, allowed the utility to securitize costs from extreme storm events. In addition, the North Carolina Utilities Commission agreed the storm recovery costs were necessary and would result in lower overall costs for customers. As a result, residential customers using 1,000 kWh per month saved about 37% compared to traditional storm cost recovery.[64]

Storm recovery mechanisms cannot be used to reduce the cost to customers, but they can be used as a proxy for the cost of what a state or utility should consider for implementing a storm resilience program. Key stakeholders, such as regulators, utilities, and legislative bodies, should consider leveraging historical storm recovery costs to provide an investment measure for resilience infrastructure.

Though foundational methodologies are available to value resilience downstream of the city gate, there lacks sufficient data to quantitatively analyze the impacts of high-impact, low-probability events on distribution gas supply. This includes customer interruptions, disruption costs, the need for new distribution infrastructure investments to support DERS, and other measures to enhance energy system resilience. As a result, more work is required to collect the applicable data and establish the value of resilience in the gas distribution sector.

3.2 Implementing Resilience

To establish a foundation for resilience investments, key stakeholders must prepare to address a range of issues and considerations. Three types of support are required for resilience investments: public, regulatory, and financial. These foundational principles help identify the key recommendations to implement resilience across the energy system through federal and state policies and frameworks and build off the recommendations listed in the prior sections of this report (detailed recommendations can be found in Appendix A).

3.2.1 Foundational Principles

Public Support

Customers and operators have experienced first-hand the impacts of extreme-weather events on the cost and availability of energy. New investments and commercial constructs are required to enhance energy system resilience and mitigate against the significant increase in commodity costs that have occurred during extreme weather events. To enable resilience investments, energy prices need to reflect the costs associated with incremental investments in resilience enhancement, and public recognition and acceptance will be needed to prevent significant backlash.

[64] December 2, 2021. "Storm bonds save $300m for Duke Energy Customers in North Carolina." *Duke Energy.*

In addition to broader public recognition of the necessity for resilience, energy providers need to properly communicate proposed resilience investments, their projected cost increases to customers, and the value they will provide to customers and the broader energy system.

Regulatory Support

The current regulatory structure, as explored in Section 2.2, has significant gaps in its ability to support resilience infrastructure and investments. Current regulations and frameworks emphasize reliability over resilience, and often lack proper collaborative actions across the natural gas and electric industries. Resilience should be considered as a separate characteristic of the energy system, rather than a component of reliability.

Financial Support

The costs of extreme weather events are likely to grow over time as the frequency and severity of these events increase. To mitigate against the impacts of these events, energy operators require additional financial support to enable resilience investments, as the current regulatory environment makes it difficult for energy providers to demonstrate the need for resilience investments and gain approval to incorporate them into the rate-base. Cost recovery mechanisms are needed for LDCs to be compensated for necessary capital and operating costs associated with resilience investments. These costs must be distributed equitably across customer classes and the energy system.

The design of the cost recovery mechanisms should also include provisions to allow lower-income customers to install DERs and obtain resilience benefits that are typically only available to higher-income customers. Similar to community solar generation, community DERs can be incorporated into under-served residential and commercial customers to provide resilience enhancement.

3.2.2 Recommendations to Implement Resilience

To achieve the foundational principles of implementing resilience, broader energy policies and regulatory constructs at the federal and state level are required to support resilience investments across the energy system.

While there has been some federal and state activity, it is not yet sufficient to support broad, system wide resilience. For example, the IIJA provided over $50b to make energy infrastructure more resilient to climate change.[65] However, the law provides significant funding for electric transmission and fails to provide funding for enhanced resilience of the distribution pipeline and storage systems. In addition, it does not provide a sustainable basis for funding infrastructure costs after the appropriations are exhausted.

States, ISOs, and federal agencies (e.g., FERC, NERC) have undertaken initiatives to harden certain components of the energy system. Even so, these efforts have not resulted in changes to the gas system in response to weather events nor a sustainable construct for funding the costs associated with resilience investments. State responses have been highly varied, with states like Illinois launching detailed reviews of resilience planning, while others have not been as active in assessing resilience risk and mitigation plans.

[65] "President Biden's Bipartisan Infrastructure Deal." *The White House.*

The following recommendations outline specific actions, policies, and frameworks that should be implemented at the federal and state level to achieve the foundational principles of implementing resilience.

1. Federal and state intervention and approval to implement resilience measures

Consider holding federal and state hearings on the impacts and consequences of extreme weather events, including the risks of prolonged outages to customers, utilities, and state economies. Goals would be to obtain guidance on forecasting future extreme weather events, their associated impacts, and risk mitigation strategies. In addition, they should understand the role of distribution supply on electric grid resilience and the use of low-carbon fuel distribution infrastructure to achieve net-zero goals.

Federal

The US Congress could formally recognize the critical importance of enhancing gas system resilience, including the pipeline network and electric grid, to meet the challenges associated with climate change.

State

At the state level, legislators could request utilities to develop climate change adaptation plans that describe the resilience investments necessary to mitigate against the impacts of extreme weather events. For example, New York recently passed legislation that allows utilities to recover their climate resilience plan costs through a specific cost recovery clause.[66]

2. Require resilience regulatory requirements

Both state and federal regulators should incorporate resilience into updated regulatory frameworks that govern the broader energy system. Commissions should explore improved methodologies to understand the value of gas resilience projects to the energy system instead of relying on unapplicable criteria (i.e., “used and useful”). Standards for including high-impact, low-probability events in used and useful gas system analysis are needed to allow for system upgrades to properly go into the rate base.

Federal

By the means of legislation or other federal directives, FERC may be required to establish resilience requirements for jurisdictional energy systems. In addition, they should develop rules that require electric generators operating in regulated power markets within FERC to engage with fuel suppliers that adhere to resilience requirements in the form of clear rules and regulations adopting standards or simply high-level parameters of operation that allow companies to implement. It should also require state jurisdictional energy infrastructure to adhere to FERC resilience requirements.

Representative FERC reference points are outlined in a policy document by the Center for Climate and Energy Solutions.[67] Additionally, FERC rulings on this topic have been on a case-by-case basis; an example is seen in a FERC case: “Order Approving Stipulation and Consent Agreement: Florida Blackout.[68]

[66] New York State Senate. January 26, 2021. “Assembly Bill A3360A.” New York State.

[67] January 2018. “Policy Options for Climate-Resilient Infrastructure.” *Center for Climate and Energy Solutions.*

[68] October 8, 2009. “Order Approving Stipulation and Consent Agreement: Florida Blackout.” 129 FERC 61,016, Docket No. IN08-5-000. *Federal Energy Regulatory Commission.*

State

State legislation or regulation may establish resiliency standards under their relevant state jurisdictional energy infrastructure powers. State regulators will also need legislative support to expand the principle of "used and useful" to include the approval of resilience asset investments that may have very low utilization through their targeted response to high-impact, low-probability events.

3. **Enable federal and state funding support for gas system resilience investments**

Federal

Federal legislation can provide funding avenues for resilience investments across the natural gas system. Congress can also consider either amending the IIJA or producing new legislation to provide gas system infrastructure resilience investment avenues.

Support can include grants to possibly aid construction, federal financing (e.g., loan guarantees), and tax credits, such as those presently offered for renewable energy and carbon capture and storage projects. Federal grants are possibly more appropriate to fund research and development since gas companies are capable of raising capital independently for asset projects and do not necessarily need federal assistance for construction and asset-based projects. To ensure that utilities can use tax credits effectively, the tax normalization should be waived for resilience investments.

State

A tariff for natural gas DERs should be developed to compensate LDCs for resilience investments. This would help address supply during peak demand periods (e.g., winter heating season) and help allocate a portion of the revenues earned by DERs from participation in wholesale capacity markets and demand response programs.

States should also consider innovative regulatory constructs to manage the costs from gas system resilience investments and extreme weather impacts. These can include:

b. Legislation that allows the recovery of approved resilience costs within the rate base, which can be explicitly designated to a separate line item in the customer bill, so customers understand the use of the funds. This can be achieved through an adder or a rider.

c. Update and expand storm recovery reserves to reflect realistic forecasts for extreme weather events, funded through conventional rate-base recovery or more innovative financing constructs.

d. Fund approved resilience projects through alternative financing constructs that reflect the potential low utilization of the investments, including financing that could result in higher debt-to-equity capital ratios than what is approved for other utility investments.

4. **Improve the interdependencies between the electric and natural gas industries**

Federal

FERC and the DOE need to drive policy and rules that recognize the importance and interdependencies of the natural gas and electric energy systems to ensure the points raised above are recognized and implemented at the federal level.

The electric service to pipeline and distribution infrastructure should be classified as critical loads such that they are excluded from load shedding by ISOs and electric utilities during extreme weather events. In addition, a broader energy system docket should be established to consider electric, and natural gas industry support for overall energy system resilience.

State

In parallel, state commissions may establish workshops and/or dockets that:

a. Establish policy and rules that recognize the interdependencies of the natural gas and electric energy systems to ensure the points raised above are recognized and implemented at the federal level.

b. Recognize electric service to pipeline and distribution infrastructure as critical load so they are excluded from load shedding by utilities during extreme weather events.

c. Establish broader state energy system dockets which review electric and natural gas initiatives that support overall energy system resilience.

4. Conclusions

This report examined gas system resilience attributes – specific focus on (i) how it enables overall energy system resilience, (ii) the changes required to the regulatory framework to support gas resilience investments, and (iii) the infrastructure improvements necessary to support broader energy system resilience. All critical to success of the gas system. Also examined were opportunities to enhance resilience of the entire “energy system” with a focus on how future gas system investments can support the resilience of other parts of the energy system can also support aa low-carbon future and the increased integration of renewables in both the gas and electric grids – focus on the evolution of electric and gas grids with the addition of renewable supply. Resilience is a crucial component of a dependable energy system. Gas system ability to meet peak day and seasonal demands is a valuable resource and must be considered when designing future energy systems – also important when designing and building low-carbon pathways. As extreme weather events have increased in frequency and severity, the need for enhanced energy system resilience has become demonstrable.

There is broad recognition that gas system resilience is critical to overall energy system resilience. The resilience of the overall energy system rests upon gas system resilience since natural gas accounts for one-third of primary energy consumption across all principal sectors of the economy and is the primary fuel for the generation of electric power in the US. As the use of natural gas has become the primary fuel for the generation of electric power, the importance of natural gas has increased beyond its role as a fuel for homes and businesses. Extreme weather events have shown the value and necessity of a resilient gas system and the inextricable linkage between fuel delivery, the supply of electricity, and peak energy management across the gas and electric system. This analysis builds off the prior report published by the American Gas Foundation and Guidehouse in January 2021: *Building a Resilient Energy Future: How the Gas System Contributes to US Energy System Resilience*. This report also provides technical, commercial, and regulatory considerations associated with gas US gas system resilience – this focused on identifying necessary changes to the policy and regulatory framework for the energy industry to support gas resilience investments.

Resilience attributes of the gas system were focusing on how it enables overall energy system resilience, the changes required to the regulatory framework to support future gas resilience investments, and the infrastructure improvements necessary to support broader energy system resilience into the future. The report was developed using data and inputs from a diverse array of sources including interviews with industry recognized state regulators, detailed review of available studies and assessments of the impact of severe weather events upon energy infrastructure and broader regional economies, regulatory initiatives to address resiliency implemented in the US and overseas, reliability studies and analyses performed by the University of California at San Diego (UCSD), discussions with representatives of local distribution companies (LDCs) active in addressing issues associated with the energy transition and resiliency and independent analytics of key features of the energy system including the deployment of distributed energy resources.

High-Level Recommendations: There are a number of recommendations that should be considered and implemented to achieve enhanced energy system resiliency:

Recommendation: Commission Analysis into Value of Gas Infrastructure

Commissions should explore methodologies that look beyond used and useful analysis to understand the true value gas infrastructure provides to the resilience of the entire energy system - relying on traditional regulatory criteria may not cover the future benefits of resiliency or weather-related system improvements.

Recommendation: Emphasize Safety and Renewable Integration When Seeking Approval

When seeking approval for resilience infrastructure investments and stakeholder support, gas utilities should emphasize the investment's value to ensure safety and the future integration of renewables in both the gas and electric systems.

Recommendation: Focus on Enabling Mechanisms Emphasizing a Low-Carbon Future

To achieve current and future resilience, the US gas system should focus on enabling supportive regulatory and financial mechanisms that emphasize the gas system's long-term role in a low-carbon energy system, including through the integration of zero-carbon fuels such as hydrogen. Also, require modeled industry scenarios for planning and regulatory approval so that future conditions are understood.

Recommendations: Downstream and Upstream of the City Gate

Investment downstream of the city gate address the risk of upstream supply chain disruptions today, but greater investment should occur to provide greater contingency planning.

Key **downstream** investment recommendations include:

- Increase investments in the weatherization of pipelines and storage distribution infrastructure.
- Continue improving downstream of city gate pipeline interconnections.
- Develop additional storage facilities on the gas distribution system to enhance the resilience of the overall pipeline distribution system.
- Introduce and expand the integration of alternative fuels (e.g., hydrogen or RNG) or LNG produced and stored behind the city gate.
- Continue replacing aging infrastructure, including distribution pipelines.

Key **upstream** investment recommendations include:

- Increase investments in the weatherization of well-heads, gathering, and processing systems, gas transmission networks, and storage facilities to ensure they are prepared for extreme weather events and potential duration changes.
- Continue to replace aging pipelines and interconnections with long lived assets that support broader energy system resilience.

- Design systems to accommodate low-carbon fuels such that future system operations can continue to provide resilience benefits while supporting mid-century decarbonization emissions reduction goals.

Recommendations: Federal and state intervention and approval to implement resilience measures

At both the federal (e.g., US House of Representatives and Senate) and the state (e.g., state legislative or regulatory commission) level should hold hearings on the impacts and consequences of extreme weather events on the US or state, including the risks of prolonged outages to customers, utilities, and state economies.

Federal

From the findings, Congress should issue formal documentation notating the critical importance of enhancing energy system resilience, including the pipeline network and electric grid, to meet the challenges associated with climate change.

State

At the state level, legislators should request utilities to develop plans that describe the resilience investments necessary to mitigate against the impacts of extreme weather events. Resilience is important for forward looking plans required by regulatory agencies or submitted to reduce carbon going forward. For example, New York recently passed legislation which allows utilities to recover their climate resilience plan costs through a specific cost recovery clause.[69]

Recommendations: Implement resilience regulatory requirements

Both state and federal regulators should incorporate resilience into updated regulatory frameworks that govern the broader energy system.

Federal

By the means of legislation or other federal directives, Federal Energy Regulatory Commission (FERC) can address this issue by establishing baseline resilience requirements for jurisdictional energy systems. In addition, they can develop rules that require electric generators operating in regulated power markets within FERC to engage with fuel suppliers that adhere to resilience requirements. State jurisdictional energy infrastructure can also be required to adhere to FERC resilience requirements.

State

State legislation or regulation should establish resiliency standards under their relevant state jurisdictional energy infrastructure powers. State regulators will also need legislative support to expand the principle of "used and useful" to include the approval of resilience asset investments that may have very low utilization through their targeted response to high-impact, low-probability events.

[69] New York State Senate. January 26, 2021. "Assembly Bill A3360A." New York State.

5. **Enable federal and state funding support for energy system resilience investments**

Federal

Federal legislation should provide federal funding avenues for resilience investments, including both upstream and downstream of the city gate. Congress can also consider either amending the Infrastructure Investment and Jobs Act (IIJA) or producing new legislation to provide energy system infrastructure resilience investment avenues.

State

A tariff for natural gas distributed energy resources should be developed to compensate LDCs for resilience investments. This would help address supply during peak demand periods (e.g., winter heating season) and help allocate a portion of the revenues earned by distributed energy resources (DERs) from participation in wholesale capacity markets and demand response programs.

States can also consider innovative regulatory constructs to manage the costs from energy system resilience investments and extreme weather impacts.

Recommendations: Improve the interdependencies between the electric and natural gas industries

Federal

FERC and the Department of Energy (DOE) need to drive policy and rules that recognize the importance and interdependencies of the natural gas and electric energy systems to ensure the points raised above are recognized and implemented at the federal level.

State

In parallel, state commissions should establish workshops and/or dockets that (i) establish policy and rules that recognize the important and interdependencies of the natural gas and electric energy systems to ensure the points raised above are recognized and implemented at the federal level, (ii) recognize electric service to pipeline and distribution infrastructure as critical load so they are excluded from load shedding by utilities during extreme weather events; and (iii) establish broader state energy system dockets which review electric and natural gas initiatives that support overall energy system resilience.

Appendix A. Recommendations To Facilitate Resiliency

The following section lists all the recommendations outlined in the main body of the report.

- Commissions should consider exploring improved methodologies to understand the value of gas resilience projects to the energy system instead of relying on unapplicable criteria (i.e., “used and useful”). Proper measurements of the potential benefits resilient assets provide to the gas system and to the energy as a whole during certain events, need to be incorporated going forward. Standards which include large impact, low-probability events in used and useful gas system analysis are needed to allow for system upgrades to be properly evaluated and integrated into the rate base.
- When seeking approval for resilience infrastructure investments and stakeholder support, utilities should consider emphasizing the investment’s use to ensure safety and the future integration of renewables.
- Utility planning needs to account for the increased use of backup generators and DERS on forecasted demand assumptions to adequately prepare for peak-demand scenarios, such as during high-impact, low-probability events. This increase in gas supply may require expansion of existing gas distribution infrastructure as well as additional sources of gas supply, including behind city gate storage and alternative fuels to meet peak demand.
- To generate support for increased resilience investments and beneficial regulations, LDCs should consider collecting data that shows the impact of extreme weather on their distribution network and capabilities. Also, consider leveraging behavioral models that use system data to demonstrate real-world operations and where systems may fail or not operate properly.
- The US gas system should consider a focus on enabling supportive regulatory and financial mechanisms to ensure long-term viability of resilience investments, including through the integration of low-carbon fuels and hydrogen.
- Investment recommendations downstream of the city gate:
    - Increase investments in the weatherization of pipelines and storage distribution infrastructure.
    - Expand or build upstream pipeline interconnections.
    - Develop additional distributional storage facilities to enhance the resilience of the overall pipeline distribution system.
    - Introduce and expand integration of alternatives fuels (e.g., hydrogen or RNG) or LNG produced and stored behind the city gate.
    - Replace aging infrastructure, including distribution pipelines.
- Investment recommendations upstream of the city gate:
    - Increase investments in the weatherization of well-heads, gathering and processing systems, gas transmission networks, and storage facilities to ensure they are preparing for extreme weather events and potential duration changes.
    - Continue to replace aging pipelines and interconnections with long lived assets that support broader gas system resilience.

    - Design systems to accommodate low-carbon fuels such that future system operations can continue to provide resilience benefits while supporting mid-century decarbonization emission reduction goals.

- Resilience models either need to take into consideration the gas industry’s contributions to and interdependence with the electric industry or broaden their applicability to the gas industry.
- Avoided costs should be properly used in benefit-costs tests so that benefits of resilience asset investments are correctly measured.
- Entities downstream of the city gate, including LDCs and combined electric and pipeline utilities, can utilize similar strategies by providing individualized data for their jurisdictions. This includes distribution level energy outages, proposed mitigation measure costs, and the direct and indirect costs to customers and utilities.
- Section 3.2 outlines the recommendations to implement gas resilience in the energy system.

Appendix B. NERC Reliability Standards

Standard Number	NERC Electric Reliability Standard	Applicability to Gas Industry
(TPL-001-4)	**Transmission Planning**	Establishes transmission system planning performance requirements within the planning horizon to develop a Bulk Electric System (BES) that will operate reliably over a board spectrum of system conditions and following a wide range of probable contingencies. **(Prepare)**
(CIP-002-5.1a)	**Critical Infrastructure Protection**	Identify BES Cyber Systems and their associated BES Cyber Assets for the application of cyber security requirements commensurate with the adverse impact that loss, compromise, or misuse of those BES Cyber Systems could have on the reliable operation of the BES. **(Prepare)**
(EOP-006-3)	**Emergency Preparedness and Operations**	Ensure plans are established and personnel are prepared to enable effective coordination of the System restoration process to ensure reliability is maintained during restoration and priority is placed on restoring the Interconnection. **(Prepare)**
(COM-002-4)	**Communications**	Improve communications for the issuance of operating instructions with predefined communications protocols to reduce the possibility of miscommunication that could lead to action or inaction harmful to the reliability of the Bulk Electric System (BES). **(Prepare)**
(FAC-011-3, FAC-003-4)	**Facilities Design, Connections, and Maintenance**	Ensure that System Operating Limits (SOLs) used in the reliable operation of the (BES) are determined based on an established methodology or methodologies. Use a defense in-depth strategy to manage vegetation located on transmission rights of way (ROW) and minimize encroachments

Standard Number	NERC Electric Reliability Standard	Applicability to Gas Industry
		from vegetation located adjacent to the ROW, thus preventing the risk of those vegetation related outages that could lead to cascading. **(Prepare)**
(MOD-028-2)	**Modeling, Data, and Analysis**	Increase consistency and reliability in the development and documentation of Transfer Capability calculations for short-term use performed by entities using the Area Interchange Methodology to support analysis and system operations **(Prepare) (Adapt)**
(IRO-006-5)	**Interconnection Reliability Operations and Coordination**	Ensure coordinated action between Interconnections when implementing Interconnection-wide transmission loading relief procedures to prevent or manage potential or actual SOL and IROL exceedances to maintain reliability of the bulk electric system. **(Prepare) (Withstand) (Recover) (Adapt)**
(TOP-001-5)	**Transmission Operations**	Prevent instability, uncontrolled separation, or cascading outages that adversely impact the reliability of the Interconnection by ensuring prompt action to prevent or mitigate such occurrences. (Prepare) (Withstand)
(PRC-005-1.1b)	**Protection and Control**	Ensure all transmission and generation Protection Systems affecting the reliability of the Bulk Electric System (BES) are maintained and tested. (Prepare) (Withstand) (Recover) (Adapt)

Appendix C. Resilience Examples Overseas

Case Study 1: United Kingdom's Natural Gas Resilience System

Key Finding

Despite a sustained need for natural gas from the residential and commercial sectors, the United Kingdom is focused on rapidly decarbonizing and electrifying through cleaner energy sources such as hydrogen. To balance decreasing domestic production of natural gas, the UK plans to increase its reliance on gas imports and employ decarbonization plans to ensure future energy resiliency.

New gas infrastructure is currently not supported through government incentives or funding, but instead relies on market signals to spur private investment. More work is needed to give gas producers better access to funding for new infrastructure investment, including innovation funding, capacity market contracts, and fair compensation from energy tariffs.

The UK Natural Gas Market

Natural gas has been a vital component of the UK energy supply for decades, and the country is expected to sustain a significant demand for natural gas until at least 2035.[70] Natural gas heats 80% of homes and is essential for industries such as ceramics and chemicals, and, at peak times, can fuel as much as half of the country's electricity generation.[71]

The UK currently sources its natural gas from three key categories:

1. Domestic production, mainly from the United Kingdom Continental Shelf (UKCS)
2. Liquefied natural gas (LNG) imports
3. Interconnector pipeline imports

In 2019, production met 46% of supply, LNG met 21% of supply, and pipeline imports met 33% of supply.[72] The UK only considers natural gas storage as a supply source in times of high demand. During the COVID-19 pandemic, the UK saw an overall increase in imports, compensating for reduced gross gas production, as seen in Figure 4-1, and an increased

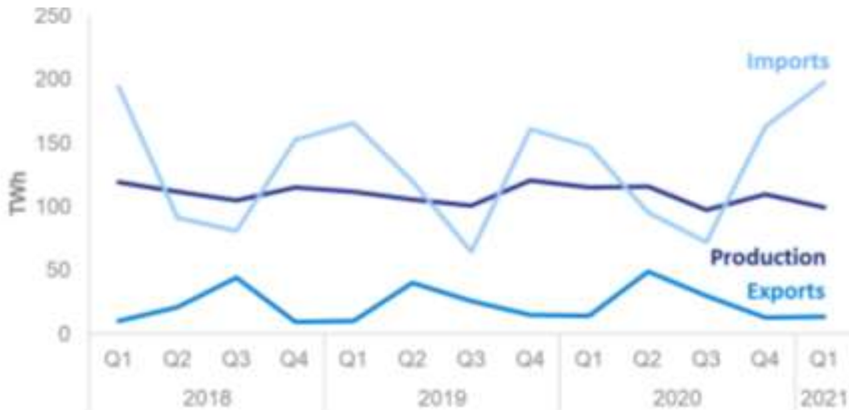
[70] Department for Business, Energy & Industrial Strategy. October 2017. "Gas Security of Supply: A strategic assessment of Great Britain's gas security of supply." *United Kingdom.*

[71] Susanna Twidale. March 19, 2018. "Exclusive – Rough justice? UK snubs call for gas storage capacity review." *Reuters.*

[72] Department for Business, Energy & Industrial Strategy. December 22, 2020. "Diversity and security of gas supply in the EU, 2019." *United Kingdom.*

demand of 8.1% from Q1 2020 to Q1 2021.[73] Domestic natural gas production is expected to continue decreasing in the future.

Figure 4-1. Production and Trade of Natural Gas, United Kingdom, 2018-2021



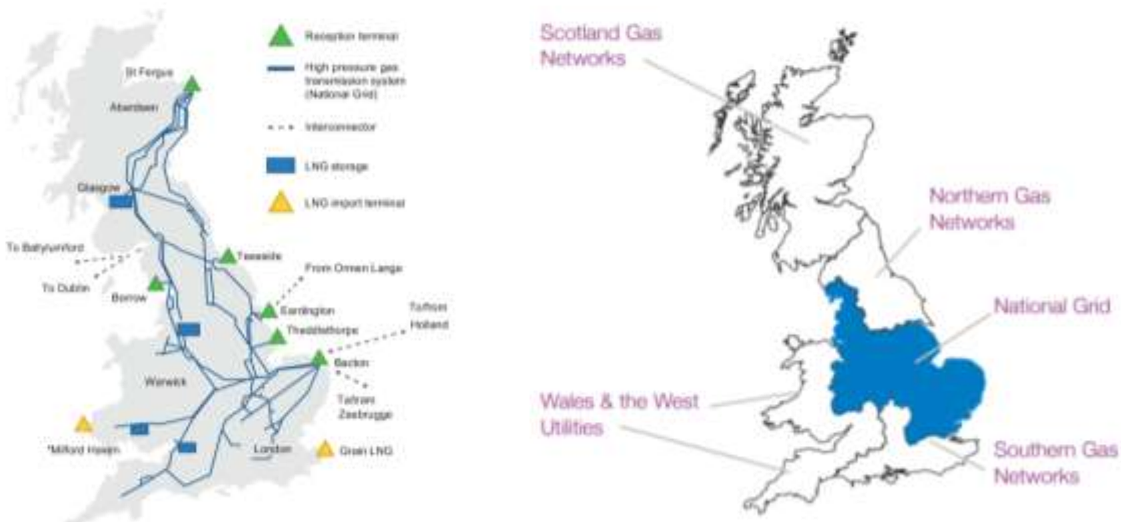
Source: The Department for Business, Energy & Industrial Strategy (UK)

The UK operates on a wholesale natural gas market, currently valued at £5bn[74], supplied by distributors who utilize regional monopolies. In Great Britain, the gas market is regulated by the Office of Gas and Electricity Markets (Ofgem) and in Northern Ireland, it is regulated by the Northern Ireland authority for Utility Regulation (NIAUR). Production and processing infrastructure is owned by private companies. The owner and operator of the gas transmission network is National Grid Gas plc, and the eight regional gas distribution networks (GDNs) are owned and operated by four companies: Wales and West Utilities Limited, Cadent Gas Ltd, Scotia Gas Networks Ltd, and Northern Gas Networks Ltd (as shown in Figure 4-2). There are also several smaller networks owned and operated by independent gas transporters within the areas covered by GDNs.

[73] Department for Business, Energy & Industrial Strategy. September 30, 2021. “National Statistics Energy Trends; UK gas.” *United Kingdom.*

[74] September 9, 2021. “Gas Distribution in the UK – Market Research Report.” *IBISWorld.*

Figure 4-2. Great Britain's Gas Transmission Network [Left] and Gas Distribution Network [Right]



Source: National Grid

Energy prices have been rising in recent years, partly due to declining domestic production. In January 2021, the UK paid an additional £4/MWh for energy compared to countries on the European continent.[75]

Prior to 2019, consumers were responsible for increased energy prices during periods of high demand or supply stress.[76] Since 2019, Ofgem has instituted an energy price cap, the maximum price suppliers can charge customers, even during periods of high demand or supply stress, for variable rate energy tariffs. This price cap varies depending on the average cost of natural gas and has been rising in the last year due to the increasing energy prices.

In April 2021, the price cap rose by 9% and rose by another 12% in October 2021.[77] Ofgem states the increase in the price cap is due to over a 50% increase in energy prices.[78] The collapse of small energy providers in late 2021 has put increased stress on the energy system, with prices further increasing for consumers and forcing Ofgem to move customers to new suppliers.[79]

As part of the UK Fuel Security Code, the government may reimburse gas suppliers for exceptional costs due to an energy emergency, reallocating the cost of high gas prices during emergency situations from the consumers and utilities to the government.[80] However, during most of the year, energy suppliers are required to consume the cost of high energy prices.

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[75] November 27, 2018. "Gas Storage in the UK leveling the playing field." *Storengy.*

[76] March 2017. "A review of gas security of supply within Great Britain's gas market – from the present to 2035: a report to the Department for Business, Energy & Industrial Strategy." *Ofgem.*

[77] Rachel Wait. September 29, 2021. "Ofgem's Energy Price Cap Explained." *Forbes*.

[78] August 6, 2021. "Record gas prices drive up price cap by £139 – customers encouraged to contact supplier for support and switch to better deal if possible." *Ofgem.*

[79] Kevin Peachey. September 24, 2021. "Thousands of energy customers facing bill shocks." *BBC News.*

[80] Department for Business, Energy & Industrial Strategy. November 6, 2019. "The Fuel Security Code." *United Kingdom.*

Energy suppliers have come under increasing financial strain from a combination of high energy prices and Ofgem's energy price cap, such as Centrica (British Gas's owner) recording a loss of £849m in 2019 when it struggled to adjust for the price cap when it was first introduced.[81]

The UK has outlined aggressive commitments to decarbonization, including a Ten Point Plan for a Green Industrial Revolution, which focuses on increasing the supply of renewable energy in its portfolio and replacing natural gas with hydrogen supplied power.[82]

Resilience Policy and Regulations

The resiliency of the UK's natural gas system and infrastructure is monitored by Ofgem, National Grid, and the Department for Business, Energy & Industrial Strategy (BEIS), which publishes strategic documentation and policy framework, safeguards security of supply, and supports the necessary investment in energy infrastructure. The Statutory Security of Supply report is an annual requirement of UK law to assess the availability of secure and affordable electricity, oil, and gas for meeting the needs of UK consumers. The most recent 2020 report[83] states the UK natural gas infrastructure is resilient:

- Due to a diverse range of supply sources, both domestic and imported.
- To all but the most extreme and unlikely combinations of severe infrastructure and supply shocks.

These conclusions are supported by robust scenario analyses of infrastructure failures and unusually high demand, which can often stem from extreme weather events like the March 2018 cold wave. This analysis was detailed in the 2017 Strategic Assessment of Gas Security of Supply[84] and the 2018 National Risk Assessment[85], with support from the external consultancy group Cambridge Economic Policy Associates (CEPA).

In addition to the Annual Statutory Security of Supply Report and risk assessments detailed above, BEIS has published other policy and regulatory framework guides to follow in preparation and in the event of a natural gas supply emergency:

- UK Fuel Security Code (2019 revised)[86]
- National Emergency Plan (2019)[87]

[81] February 13, 2020. "British Gas owner Centrica hit by energy price cap." *The BBC.*

[82] Department for Business, Energy & Industrial Strategy. November 18, 2020. "The Ten Point Plan for a Green Industrial Revolution." *United Kingdom.*

[83] Department for Business, Energy & Industrial Strategy. December 2020. "Statutory Security of Supply Report 2020." *United Kingdom.*

[84] Department for Business, Energy & Industrial Strategy. October 2017. "Gas Security of Supply: A strategic assessment of Great Britain's gas security of supply." *United Kingdom.*

[85] Department for Business, Energy & Industrial Strategy. November 2018. "UK National Risk Assessment on Security of Gas Supply." *United Kingdom.*

[86] Department for Business, Energy & Industrial Strategy. November 6, 2019. "The Fuel Security Code." *United Kingdom.*

[87] Department for Business, Energy & Industrial Strategy. November 2019. "National Emergency Plan: Downstream Gas and Electricity." *United Kingdom.*

- National Preventive Action Plan (2019)[88]

In Great Britain, both the natural gas regulator (Ofgem) and main distributor (National Grid) outlined resiliency scenario assessments separate from the BEIS reports.[89] National Grid requires a 1-in-20 peak day resiliency scenario as part of its Gas Transporters license.[90] The UK natural gas system benefits from multiple viewpoints of resiliency at all levels of the energy distribution and transmission network.

Example 1: The UK's Changing Energy Relationship with the EU

Post-Brexit Energy Resilience: Prior to its departure from the European Union (EU), the UK was bound to the EU's energy laws and regulations. Many of the frameworks and guides published by BEIS were required in accordance with the European Union Regulation Security of Gas Supply 2017/1938, including the solidarity principle.

The Regulation also outlines a solidarity principle, where countries will supply neighboring countries with gas in cases of an extreme supply shortage. While the UK has benefited from the solidarity principle in the past, the EU is no longer bound to uphold this principle since the UK has left the EU. In addition, the UK is no longer required to release or update documentation published in accordance with the Regulation.

The UK has benefited from its partnership with the EU in the past, and its withdrawal from the EU is not expected to have a large impact on natural gas trade,[91] but further regulatory clarity is required moving forward.

Current Regulatory Framework to Support Energy System Resilience

The UK's primary strength for a resilient natural gas system is its diverse range of energy supply sources and its ability to rely on imports in times of high demand or supply stress.

Figure 4-3 shows where the UK stands in relation to EU countries in terms of self-sufficiency and diversity of supply. The UK shows it is considerably self-sufficient, due to high domestic natural gas production, but also benefits from a large range of supply sources (diversity index).

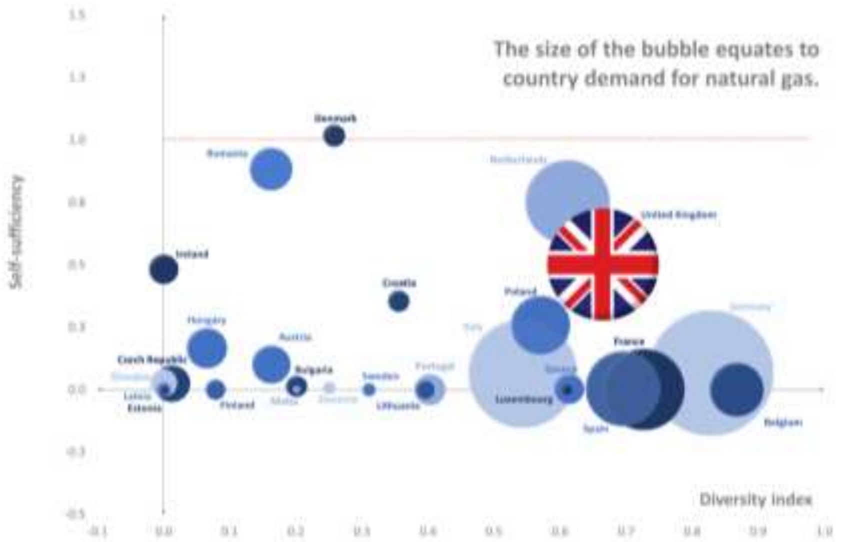
[88] Department for Business, Energy & Industrial Strategy. March 2019. "National Preventive Action Plan: Gas." *United Kingdom.*

[89] March 2017. "A review of gas security of supply within Great Britain's gas market – from the present to 2035: a report to the Department for Business, Energy & Industrial Strategy." *Ofgem.*

[90] Department for Business, Energy & Industrial Strategy. December 2020. "Statutory Security of Supply Report 2020." *United Kingdom.*

[91] December 24, 2020. "UK, EU agree to provisional post-Brexit trade agreement." *S&P Global Platts.*

Figure 4-3. Diversity and Self-Sufficiency Indices for Europe/UK Natural Gas Supply, 2019



Source: Department for Business, Energy & Industrial Strategy (UK)

Along with utilization, one of the first steps in the National Emergency Plan is to use available linepack, or the amount of natural gas in pipelines, to balance the demand.[92] Linepack is increasingly being used to balance the energy system, yet there are regulations on how much linepack can be changed during a single day.[93] The linepack performance measure (LPM) incentivizes National Grid to minimize differences in linepack volumes between the start and end of each gas day to standardize prices on the market.[94] This limits the amount linepack can be used to store natural gas in the system.

While the utilization of storage facilities is included in the National Emergency Plan, the UK does not operate natural gas storage as a "strategic reserve" of gas to be used only in emergencies. Instead, the UK sees the value of storage as a regulator on the natural gas market to respond to short-term price signals and to reduce price volatility. Compared to European countries, the UK is significantly behind on natural gas storage. The UK stores under 2% of its annual gas demand compared to 25% on average stored in other European countries (Figure 4-4).[95]

UK storage capacity decreased 70% in 2017 after the closure of the Rough storage facility to a current state of 1.5 bcm.[96] A further 5 bcm of potential capacity is held in projects in planning, though the lack of government incentives and the decrease in economic viability has left some

[92] Department for Business, Energy & Industrial Strategy. November 2019. "National Emergency Plan: Downstream Gas and Electricity." *United Kingdom.*

[93] Grant Wilson and Paul Rowley. May 2019. "Flexibility in Great Britain's gas networks: analysis of linepack and linepack flexibility using hourly data." *UK Energy Research Centre.*

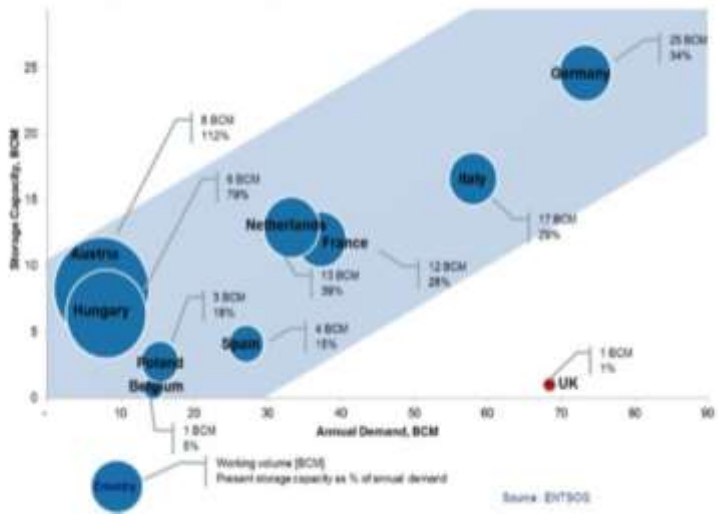
[94] January 2021. "National Grid Gas: System Operator Incentives." *National Grid Gas.*

[95] January 25, 2021. "The expense of 'just-in-time' gas imports over gas storage." *Storengy.*

[96] Anita Oluyede, Adam Brown, Angela Cheng, David Tennant, Gemma Dreelan, Rebecca Owen-Howes, and Sam Boileau. "At a glance: natural gas pipeline transportation and storage in United Kingdom." *Lexology*.

facilities in the planning stage for a decade, like Gateway, who's 1.5bcm gas storage project has been in development since 2010.

Figure 4-4. Storage Capacity and Annual Demand for European Countries, 2021



Source: Storengy

Gateway, along with operators of gas storage sites, reliant industries, and developers of new projects have been asking for an inquiry since they filed a letter to the government in 2017. They requested the government investigate the role of natural gas storage to the security of gas supply in the UK. The government stated it was up to the market to determine whether new investments were economical, but they will continue to monitor the situation and utility of gas storage in the future.[97]

Regulatory and Market Support for Gas Infrastructure Investment

The UK natural gas market operates on a range of regulations and incentives, many of which are managed by Ofgem, to ensure consumers are charged a fair amount and to encourage responsible investment in reliable capacity and future technologies.

Regulatory Support for Innovation:

RIIO (Revenue = Incentives + Innovation + Outputs) is the main regulatory model operated by Ofgem. Using a price control framework, RIIO appraises energy companies' business plans, regulates the amount of revenue a company can recover from their customers, and offers incentive programs for innovative investments. RIIO-2 is set to replace RIIO-1, which has been in effect since 2013, from 2021.

RIIO-2 will set a network price control, like RIIO-1, which ensures companies control the end cost to consumers while earning a fair return on their activities.[98] It also allocates £30bn of upfront investment for a "greener fairer energy system", with a potential £10bn of further

[97] Susanna Twidale. March 19, 2018. "Exclusive – Rough justice? UK snubs call for gas storage capacity review." *Reuters.*
[98] December 2020. "Energy network price controls: Overview of Final Determinations 2021-2026." *Ofgem.*

funding. Part of that allocation includes £660m of innovation funding to the Strategic Innovation Fund (SIF) and the Network Innovation Allowance (NIA). The NIA provides an annual allowance, based on a percentage of a company's revenue, for individual companies to fund innovative projects that create value for their customers.[99] The SIF is a separate, £450m fund that is awarded from 2021-2026 (with a possibility of extension) to companies with projects focusing on reaching the country's decarbonization and energy resiliency goals. The SIF will replace and improve upon the Network Innovation Competition (NIC), a component of RIIO-1, by focusing on commercialization and reduce the administrative and financial cost of applying.

In the past, National Grid has utilized both NIC and NIA funds to support innovation projects, though they were focused mainly on hydrogen adoption and storage, infrastructure digitization, and risk assessments, with no projects thus far on natural gas storage or resiliency efforts.

Example 2: National Grid at Odds with Regulator Ofgem
Conflicting Priorities: National Grid rebutted points in the draft RIIO-2 determinations released by Ofgem in July 2020, stating the new price control pan would prohibit the company from meeting both its business and the country's Net Zero goals.[100] The proposed annual allowances were 37% lower than their proposed business plan budget and 10% less than what they spent on RIIO-1 measures. National Grid claimed Ofgem did not allocate enough funding to meet its legislative requirements, and, with most of its innovation projects not applicable to the new SIF program, had a lack of funding to cover its current projects. Ofgem plans to release the finalized RIIO-2 network price control plan in 2022.

In addition to the RIIO plan, Ofgem operates a Gas System Operator (GSO) incentive program that rewards companies when their actual costs are below their cost targets and penalizes companies when they are above their targets, encouraging companies to stay within budget and set realistic cost targets.[101]

Wholesale and Forward Gas Markets:

The UK has traditionally depended on wholesale and futures market demand and price signals to drive investment in natural gas infrastructure. However, natural gas storage facilities have become increasingly uneconomic. The variation of wholesale and futures gas prices over time are key to storage economics, where many storage facilities purchase large quantities of gas in the summer to resell in the winter during higher demand. Seasonal volatility in the market has declined due to the diversity of supply sources and increased infrastructure capacity, which has prompted the closure of several storage facilities and in part, prevented new facilities from being built.[102]

Capacity Market:

The Capacity Market, one of Ofgem's regulatory programs, was introduced in 2014 to encourage sufficient investment in reliable capacity and to ensure energy consumption meets demand as more unpredictable renewable energy generations sources are introduced to the

[99] "Network Innovation Allowance (NIA)." *National Grid.*

[100] "Our RIIO-2 business plan (2021-2026)." *National Grid.*

[101] "Gas System Operator (GSO) regulation." *Ofgem.*

[102] Department for Business, Energy & Industrial Strategy. December 2020. "Statutory Security of Supply Report 2020." *United Kingdom.*

energy market.[103] Earlier in 2021, the government awarded £350m for new gas power stations, and historically, the Capacity Market has allocated a majority of its funding to gas over other fuel sources.[104]

The BEIS wants to align the Capacity Market with net zero goals and increasing security of supply challenges and plans to publish a statutory review of the Capacity Market by 2024. In their preliminary call for evidence, the BEIS recognized the need for gas storage facilities to complement renewables in the future and recommended possible modifications to the Capacity Market, including changing agreement lengths, potential low carbon split auctions, and strengthening incentives, to reduce or remove barrier to low-carbon technologies into the Capacity Market.[105]

Reliance on Imports for Energy System Resilience

With a dependence on natural gas in place until at least 2035, the UK seeks alternative supply sources as its domestic production of natural gas decreases. The UK government stated that sustained high prices and/or market demand would be required to drive investment in new gas storage or the expansion of interconnector capacity, even while some import infrastructure currently runs close to full capacity at times, such as Norwegian imports (the most significant contributor of natural gas imports) during the winter months.[106] However, the UK claims it has import infrastructure with the capacity to meet more than an 80% increase in their annual demand.[107]

Instead of active investments and incentives into infrastructure development, the UK plans to supplement decreased domestic production with pipeline and LNG imports while exploring other domestic production options, such as shale, despite this running contrary to the country's decarbonization goals.[108]

Key Takeaways

While currently resilient to most extreme cases, UK's natural gas market is hitting a regulatory divide: natural gas is projected to be an important energy source until at least 2035 with increased domestic consumption but there are no clear regulations or policy in place to invest in new natural gas infrastructure to support energy system resiliency.

Natural gas is becoming increasingly unprofitable in the UK, with energy suppliers taking revenue cuts from regulatory price caps despite rising energy costs and a lack of government subsidies to support new capacity investment. Gas suppliers could apply for innovation funding to source capital funding for resiliency projects. However, as the country's policies and regulations are becoming increasingly focused on its decarbonization goals, gas suppliers could run into difficulty in being allocated funding in a competitive environment where digital and low-

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[103] "Understanding the Capacity Market." *Engie.*

[104] Grace Alster. March 12, 2021. "UK spent £350m on new gas power despite nearing fossil phase-out." *Ember.*

[105] Department for Business, Energy & Industrial Strategy. July 2021. "Capacity Market: Improving delivery assurance and early action to align with net zero – Call for Evidence." *United Kingdom.*

[106] Department for Business, Energy & Industrial Strategy. October 2017. "Gas Security of Supply: A strategic assessment of Great Britain's gas security of supply." *United Kingdom.*

[107] Department for Business, Energy & Industrial Strategy. November 2018. "UK National Risk Assessment on Security of Gas Supply." *United Kingdom.*

[108] Department for Business, Energy & Industrial Strategy. November 18, 2020. "The Ten Point Plan for a Green Industrial Revolution." *United Kingdom.*

carbon solutions are rewarded. As the Capacity Market opens up to lower-carbon alternatives, gas energy suppliers could make the case to win allocation to firm intermittent renewable energy capacity.

Current UK gas resiliency is supported by a diverse range of supply sources, but with UK domestic production expected to continue decreasing in the coming years, the UK will have to balance an increase in projected pipeline and LNG imports with its hefty decarbonization targets.

Case Study 2: Australia's Natural Gas Resilience System

Key Finding

Due to the rise of liquified natural gas (LNG) exports, the Australian gas market has been grappling with competing demand from both domestic consumers and international markets. With the depletion of gas basins and lack of capacity on the internal gas market, the government and industry are now looking for other sources by exploring new fields for domestic production, increasing LNG imports, expanding pipeline capacity, and further utilizing storage facilities.

Government regulations and incentives have created an environment that highlights the importance of natural gas to the Australian energy system. Mechanisms such as the Australian Domestic Gas Security Mechanism and the Gas Supply Guarantee permit the reallocation of gas in emergency situations, such as diverting LNG from export to domestic buyers and allotting gas to the National Electricity Market during extreme weather events. To incentivize continued investment, the government recently announced a $53m Gas-Fired Recovery Plan aimed at securing reliable and resilient natural gas supply in Australia.

The Australian Natural Gas Market

Natural gas continues to be a critical resource in Australia's energy system and economy. As one of the top twenty global producers of natural gas, Australian production accounts for nearly all domestic consumption while contributing a substantial export volume to the international community, particularly in the Asian market. 70% of gas produced in Australia is converted to liquified natural gas (LNG) for export and the balance is sold to the domestic market, where a majority is distributed directly to customers and a fraction is stored to augment supply at peak times.[109] Natural gas storage facilities can be smaller seasonal storage facilities located near demand centers, short-term peak storage services on gas pipelines, or large storage facilities in depleted gas fields.

In South Australia, natural gas accounted for 35% of the primary energy consumption and 43% of eastern Australian gas-powered generation demand in 2020.[110] Liquified natural gas (LNG) provides 73% of domestic annual gas consumption, with the remainder filled by natural gas

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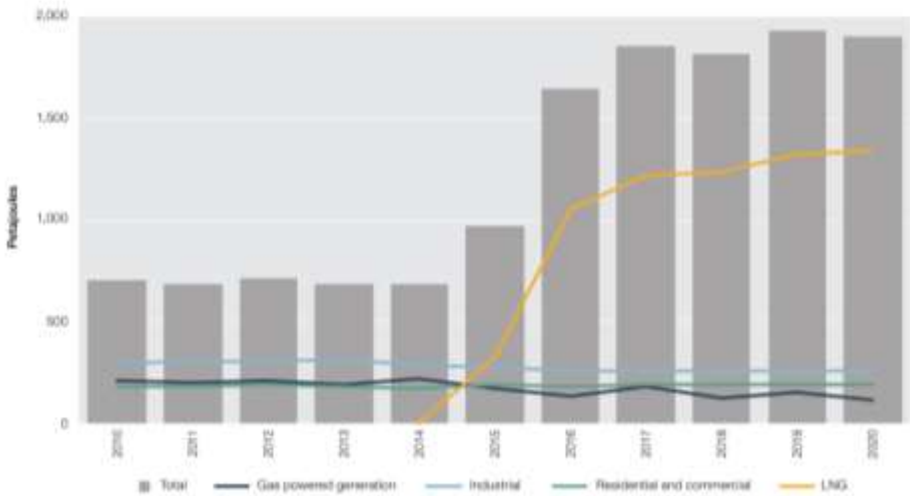
[109] Commonwealth of Australia. 2021. "State of the energy market 2021." *Australian Energy Regulator*.
[110] Commonwealth of Australia. 2021. "State of the energy market 2021." *Australian Energy Regulator*.

sourced from storage facilities and gas basins.[111] Figure 4-5 shows the rise and sustained demand of LNG in eastern Australia over the past decade.

Figure 4-5. Natural Gas Demand in Eastern Australia, 2010-2021



Source: Australian Energy Market Operator (AEMO)

Gas demand varies significantly by region due to climatic differences. Australia's natural gas market is separated into three regions based on the gas basins and the pipelines that supply them. The eastern Australian region (which includes Queensland, New South Wales (NSW), Victoria, South Australia, Tasmania, and the Australian Capital Territory (ACT)) is the primary market for natural gas in the country and has pronounced seasonal demand differences, especially in South Australia and Victoria.[112] The Queensland liquified natural gas (LNG) hub services several major Australian cities (i.e. Sydney, Brisbane, Melbourne) in the eastern Australia region. The northern gas region (Northern Territory) is the smallest producer and provides gas for both domestic consumption and exports. The western gas region (Western Australia) contains over half of the nation's gas reserves and is primarily focused on exports.[113]

For the past six years, Australia has dealt with the challenge of competing demand from both domestic consumers and international markets. With the introduction of Queensland's LNG export industry in 2015, Australia experienced a significant increase in international LNG demand and quickly became the world's largest LNG exporter.

By 2018, over 80% of eastern Australian gas production was being exported[114] and it contributed $47 billion to the economy in 2019-20.[115]

Increased LNG exports have caused volatility in international gas prices over the past few years. Domestic users compete with overseas customers to buy Australian gas, causing

[111] Clyde Russell. March 25, 2021. "Column: Australia's natural gas industry frets about supply. They should worry about demand." *Reuters.*

[112] Department of Industry, Science, Energy and Resources. "Gas markets." *Australian Government.*

[113] "Gas markets." *Australian Energy Market Commission.*

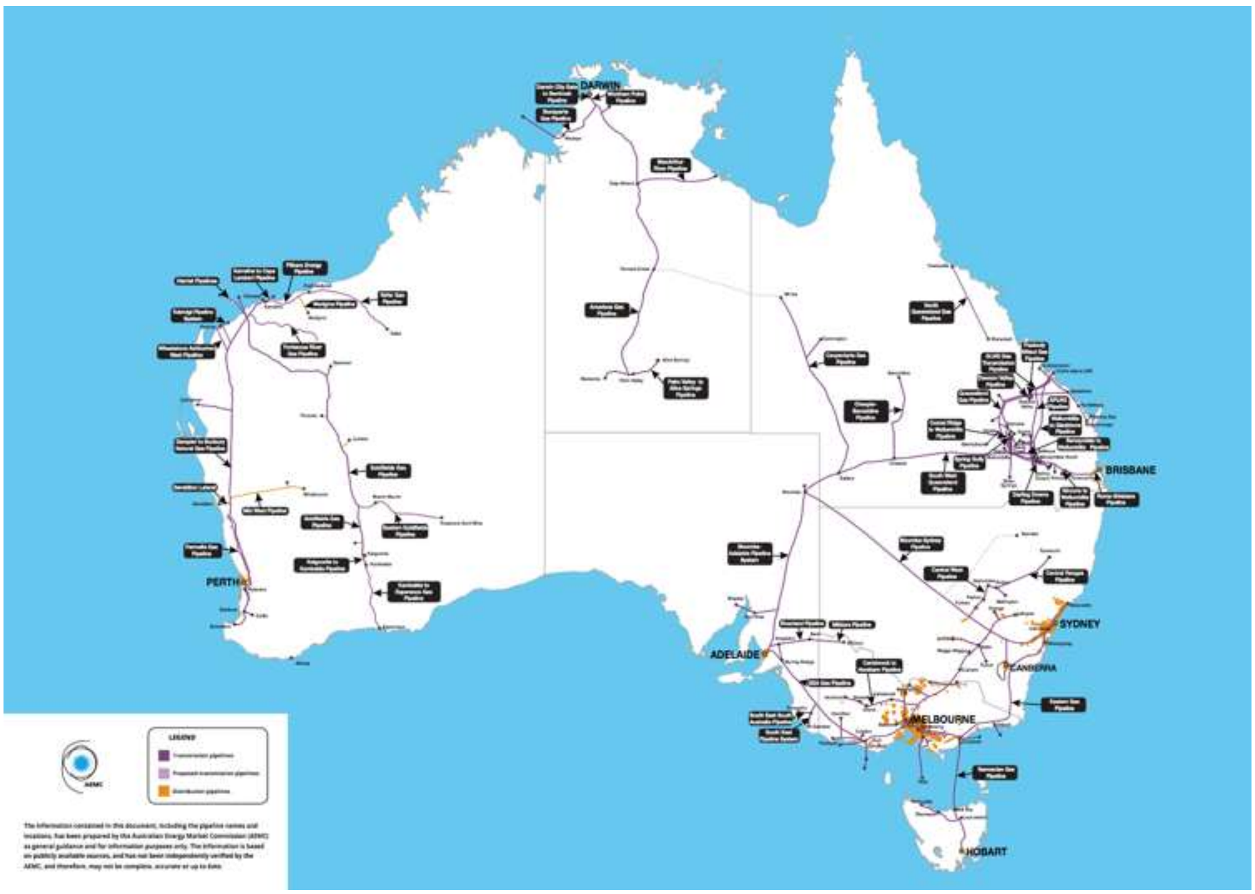
[114] Commonwealth of Australia. 2021. "State of the energy market 2021." *Australian Energy Regulator*.

[115] September 2020. "Gas Vision 2050: Delivering a Clean Energy Future." Australian Pipelines and Gas Association.

domestic and international gas prices to align. However, domestic prices have stabilized from the ability to purchase low or zero-cost pipeline capacity during regional supply-demand differences. Retail gas prices have also fallen in most regions since 2018 because of lower wholesale gas costs. In addition, energy providers have come under recent reforms to standardize energy offers, resulting in more straightforward pricing for consumers.[116]

The wholesale natural gas market is overseen nationally by the Australian government and the Department of Industry, Science, Energy, and Resources and regionally by individual state governments. Production and processing infrastructure is owned by private companies. The transmission sector is privately owned as well, with the APA Group being the largest operator. Distribution in Australia is separated by region, where several companies can operate in each region. Some major distributors include the Australian Gas Networks, which operate in Queensland, Victoria, and South Australia, and Jemena Gas Networks, which operate in New South Wales. Figure 4-6 shows the transmission pipelines in Australia.

Figure 4-6. Australia's Gas Transmission Network



Source: Australian Energy Market Commission

[116] Commonwealth of Australia. 2021. "State of the energy market 2021." *Australian Energy Regulator*.

Table 4-1 details the responsibilities of the organizations that regulate and operate the natural gas market in Australia.

Table 4-1. Australian Natural Gas Regulators and Operators

Key Market Players	Financial Impact
Australian Energy Market Commission (AEMC)	Develops rules for the market, including the National Gas Law and National Gas Rules which provide a framework of regulation and gas pipeline services.
Australian Energy Market Operator (AEMO)	Operates the wholesale markets in southern and eastern Australia.
Australian Energy Regulator (AER)	Holds regulatory responsibilities across the entire gas supply chain in eastern Australia and pipelines in the northern territory. Ensure participants in the market comply with the National Gas Law and Rules.
Australian Competition and Consumer Commissions (ACCC)	Regulates competition in the market and operates at a national scale.
Economics Regulation Authority	Regulates gas markets and pipelines in western Australia.

Source: Guidehouse

Australia has committed to several international climate agreements, such as the 2030 Paris Climate Agreement, and has multiple national initiatives to promote renewable energy and emission reduction strategies, such as transitioning to a hydrogen economy.[117] Almost all the states in Australia have a net-zero emissions target to be achieved by 2050.[118]

Resilience Policy and Regulations

Due to a robust domestic supply source, Australia has not had a natural gas emergency in over 40 years. In the past five years, the government, regulators, market operators, and infrastructure owners and operators have produced increasing amounts of documentation and strategies meant to address the issue of future gas resiliency.

Recent extreme weather events like fires, heat waves, and storms have called the future stability of Australia's natural gas system into question. AEMO recently called for enhanced energy system resilience in 2020 after a prior season of extreme bushfires, record high temperatures, smoke, and dust affecting energy operations.[119]

[117] Commonwealth of Australia. 2021. "State of the energy market 2021." *Australian Energy Regulator*.
[118] Sanja Pekic. February 8, 2021. "Australian LNG export revenue down 25 percent in 2020." *Offshore Energy*.
[119] June 6, 2020. "2019-20 summer highlights need for enhanced energy system resilience." *Australian Energy Market Operator.*

The Australian Department of Industry, Science, Energy, and Resources plays a critical role in maintaining gas supplies in emergency cases by coordinating responses between state governments, the AEMO, and regulators. However, many of their emergency management systems are focused on the national electricity system rather than the natural gas distribution and transmission network.[120] The government has set regulations in place to safeguard national resiliency with the recent increase in LNG exports and limited domestic natural gas supply.

The Australian Domestic Gas Security Mechanism was implemented in 2017 which allowed the government to require LNG projects to limit exports if a supply shortfall was likely.[121] To avoid export controls, Queensland's LNG producers have entered into a series of agreements with the government since 2017. One such agreement in 2020 requires uncontracted gas to be offered to domestic buyers on competitive terms before being offered for export. The Australian government also has a nationwide climate resilience and adaptation strategy in place, but it does not currently outline specific measures related to energy resilience, though a revised strategy is expected to come out in late 2021.[122]

Regulators hold a key role in monitoring the gas market's reliability and resiliency. The AER releases an annual report on Australia's gas markets called the State of the Energy Market, which aggregates information on current industry conditions, market demand and supply, and requirements for future industry stability.[123] The ACCC is conducting a gas inquiry from 2017-2025 into the supply and demand of gas in Australia and releases interim reports annually. AEMO publishes an annual Gas Statement of Opportunities, in accordance with the National Gas Law and Rules, that reports on the ability for the industry to meet demands in the future and provides their forecast of annual gas consumption and maximum gas demand.[124] It also analyzes four scenarios for the future of gas to determine system security and supply risks, including a hydrogen and low gas price scenario.

All these reports show that Australia is currently resilient to extreme weather events or supply shortfalls due to its substantial domestic natural gas supply, but a significant shortfall in natural gas is expected in the next decade due to the depletion of natural gas basins, high LNG exports, and limited pipeline capacity.

AEMO holds a significant role in monitoring the natural gas industry for future resiliency, preparing for an emergency gas event, and aiding in the event of an emergency. At the national level, AEMO manages supply disruptions in the short-term trading markets and organizes the National Gas Emergency Response Advisory Committee (NGERAC), which advises governments on the response to and management of major gas supply interruptions.[125] AEMO also has a Victoria state-specific strategy (due to the state's different wholesale gas market setup), including a Gas Emergency Protocol, which outlines steps to be taken in a gas supply emergency, and the organization of several committees that formulate strategic plans and coordinate with the government and industry to respond to an emergency.[126]

[120] Department of industry, Science, Energy and Resources. "Energy supply emergency management in Australia." *Australian Government.*

[121] Commonwealth of Australia. 2021. "State of the energy market 2021." *Australian Energy Regulator*.

[122] Department of Agriculture, Water and the Environment. "National Climate Resilience and Adaptation Strategy." *Australian Government.*

[123] Commonwealth of Australia. 2021. "State of the energy market 2021." *Australian Energy Regulator*.

[124] January 2021. "Gas inquiry 2017-2025: interim report." *Australian Competition & Consumer Commission.*

[125] "Emergency Management: National role." *Australian Energy Market Operator.*

[126] "Emergency Management: Victorian role." *Australian Energy Market Operator.*

Lastly, the Gas Supply Guarantee was developed by facility and pipeline operators to ensure enough gas is available to meet peak demand periods on the National Electricity Market (NEM), such as making extra gas available to gas-fired generators during extreme heat waves.[127] The Trusted Information Sharing Network is an information-sharing platform that allows infrastructure owners and operators to share information on vulnerabilities and collaborate on measures to mitigate risk and boost resiliency.

Market Support for Natural Gas Resilience

The Australian natural gas market operates on a range of regulations and investment incentives to ensure current and future reliability and resiliency.

Wholesale Market Structure:

Outside of Victoria, the natural gas market operates via gas supply and short-term trading hubs. In gas supply hubs, pipeline capacity is managed through contractual obligations between the operator and user, where pipeline users can also trade their contracted pipeline capacity between themselves on the market.[128] Short-term trading market hubs allow parties to facilitate short-term trades without contracts. Most gas sales in eastern Australia are under confidential contracts, while 10-20% trade in spot (short-term) markets, which allows flexibility when demand does meet the user's allocated capacity. Victoria trades on a declared wholesale gas market, where AEMO manages pipeline capacity by offering gas up for bidding on the market. The AEMC wants Australia to transition to a single market to decrease complexity and remove inhibitions of trading between regions.[129]

The spot market structure offered outside of Victoria enables operators to buy short-term contracts to mediate supply constraints, while inside Victoria, AEMO can step in and regulate operator bids in case of a gas supply emergency. This allows for flexibility between distributors and transmission networks to deliver gas during supply risk situations.

Example 3: Nationwide Initiatives to Provide Accurate Energy Data

A Transparent System: The Gas Bulletin Board provides current information on gas production, storage, and transmission in eastern Australian and is monitored by the AER for compliance. The Australian government national science agency, the Commonwealth Scientific and Industrial Research Organization (CSIRO), also established the Gas Industry Social and Environmental Research Alliance, which is a nation-wide collaboration to publish publicly reported independent research on the gas industry.[130] Working with the Energy National Cabinet Reform Committee, the government is considering new measures that require even greater transparency around the energy market.[131]

[127] March 11, 2021. "Stakeholder submissions invited on review of the Gas Supply Guarantee." *Australian Energy Market Commission.*

[128] "Gas markets." *Australian Energy Market Commission.*

[129] Commonwealth of Australia. 2021. "State of the energy market 2021." *Australian Energy Regulator*.

[130] October 2020. "The role of gas in South Australia." *Gas Industry Social and Environmental Research Alliance.*

[131] Department of Industry, Science, Energy and Resources. "Gas markets." *Australian Government.*

Current and Future Energy System Resilience

Resiliency is highly dependent on region in Australia, where some regions, like Victoria and South Australia, require higher levels of resiliency than others due to seasonal natural gas demand. For current emergency fuel supply situations, LNG is redirected from international exports to domestic consumption. The northern territory LNG projects are connected to the grid for emergency use, but otherwise solely export natural gas.[132]

Natural gas storage also offers a resilient supply source for Australia. The government, regulators, and industry have all recognized the important role of gas storage to stabilize the natural gas system by offering emergency supply and supplement to the electricity system by balancing out the variability of renewable energy sources. Some storage facilities, like the Dandenong LNG storage facility in Victoria, are used to store small amounts of gas to be injected quickly into the market to address short-term peaks and system security issues [11]. Other storage facilities, like the Iona underground storage facility, store large amounts of gas during the summer mounts and are relied upon to meet maximum winter demand.[133]

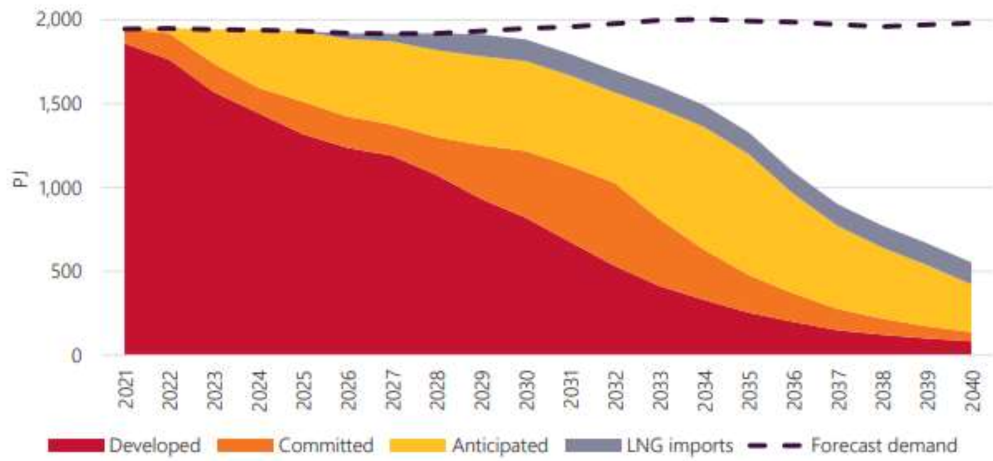
From 2017 to 2019, the gas system successively drew on more storage each year to help meet supply peak and seasonal demands.[134] To further secure their own supply risks, some large gas customers have secured their own storage capacity, such as AGL contracting use of a storage facility to meet seasonal demand in January 2021.[135]

Forecasts from the government and regulators have all shown supply shortage risks in the coming decade. Consensus from the industry, regulators, and the government agree that LNG import projects, expanded or new storage facilities, and/or the expansion of pipeline infrastructure are key avenues to secure future supply security. Not only does the National Gas Infrastructure Plan outline these options, but AEMO and the ACCC have identified risk mitigation projects, such as expanding key pipelines linking east coast markets by 25% and developing five LNG import terminals under consideration in NSW, Victoria, and South Australia.

In addition, the APA announced they were investigating whether delivery capacity from the northern fields to southern markets could be increased by adding compression to pipelines. The industry is investing in new infrastructure, with full regulation transmission pipelines forecasted to invest a total of $332m in 2020. [136] If committed and anticipated projects are developed (which includes new LNG projects, new exploration of domestic natural gas reserves, and expanded storage facilities), there is enough supply to cover seasonal demand requirements and extreme peak conditions until at least 2029 [Figure 4-7].

Figure 4-7. Projected Eastern and South-Eastern Australian Gas Production, 2021-2040

[132] Commonwealth of Australia. 2021. "State of the energy market 2021." *Australian Energy Regulator*
[133] January 2021. "Gas inquiry 2017-2025: interim report." *Australian Competition & Consumer Commission.*
[134] March 2021. "Gas Statement of Opportunities." *Australian Energy Market Operator.*
[135] Commonwealth of Australia. 2021. "State of the energy market 2021." *Australian Energy Regulator*
[136] Commonwealth of Australia. 2021. "State of the energy market 2021." *Australian Energy Regulator*



Source: Australian Energy Market Operator

Example 4: Potential Southern Supply Shortfalls in Winter 2023

Near-Term Supply Security: Originally, forecasts from regulators including AEMO and the AER noted a potential supply shortfall by the winter of 2023 due to the depletion of the last major southern gas field offering flexible supply. Gas supply forecasts have improved recently because of the commitment to develop the first LNG import terminal (Port Kembla Gas Terminal (PKGT) in New South Wales), deferring gas shortfall forecasts to at least 2026 provided gas from PKGT is first delivered ahead of winter 2023. If the project is delayed, southern supply could risk shortfalls for winter 2023 under certain conditions, like an extreme 1-in-20 maximum winter daily demand in Victoria, increased demand for gas-powered generation caused by events on the NEM, coinciding demand peaks across southern regions, or gas production outages.[137]

Reliance on gas pipelines and storage has been increasing, and projected to continue increasing, in response to declining traditional gas supply sources. Increase in annual production is not being met with further expansion on existing pipeline infrastructure, which may limit gas delivery in the southern region during peak demand periods. Without further pipeline expansion, the ability for gas from the Iona underground storage and for redirected, otherwise-exported gas from the northern regions to be supplied to the southern regions in times of shortfalls would be extremely limited. This would make it unlikely for these strategies to be effective in maintaining gas security. Even with the clear need for improved and expanded infrastructure, low gas prices have created a challenging investment environment for new production infrastructure.[138]

Natural gas is also a resiliency strategy on the NEM, responding to variations in renewable energy generation or extreme cold snaps. Over time, gas-powered generation demand is projected to peak in the winter instead of summer, further stressing a system that is already under supply risks in the winter.[139]

[137] March 2021. "Gas Statement of Opportunities." *Australian Energy Market Operator.*
[138] March 2021. "Gas Statement of Opportunities." *Australian Energy Market Operator.*
[139] March 2021. "Gas Statement of Opportunities." *Australian Energy Market Operator.*

Government Support for Gas Infrastructure Investment

In response to COVID-19's impact on the economy and the forecasted lack of natural gas supply, the government released the Gas-Fired Recovery Plan in 2020 that identified natural gas as a means to reviving the Australian economy. The plan allocated $52.9m in funding support to implement the plan, including support to the CSIRO's Gas Industry Social and Environmental Research Alliance and execution of the Gas Infrastructure Plan.[140] Individual state governments, including South Australia and NSW, also have plans to unlock additional gas supply.[141]

Through the Gas-Fired Recovery Plan, the government plans to identify and invest in critical infrastructure if private sector investment is not forthcoming. It includes $38.7m for critical gas infrastructure projects and $3.5m for developing a long-term Future Gas Infrastructure Investment Framework.

In addition, the Australian government launched the Gas Acceleration Program in 2017 that, with a total budget of $26m, offered grants of up to $6m for projects that increase domestic gas flows in the eastern market by June 30, 2020.[142] Projects are currently in progress and a progress report is expected in 2021-22.

[140] Department of Industry, Science, Energy and Resources. "Gas markets." *Australian Government.*
[141] Commonwealth of Australia. 2021. "State of the energy market 2021." *Australian Energy Regulator*
[142] Commonwealth of Australia. 2021. "State of the energy market 2021." *Australian Energy Regulator*