GTI ENERGY

NZIP

The Role of Natural Gas Infrastructure in A Decarbonized Future

GTI Energy launched the Net Zero Infrastructure Program (NZIP) in June of 2023. NZIP is a collaborative research effort among 25 companies, supported by a diverse array of environmental NGOs, investors, and academics focused on evaluating the role of natural gas infrastructure in reaching the nationwide net-zero goals affordably and sustainably. Because of the challenges and length of time to build new energy infrastructure, ***energy systems of the future must capitalize on the infrastructure of today to meet decarbonization targets***.

Gas Infrastructure Decarbonization Pathways

Given the urgency to make meaningful progress on decarbonization, it is imperative to leverage what is in place today while expanded infrastructure is being permitted, financed, and developed. The current natural gas delivery network includes a variety of inter- and intra-state pipelines, processing facilities, and underground storage sites (Figure 1). These networks have grown to three million miles in transmission and distribution pipelines and nearly five trillion cubic feet in underground storage capacities across the U.S. over the last century.[1]

As a result of the expansiveness of natural gas infrastructure, there are several opportunities to utilize existing natural gas networks to transport and store renewable and low-carbon gases, thereby establishing long-term decarbonization solutions in the United States.

Towards this objective, NZIP is researching decarbonization pathways that can utilize existing gas infrastructure to enable and potentially accelerate low-carbon solutions. We ground our research on the following fundamental aspects:

- Modernization efforts are already underway to future proof existing natural gas infrastructure, including by replacing older materials, reducing emissions across the system, and increasing the lifespan of the current infrastructure by making the system compatible with low-carbon fuel sources.
- The unmatched efficiency of fuel pipeline delivery networks makes natural gas systems strong candidates for utilization in future U.S. energy systems. Further integration of the electric and natural gas systems will accelerate decarbonization goals, to ensure continued reliability for consumers and support an economically stable energy transition.

[1] U.S. EIA, 2024. Natural gas explained: Natural gas pipelines. Source

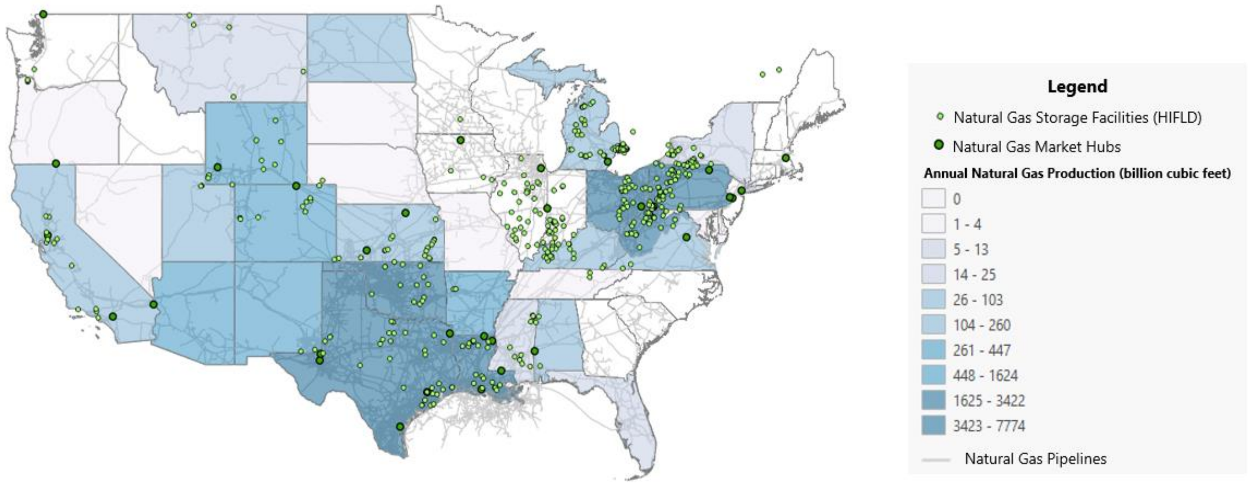

Figure 1: Natural Gas Infrastructure Pipeline & Storage in the United States

Modernization of the Grid

Natural gas infrastructure growth shares a similar timeline with the growth of electric infrastructure in the United States, with legacy materials still in use in both systems. Older pipeline materials installed in natural gas delivery systems, like cast and wrought iron as well as unprotected steel, are susceptible to premature corrosion.

In 2011, the Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA) initiated a call to expedite the replacement and repair of cast iron and bare steel pipelines.[2] As a result, numerous natural gas utilities have already initiated extensive pipeline replacement programs to reduce the number of aging materials in transmission and distribution segments and incorporate corrosion protection methods. Natural gas pipeline replacement programs have succeeded in reducing cast and wrought iron gas distribution main miles by over 50% from 2005 to 2022, To date, 22 states have eliminated cast-iron pipes in their natural gas distribution systems.[3]

Natural gas pipeline replacements currently far exceed pipeline expansions and new pipeline developments. Through its maintenance and replacement programs, PHMSA distributed nearly

[2] U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration, 2024. Pipeline Replacement Background. Source

[3] U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration, Cast and Wrought Iron Inventory, 2024. Source

$400M to publicly and community owned natural gas systems.[4] Replacing all pipelines is projected to cost around $270B, and natural gas utilities invest $32B annually to improve the distribution network's safety.[5]

Emissions management practices of natural gas delivery segments, such as pipeline replacement and modernization, support the development of future decarbonization pathways. Existing upgraded networks and best-in-class operation practices can efficiently, sustainably, and safely deliver alternative energy carriers to future end users, with their upgrades, maintenance, and emphasis on leak detection. Major emission reductions from 1990 to 2021 were observed across Transmission, Storage, and Distribution systems, which saw significant decreases in emissions, from 31%, and 70%, respectively.[6]

Embracing the replacement of aging pipelines is a crucial step toward mitigating emissions and improving the efficiency of the existing natural gas infrastructure. Pipelines remain the most affordable and efficient way to transport liquid and gaseous fuels, exceeding the capabilities of alternative modes like rail or barge transportation. Currently, the U.S. natural gas infrastructure system facilitates the delivery of around 36% of total U.S. primary energy supply. For the U.S. to achieve net-zero emissions, multiple net-zero scenarios show that pipeline gas produced via low-carbon approaches (i.e., bioenergy such as RNG, synthetic fuels with hydrogen and carbon dioxide as feedstock, and production pathways coupled with CCUS, etc.) are still needed by 2050. Findings from the Meta Analysis of U.S. Economy-Wide Decarbonization Studies report demonstrate that gas infrastructure systems will continue to play a critical role in net-zero energy systems. Prioritizing, and strategically investing in the modernization of U.S. gas infrastructure builds a foundation for incorporating emerging fuels and technologies while continuing to ensure the safe, reliable and efficient delivery of energy.

The electric grid has not experienced the same maintenance trajectory as natural gas infrastructure in the United States. An estimated 140,000 miles of electric transmission lines will require replacements over the next three decades.[7] The current state of the electric grid has also affected the rate of renewable electricity interconnections and potential for increased consumption of electricity due to the increased use of electrification in transportation and other uses. Due to the aging electric grid, an estimated 1,250 GW from renewable sources may take years to be integrated.[8]

It is estimated that the total cost to upgrade electric infrastructure in United States will be roughly $5 trillion dollars, just to maintain reliability at current demand levels.[9] In addition to the

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[4] U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration, 2024. "Biden-Harris Administration Announces $392 Million In Grants to Fix Old, Leaky Natural Gas Pipes, Improve Public Safety, and Reduce Energy Costs". Source

[5] Business Roundtable, 2024. Natural Gas Infrastructure. Source

[6] U.S. EPA, 2024. Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2021. Source

[7] Oliver Wyman, 2024. "Modernizing Aging Transmission". Source

[8] Duke University, 2024. "Electric gridlock: aging U.S. infrastructure imperils the dawning age of "electrification of everything". Source

[9] The Conversation, 2017. "The old, dirty, creaky US electric grid would cost $5 trillion to replace. Where should infrastructure spending go?". Source

cost of maintenance, the Department of Energy estimates that the electric transmission infrastructure must grow by 60% to achieve the energy targets for 2030 and potentially triple electric transmission infrastructure needed by 2050.[10]

Infrastructure remains a key barrier for widespread electrification growth and to meet electrification-only decarbonization strategies. **A decarbonization strategy that combines electrification with utilization of the natural gas system will have a much higher chance of successful implementation because it will leverage the trillions of dollars of investments that have already been deployed into natural gas infrastructure.** Alternative fuels like renewable natural gas and hydrogen can use existing, modernized natural gas infrastructure and are produceable from a wide variety of feedstocks, and in some instances are a viable fuel source for power generation, offering emissions reductions when compared to fossil natural gas. Similarly, captured CO_2 from large industrial sources can be transported via existing pipelines to be delivered to CO_2 utilization and storage facilities. The incorporation of carbon capture, utilization, and storage (CCUS) is recognized as a decarbonization solution for major emitting industries, as well as an opportunity to decarbonize fuel production.

Perspectives on the Future of Energy Infrastructure

Increased electrification and the large-scale integration of renewable energy resources are needed to accelerate economy-wide decarbonization, but this poses urgent and complex challenges to the reliability of the electric grid system across the country.[11] The weather-dependency of clean energy resources does not provide the same reliability attributes and security of supply as the dispatchable fossil-based resources that they replace, which are facing clean energy policy and regulatory pressures to retire early. Driven by extreme weather events, electrification, industrial development and growth in data centers, grid systems are also facing faster-than-expected significant load growth and peak demand rates reversing the past 20 years of low or relatively flat growth.[12]

Upgrades, expansions, and increased maintenance efforts are required to prepare the electric grid for the next storm, but gas systems have a complementary role alongside large-scale electrification, and renewable energy generation, which can effectively mitigate fuel affordability and reliability concerns. Low natural gas prices and increased natural gas power generation capacity from new combined-cycle turbines have helped drive the 7% decline in U.S. electric power related emissions reductions in 2023 by displacing coal-fired power generation.[13] Gas-fired power generation enables the U.S. to meet increased electricity consumption, both during extreme cold weather as well as during the hot summer months. It is essential to acknowledge the interdependencies between natural gas and the electricity markets in the United States. There remain challenges with offsetting natural gas consumption with renewable sources for electricity generation, such as reliability and affordability, as noted by members of the Federal

[10] U.S. Department of Energy, 2022. Queued Up… But in Need of Transmission. Source
[11] MISO Energy, 2024. MISO's Response to the Reliability Imperative. Source
[12] Clean Grid Initiative, 2023. The Era of Flat Power Demand is Over. Source
[13] U.S. EIA, 2024. U.S. Energy-Related Carbon Dioxide Emissions. Source

Energy Regulatory Commission (FERC).[14] This reliability of natural gas is in part due to the interconnectivity of natural gas delivery networks, which can isolate the effects of service disruptions more easily than the electric grid.[15]

A decarbonized future that does not utilize natural gas infrastructure will also significantly reduce available flexible energy storage. The United States possesses around 5 trillion cubic feet (Tcf.) of natural gas storage capacity, with the capability to provide up to 20% of the total natural gas consumption in the cold season.[16] The continued integration of intermittent energy sources like wind and grid-scale photovoltaic electricity will require increased storage capacity particularly for flexible, high-deliverability storage solutions that underground storage facilities can provide.

Ensuring a variety of fuel options to U.S. energy consumers through the utilization of existing infrastructure can support economic stability, buffering against disruptions, including those caused by extreme weather events. Natural gas infrastructure is now being considered to transport renewable natural gas and molecules like CO_2, and hydrogen to diversify and decarbonize the energy systems, allowing the infrastructure in place today to provide a direct path to the energy consumers of tomorrow.

For more information, please visit the NZIP website to view the full whitepaper, *Natural Gas Infrastructure in the United States: Evolving Towards a Net-Zero Emissions Future*.

[14] National Rural Electric Cooperative Association, 2023.
[15] The Natural Gas Council, 2019. Reliable and Resilient. Source
[16] U.S. Department of Energy, U.S. Natural Gas Storage Capacity and Utilization Outlook, 2016. Source