Potential Hydrogen Blending Study

Gas Transformation & Planning

ISSUED: 01/26/2024

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EXECUTIVE SUMMARY

Progressing toward a clean energy future requires utilities to evaluate methane emission reduction strategies. Blending hydrogen into natural gas pipelines has the potential to be a long-term solution. Gas Transformation & Planning's 2023 Potential Hydrogen Blending Study aims to estimate the amount of hydrogen Central Hudson can blend into its existing infrastructure without any modifications.

Approximately 25% of the Central Hudson distribution system was modeled. A broad sample of the system considerations include the feed type, system pressure, system size, operating district, capacity, and dependent downstream systems. Each system was modeled using hydrogen blends of 0% (standard Natural Gas), 10%, 20%, 30%, 50%, and 80%. A 0-20% blending range was highlighted due to its current achievability and interchangeability restrictions. Some utilities have started delivering low blends to their customers through pilot projects. For example, Dominion Energy is currently delivering a 5% hydrogen blend to approximately 1,800 customers in Utah.[1] A maximum blend of 80% was selected due to its status as a potential pathway. The maximum downstream velocity and minimum system pressure were used to evaluate the feasibility of the blends for each system, where the limits are 70 feet per second (ft/s) and 50% of the maximum allowable operating pressure (MAOP), respectively. These parameters have been previously established as standards for gas planning and design, and were selected because system reliability would be compromised if they were surpassed.[2] Home weatherization, system demand reduction, and the Wobbe Index (a standardized index of interchangeability) affect end use (i.e., customer appliances) and were outside of the scope of this study.

Central Hudson gas quality data supports that when the Wobbe Index exceeds the interchangeability limit (approximately 20% blend), modification of end-use appliances would be required. Out of the 25 systems studied, 23 (92%) of the systems can run hydrogen, as they currently are in good standing compared to the criteria set limits. The systems that cannot currently support hydrogen have already been identified by previous system studies and reinforcement recommendations have been made. Eighteen systems can run up to a 20% hydrogen blend and nine systems can run up to an 80% blend. Velocity was the major limiting factor, causing 16 of the

[1] Dominion Energy, "Therm2 Hydrogen Blending Project", Dominion Energy, 2023, https://www.dominionenergy.com/projects-and-facilities/natural-gas-projects/hydrogen-blending-in-delta-utah.
[2] Gas Regulator Station Design Manual, Central Hudson Gas & Mechanical Engineering, Section 6.2.

systems (70%) to require modifications to the current pipeline. Five of the systems (20%) are also limited by minimum pressure. The upgrades necessary to improve the velocity of a system are more economical than to improve the system pressure. It can be concluded that maximum downstream velocity will be a more prevalent problem in working towards a full hydrogen network. This is due to the exponential growth in velocity compared to a relatively linear pressure drop.

This was a preliminary study to assess the hydrogen potential of the company's network in its current state based on the limitations previously noted. Following this preliminary study, a full network analysis should be performed for all systems to better understand the potential of hydrogen blending in Central Hudson's infrastructure.

SCOPE OF WORK

Introduction

Before the use of natural gas, coal gas was used for energy within Central Hudson's infrastructure. Coal gas consists of approximately 49% hydrogen and 28.5% methane[3]. Today, the use of natural gas is more prevalent, containing more than 85% methane. There are many benefits to the potential of injecting hydrogen into company pipelines. The primary benefit is the greenhouse gas (GHG) reduction potential. Water vapor is the only byproduct of burning hydrogen, eliminating emissions in a 100% hydrogen network. Research is currently being conducted to better understand the feasibility and safety of blending hydrogen into today's pipelines. Hydrogen blending is a key component of long-term emission reduction goals. Producing green hydrogen through electrolysis further increases GHG reductions. As a starting point, many utilities within the United States are running low-blend hydrogen pilot projects to assess the future potential. Additionally, injecting hydrogen leverages the company's existing infrastructure. This reduces cost as opposed to other methods requiring new infrastructure. This preliminary study aims to assess the thermal capacity of a representative selection of systems, providing insight on the effects of hydrogen on pipeline operation. Hydrogen blending was simulated from 0-80% hydrogen to methane, where 80% hydrogen blending is a feasible long-term pathway aligned with Central Hudson GHG reduction goals. Evaluating the network at a 20% blend demonstrates the capabilities of the system without the need for modification on end use equipment.

[3] National Grid and Atlantic Hydrogen, Inc., "Hydrogen-Enriched Natural Gas: Bridge to an Ultra-Low Carbon World", National Grid plc and Atlantic Hydrogen, Inc., 2009, https://www.osti.gov/etdeweb/servlets/purl/21396875.

Overview

The properties of hydrogen differ from those of methane, which impacts the behavior of the blended gas. Although hydrogen contains more energy per unit mass, it is much less dense than natural gas. This difference requires more flow of hydrogen to create an equivalent energy output. These properties result in an increase in velocity, a decrease in pressure, and a decrease in Wobbe number. Additionally, the increased heat from blending hydrogen with methane can affect the rate at which Nitrous Oxide (NOx), a byproduct of burning natural gas, is emitted.

For this study, the maximum downstream velocity and minimum system pressure were used to evaluate the feasibility of the blends for each system, where the limits are 70 feet per second (ft/s) and 50% of the maximum allowable operating pressure (MAOP), respectively. These factors were selected as criteria due to their effect on pipeline operation. A downstream velocity over 70 ft/s can affect the integrity of the pipeline due to its high speed. This will lead to erosion of the inside of the pipe over time. Additionally, noise pollution can affect the surrounding community. For pressure, a system operating below 50% MAOP risks losing pressure entirely. Loss of pressure represents that the pipeline has reached capacity. This is a preliminary study focused on the potential for hydrogen blending. Wobbe Index and NOx emissions were out of the scope of the study and were not accounted for in the assessment of feasibility.

Emissions

Research shows that blending hydrogen can potentially increase Nitrous Oxide (NOx) emissions. This is due to the increased temperature of the flame produced from hydrogen blending. This does not invalidate potential greenhouse gas reductions, but NOx emissions should be raised as an item of concern. For industrial uses, catalytic solutions can remove up to 95% of NOx emissions from flue gas.[4] For residential equipment, further research is required to assess the change in NOx emissions compared to natural gas. Simulations using natural gas data suggest that hydrogen blending can produce more NOx emissions in some gas boilers, but a majority of commonly used boilers do not.[5] This demonstrates the need for testing on residential equipment in order to create a list of approved devices, while also taking customer equipment into consideration when looking for potential electrolyzer locations. Research also recommends modification to NOx emissions accounting for improved reporting.

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[4] Mitsubishi Power, "Selective Catalytic Reduction (SCR) System," Mitsubishi Power, accessed December 15, 2023, https://power.mhi.com/products/aqcs/lineup/flue-gas-denitration.

[5] Wright, Madeleine L. and Lewis, Alastair C., "Emissions of NOx from blending of hydrogen and natural gas in space heating boilers," *Elementa: Science of the Anthropocene* 10, 1 (2022), https://online.ucpress.edu/elementa/article/10/1/00114/183173/Emissions-of-NOx-from-blending-of-hydrogen-and.

Interchangeability and Wobbe Index

$$Wobbe\ Number = \frac{Higher\ Heating\ Value}{Specific\ Gravity}$$

Equation 1: Wobbe Number

The Wobbe Index is commonly used to assess the interchangeability of different gases through a fixed orifice. Interchangeability is a measure of the degree to which combustion characteristics of one gas resemble those of another gas. Similarly to heating value, the Wobbe Index measures the combustion energy of the gas stream while also accounting for density. Since hydrogen requires more flow to achieve equivalent energy output relative to natural gas, it will lower the Wobbe Index of the blended mixture. Literature suggests customer appliances will be affected within +/- 4% of the current gas stream's Wobbe Number. The table below uses historical Central Hudson gas stream data to simulate the Wobbe Index at a 20% blend of hydrogen.

The simulation shows the Wobbe Number at a 20% blend is 1307 (Row 5), while the lower limit based on historical data is 1310. This reaffirms the literature findings, with the simulation differing by 0.23%. This data suggests investigating blending potential up to 20% hydrogen to assess the system's potential without needing to modify end use equipment.

Category	Value
Historic Central Hudson Average Wobbe	1364.827
Historic Central Hudson Interchangeability Range	+/- 54
Central Hudson Wobbe Index Lower Limit	1310.827
Synergi Calculated Wobbe (Natural Gas)	1363.16
Synergi Calculated Wobbe @ 20% Hydrogen Blend	1307.18

Table 1: Wobbe Index Data

Hydrogen Production

The production of hydrogen can be achieved in several different methods. The figure below reviews these different types of production and categorizes them into a color code.[6]

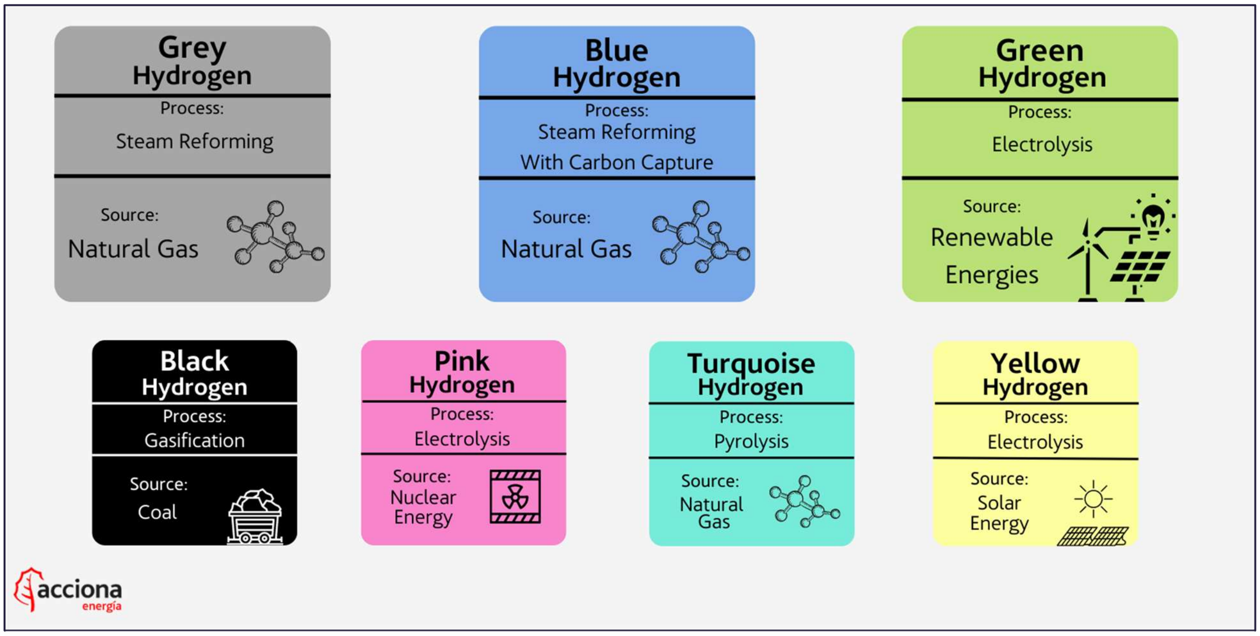

Figure 1: Hydrogen Production Types

The intention for Central Hudson would be to eventually obtain green hydrogen due to its clean production. Electrolysis is the process by which electricity (preferably from renewable energy) is used to separate hydrogen and oxygen from water. Central Hudson is planning to assess potential electrolyzer locations for the purpose of future hydrogen blending, as outlined in Central Hudson's 2023 Rate Case (Case 23-G).[7] Electrolyzers are a vetted and implemented technology for hydrogen production and are currently used for the production of ammonia.

[6] Acciona, "What Are The Colors of Hydrogen And What Do They Mean?", Acciona, June 16 2022, https://www.acciona.com.au/updates/stories/what-are-the-colours-of-hydrogen-and-what-do-they-mean/.
[7] Proceeding on Motion of the Commission as to the Rates, Charges, Rules and Regulations of Central Hudson Gas & Electric Corporation for Gas Service 2023, 23-G-IX-A.

SIMULATION

Sampling

A sample of 25 systems out of the total 94 have been selected for this potential study. The following categories were considered to ensure these systems accurately represent the Central Hudson Territory as a whole: feed type, system pressure, system size, operating district, and capacity. The table below represents the summary of these categories.

Category		Percentage of Sample
Maximum Allowable Operating Pressure	Low pressure	20%
	Medium Pressure	36%
	High Pressure	44%
Type of Feed	Radial Fed	24%
	Multi Fed	76%
Dependent Downstream Systems	Includes downstream system	29%
	Does not include downstream system	71%
District	Poughkeepsie	24%
	Newburgh	28%
	Fishkill	20%
	Kingston	20%
	Catskill	8%
Size	Small (<75,000')	36%
	Medium (Between 75,000' and 200,000')	44%
	Large (>200,000')	20%
Capacity	Above 50% MAOP	92%
	Below 50% MAOP	8%

Table 2: System Sampling

Although this sample should be an accurate representation of the whole territory, a full network analysis should be performed for all systems to better understand the potential of hydrogen blending in Central Hudson's infrastructure.

Modeling

Synergi Gas 4.9 is a simulation tool that can analyze a gas system's quantitative data such as pressure, velocity, gas flow, and utilization factors of regulators. These simulations have the capability of running both natural gas and blends of hydrogen. The natural gas stream in Synergi uses an equation of supercompressibility for calculations, while the hydrogen blend uses a non-supercompressibility equation: the Benedict Webb Rubin Starling. System models were built using 2023 data from the company Geographic Information System (GIS) and validated by comparing pressures between actual field data and model calculations for a 57 Heating Degree Day (HDD), a normal peak day. A model is considered accurate if the validation results in a percent error less than 10%. The figure below (3) represents a model built for hydrogen blending simulation.

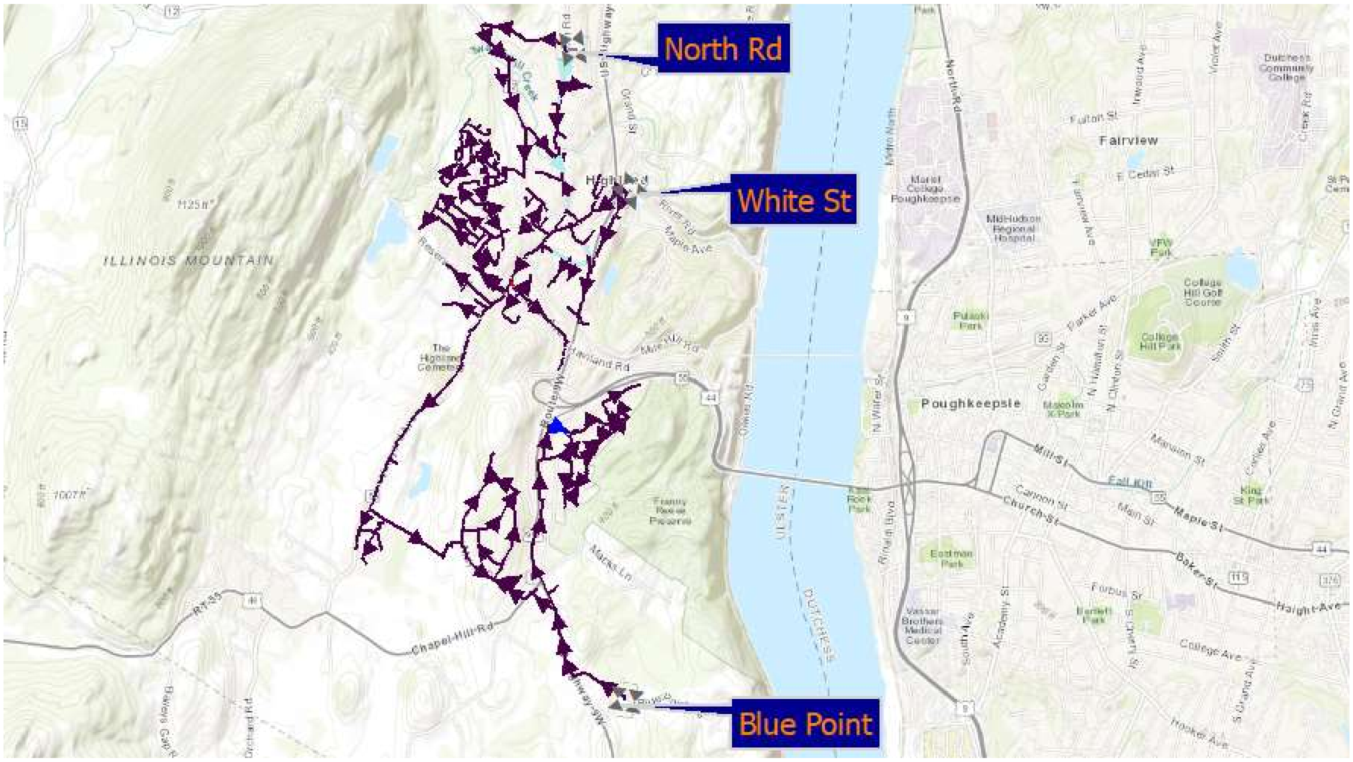

Figure 2: Synergi MS-HL System Model.

RESULTS

Figure 3 below showcases the number of systems that can operate up to the specific blend of hydrogen. Out of the 25 systems, 19 can operate with blends of hydrogen at 10% or less, demonstrating that Central Hudson is in a strong position for a hydrogen pilot in terms of pipeline operation. Previous integrity studies had already identified the need for reinforcements on the systems that cannot adequately operate at low blends of hydrogen. These systems were included in the sampling to provide a complete understanding of the effect of hydrogen on systems of all types and standings.

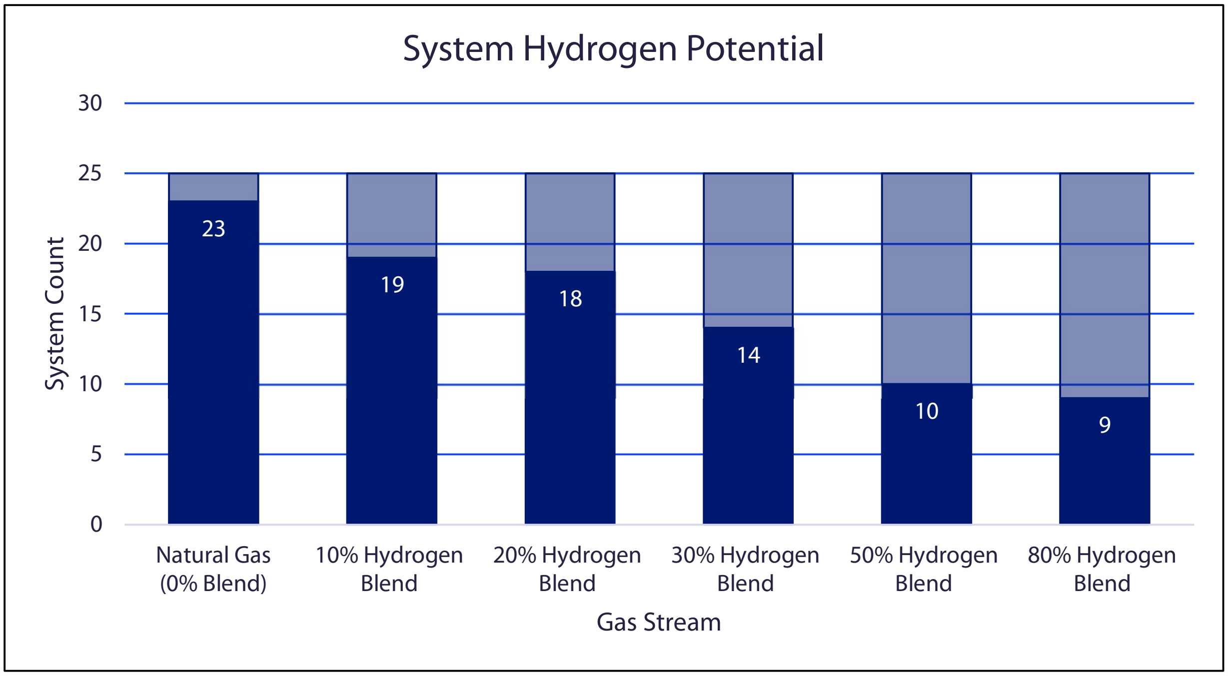

Figure 3: Capable Systems at Various Hydrogen Blends

The potential of Central Hudson's infrastructure to operate with a 20% blend of hydrogen was a focus point of this study. As previously stated, this would be approximately the maximum amount of hydrogen the system can blend without modifying customer appliances. Eighteen systems can run up to a 20% blend of hydrogen, showing potential for hydrogen blending. A blend of 20% hydrogen or less would allow Central Hudson to take advantage of its current infrastructure and reduce greenhouse gas emissions without modification to end use equipment. Most of the systems are constrained by the velocity reaching its operating limit. Several systems are limited by both velocity and pressure.

Nine systems can blend up to 80% hydrogen, further demonstrating hydrogen's long-term potential within Central Hudson's network. Similarly to the lower blends downstream, velocity is the major limitation. The systems that are projected to successfully operate up to an 80% hydrogen blend are known to be in good standing. A list of systems that can run 20% and 80% hydrogen is included in Appendix A – Full System Table.

Pressure

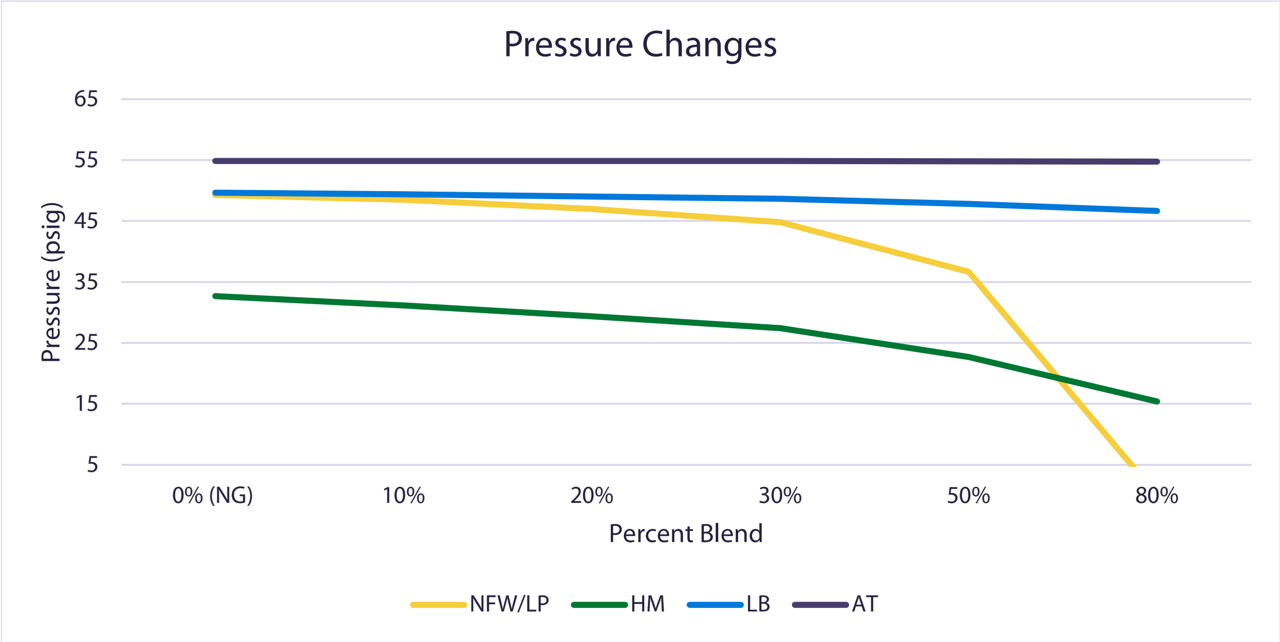

Figure 4: Pressure Changes

System pressure was not a major limiting factor. The relationship between percent of hydrogen blended and pressure appears linear. Figure 4 demonstrates how pressure decreases in a system when the percent of hydrogen in the gas stream increases. The LB and AT[8] systems are already in good standing, so the decline in pressure is steady. The NFW and LP systems are also in good standing, but feed both medium and low-pressure systems. Burning hydrogen requires a greater volume of gas to produce the same energy output. This effect, as well as increased demand from multiple dependent systems, causes a cascading effect for pressure as more hydrogen is blended. Lastly, systems such as the HM, which are already close to 50% MAOP, fall below 50% as the amount of hydrogen blended increases.

[8] A reference table of all systems and their abbreviations can be found in Appendix A – Full System Table.

Velocity

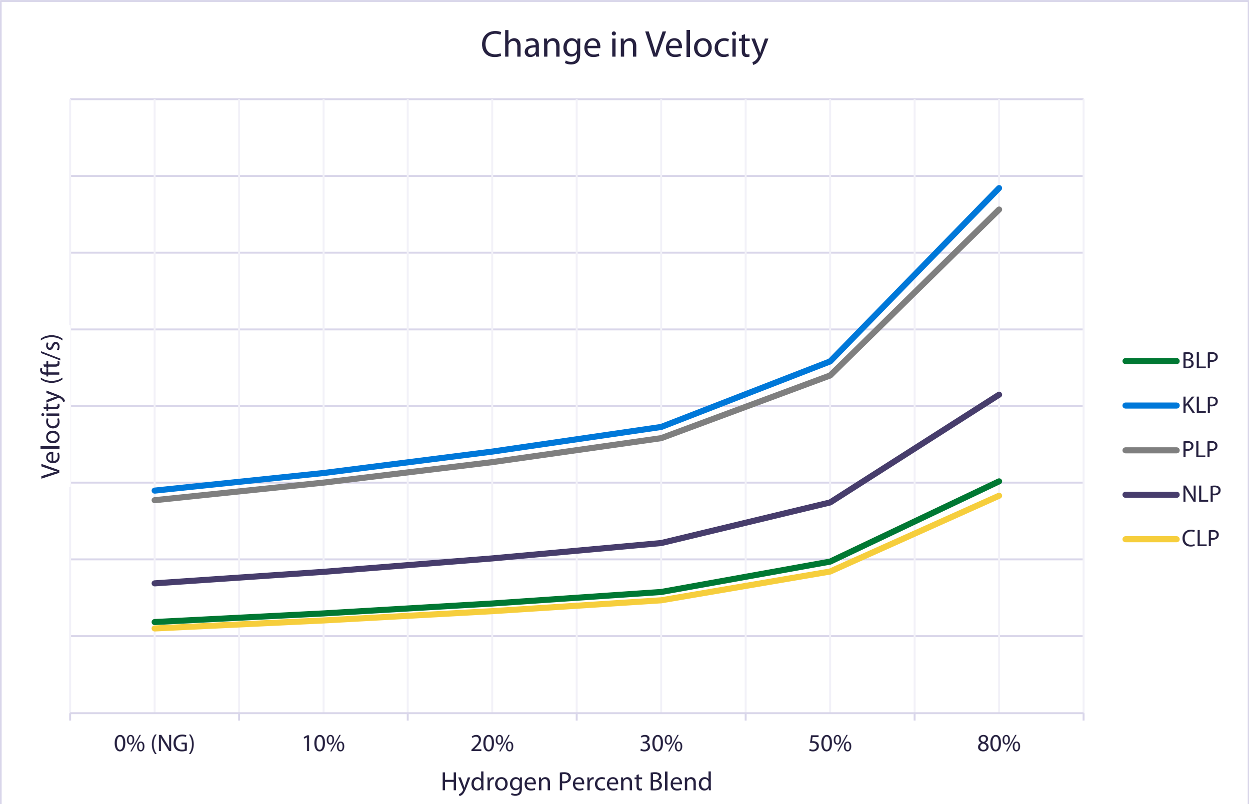

Figure 5: Change in Velocity

Downstream velocity was the major limiting factor affecting 70% of systems. Figure 5 shows that the relationship between velocity and percent of blended hydrogen is exponential. All systems have the same curve, but the system's velocity before blending hydrogen is the main contributor to whether the velocity will exceed the limit when blending. Velocity limitations would impede the potential of hydrogen in the Central Hudson pipeline. A velocity over 70 ft/s leads to pipe corrosion, as well as noise pollution. These effects are undesirable as they affect overall pipeline safety and the wellbeing of the community. Out of all the limitations previously stated, reinforcement to improve velocity would be the least costly.

CONCLUSION

This study demonstrates that Central Hudson can leverage its current natural gas infrastructure to blend hydrogen in support of New York's Climate Leadership and Community Protection Act (CLCPA), which aims to reduce GHG emissions by 85% statewide by 2050.[9] Out of the modeled sample, a majority of the systems that can operate with low blends of hydrogen can also operate with a blend of up to 20%. Slightly less than half of the systems can successfully operate at an 80% blend, which is a long-term GHG reduction goal. The major limitation with hydrogen blending is the downstream velocity, but pressure also can affect systems at higher blends. Following this preliminary study, and as identified in Central Hudson's 2023 Rate Case (23-G-IX-A)[10], a full network analysis should be performed on all systems to better understand the potential of hydrogen blending in Central Hudson's infrastructure. Thorough planning of necessary reinforcements is required to achieve the long-term goal and to reduce spending, adjust project timelines, and efficiently allocate resources. The full study can identify which systems would need additional reinforcements to achieve higher blends. It will also include an assessment of industrial locations for an electrolyzer. The full study will evaluate these locations by identifying pipelines that can operate at higher blends and assessing customer demand for hydrogen.

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[9] New York State, "Climate Act: Progress to our Goals", New York State, 2024, https://climate.ny.gov/Our-Impact/Our-Progress.

[10] Proceeding on Motion of the Commission as to the Rates, Charges, Rules and Regulations of Central Hudson Gas & Electric Corporation for Gas Service 2023, 23-G-IX-A.

APPENDIX A – FULL SYSTEM TABLE

System	Abbreviation	Can Support 20% Blend	Can Support 80% Blend
North Walnut St (Beacon Medium)	BM	x	x
Carmel – Mahopac	SM	x	x
Fishkill Plains	FP	x	x
Beacon Low Pressure	BLP	x	x
Central Valley	CV	x	x
Middlehope	MHP	x	x
Little Britain – East and West	LB	x	x
Athens	AT	x	x
Catskill Low Pressure	CLP	x	x
Newburgh Low Pressure	NLP	x	
Wappingers Falls	WF	x	
Salt Point Turnpike	ST	x	
Creek Road	CR	x	
Blue Point – Highland	HL	x	
Highland Medium Pressure	MS	x	
Port Ewen	PE	x	
Newburgh Medium Pressure	NM	x	
Cronomer Hill – Fullerton Ave	CF	x	
Highland Mills	HM		
Poughkeepsie Low Pressure	PLP		
Kingston Medium Pressure	KM		
Elmendorf St – West King	NFW		
Lake Katrine	LP		
Kingston Low Pressure	KLP		
South Gate	SG		

Table 3: Full System Data

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