

HYDROGEN BLENDING IN THE NATURAL GAS INDUSTRY: OPPORTUNITIES, CHALLENGES, AND A ROADMAP FOR IMPLEMENTATION

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Abstract

Hydrogen blending has emerged as a decarbonization strategy that leverages existing natural gas infrastructure while supporting growth of the hydrogen economy. This paper examines hydrogen fundamentals, benefits and drawbacks of blending, infrastructure and measurement impacts, and a practical roadmap for utility implementation. Research indicates that low-to-moderate hydrogen blending levels, generally up to 20% hydrogen by volume, can be accommodated in many systems with manageable modifications, although material compatibility, measurement accuracy, standards harmonization, and operational readiness remain critical challenges. Hydrogen blending offers a near-term opportunity to reduce greenhouse gas emissions while supporting renewable energy integration and establishing pathways toward a future hydrogen economy.

Introduction

Energy systems are exploring alternative energy technologies in the face of environmental and supply challenges associated with fossil fuels. Hydrogen, when produced through low emission pathways, can be injected into natural gas pipelines to generate heat and power with lower emissions than natural gas alone.

A hydrogen blended natural gas is a mixture of hydrogen and natural gas that can be blended in any proportion, but typically a mixture of 10 to 20 percent hydrogen by volume represents the most promising near-term option given equipment and material constraints. A hydrogen blended natural gas allows for the initial deployment of hydrogen of hydrogen into the energy system without the need for expensive infrastructure upgrades.

This paper will address the fundamentals of hydrogen, material risks of blending, regulatory considerations, and provide a roadmap for utilities to safely implement hydrogen blending.

Hydrogen Fundamentals and Market Overview

Energy sources are evaluated based on their energy per unit volume and energy per unit mass. Hydrogen has three times the energy by weight of gasoline, or 1 kilogram of hydrogen gas has about the same energy as 1 gallon of gas, 2.8 kilograms. However, hydrogen has low energy content by volume, about 1/6th of the energy by volume of a gallon of gasoline. This low energy by volume is one of the main barriers for adoption of hydrogen in the energy industry due to transportation and storage challenges in the hydrogen value chain. Unlike fossil fuels, hydrogen must first be produced from another energy source before it can be utilized. Hydrogen functions as an energy carrier rather than a primary energy source, similar to electrons in electricity, hydrogen enables energy generated from renewable or conventional sources to be stored, transported, and used.

Hydrogen is produced through steam methane reforming, gasification, and electrolysis. After production, hydrogen is used in what is now called the “hydrogen economy” as a tool to help lower carbon emissions since it releases no greenhouse gas emissions at usage. The produced hydrogen can be used for electricity and heating, fuel cells, and energy storage. The amount of carbon emissions associated with hydrogen depends on the production method utilized to produce the hydrogen. Producing hydrogen with electrolysis, which uses electricity to split a water molecule into oxygen and hydrogen, is the lowest carbon emission form of production but also one of the more expensive production methods today.

Benefits of Hydrogen Blending

Hydrogen blending offers several advantages. First, combustion of hydrogen does not produce carbon dioxide. When supplied from low-carbon production pathways, hydrogen can contribute to greenhouse gas reduction efforts. Studies reviewed by the National Renewable Energy Laboratory (NREL 2023) indicate that many existing natural gas systems can accommodate blends approaching 20% hydrogen by volume without major infrastructure replacement. A 20% hydrogen blend typically reduces delivered gas carbon intensity by approximately 6% to 7%, providing measurable environmental benefits while minimizing disruption to existing operations.

Blending hydrogen with natural gas changes the overall gas properties, as seen in Table 1 below. The blended gas has safer handling properties than hydrogen on its own but does contain marginally lower energy per unit volume than pure natural gas.

	Natural Gas	Hydrogen	20% H2 Blend
Lower Explosive Limit (vol %)	4.4%	4%	4.4%
Higher Explosive Limit (vol %)	15%	75%	18%
Lower Heating Value (MJ/m³)	35.8	10.8	30.8
Higher Heating Value (MJ/m³)	39.8	12.7	34.4
Flame Speed (cm/sec)	~30	~300	~40
Wobbe Index (Btu/scf)	1215	1039	1150

Hydrogen blending also provides utilities with an opportunity to utilize existing infrastructure as an energy storage asset. Through power-to-gas applications, excess renewable electricity can be converted into hydrogen via electrolysis and subsequently injected into natural gas systems. This approach helps address renewable intermittency challenges by enabling seasonal and long-duration energy storage.

Finally, hydrogen blending offers a practical transition strategy between existing methane-based energy systems and future dedicated hydrogen networks. Rather than requiring immediate infrastructure replacement, utilities can adopt hydrogen incrementally while developing operational knowledge and supporting the maturation of hydrogen technologies.

Material Compatibility and Infrastructure Considerations

One of the most important technical considerations associated with hydrogen blending is material compatibility. Hydrogen compatibility is defined as the ability of a material to maintain mechanical integrity and acceptable leakage performance in a hydrogen environment. Hydrogen compatibility is typically governed by three primary factors: material susceptibility, environmental conditions, and applied stress. Material susceptibility refers to a material's inherent response to hydrogen exposure. Certain metals can experience hydrogen embrittlement, where hydrogen diffuses into the material and reduces tensile strength, ductility, fracture toughness, and fatigue resistance. Environmental factors such as pressure, temperature, hydrogen purity, and contaminant concentration also influence compatibility. Higher pressures and elevated temperatures may accelerate aging and degradation processes or

increase the chance of hydrogen embrittlement. Additionally, impurities including water, oxygen, ammonia, and other contaminants can impact material performance and reliability. Applied stresses, including pressure cycles and fluctuating operational loads, further influence material performance. Consequently, utilities must evaluate both operating conditions and material selection when assessing infrastructure readiness for hydrogen blending.

Impact of Blending on Consumer Appliances

Consumer and regulatory acceptance of hydrogen blending depend heavily on the performance of residential and commercial appliances. Recent studies have proven current natural gas appliances are sustainable for a hydrogen blend of up to 20% (Font, Kernan, Widder, 2023). Specifically, studies conducted by the Canada Standards Association (CSA) proved appliances to still be high performing with 5% and 15% hydrogen blends. Once the hydrogen blend surpasses 20%, the performance of an appliance begins to deteriorate and cause safety concerns, which would require shifting to appliances designed for hydrogen blended gas.

There are multiple parameters for determining the performance of a residential appliance such as ignition, burner operating characteristics (BOC), temperature rise, combustion, flue loss, and condensation (Suchovsky, Ericksen, Williams, Nikolic, 2021). Combustion, condensation, and flame speed have the most variation when testing with hydrogen blends, causing concern for widespread adoption (Font, Kernan, Widder, 2023).

Hydrogen has a higher combustion rate than natural gas by 4.25 m/s, meaning it “requires less oxygen than burning the equivalent amount of natural gas” which will result in a higher heated air content (Guarco, Langstine, Turner). A higher heated air content can degrade performance of the appliance since the temperature of the flame is affected by the higher air temperature and combustion reaction. Studies have shown “the effect on tested appliance efficiency is minimal, varying only 1 to 1.5% for 30% hydrogen blend in natural gas”, leading to concerns with 100% hydrogen or higher blends (Font, Kernan, Widder, 2023).

Hydrogen also produces more condensation in comparison to natural gas. This difference becomes a concern especially in reference to dryers, where the condensation can cause performance issues due to additional moisture. In other appliances condensation is a point of concern due to necessary improvements needed to ventilate additional moisture. The NEEA, Hydrogen-Ready Appliances Assessment Report, determined that a 20% hydrogen blend will cause an 8% increase in condensation.

A flame often indicates whether an appliance is on and working, with hydrogen, as the blend percentage increases, the flame becomes more difficult to see, resulting in safety concerns (Kiwa, 2016).

Although current research indicates that blends below approximately 20% can generally be accommodated by existing appliances, further testing and standards development will be required before widespread adoption of higher hydrogen concentrations.

Technical Challenges and Risks

Despite its benefits, hydrogen introduces important technical challenges. Hydrogen has a wider flammability range and significantly higher flame speed than methane, see Table 1. While lower blend percentages maintain combustion characteristics similar to conventional natural gas, higher hydrogen concentrations require greater attention to safety, combustibility, and system design.

Pipeline operators must evaluate metallic and non-metallic material compatibility, hydrogen embrittlement risks, leakage characteristics, and impacts on compressors, regulators, valves, meters, chromatographs, analyzers, and end-use appliances. Measurement systems require updates to gas composition algorithms, heating value calculations, compressibility correlations, and reporting processes. Existing flow computers, chromatographs, and billing systems often require both hardware and software modifications to accurately account for blended gas properties.

Industry studies demonstrate that equipment impacts vary according to blend level, operating pressure, materials, and asset age. Consequently, comprehensive asset inventory and engineering assessments are required before deployment. Utilities must evaluate each system individually rather than assuming universal compatibility across all infrastructure.

Regulatory and Standards Considerations

A major barrier to widespread adoption is the evolving regulatory landscape. Existing tariffs, gas quality specifications, and industry standards frequently treat hydrogen as a contaminant rather than an approved energy constituent. Utilities pursuing hydrogen blending must review contracts, heating value requirements, custody transfer specifications, gas quality limits, and applicable standards.

Recent developments include CSA hydrogen-related standards, updates to installation and safety codes, Measurement Canada guidance for limited blending applications, and collaborative initiatives involving utilities, research organizations, and regulators (CSA Group). However, considerable work remains to harmonize standards across jurisdictions and establish consistent requirements for gas quality, measurement, safety, and consumer protection.

Roadmap for Utility Implementation

A practical roadmap for hydrogen blending includes five major workstreams.

- 1. Standards and Regulatory Assessment:** Utilities should begin with a systematic review of standards, tariffs, contractual obligations, custody transfer requirements, and gas quality specifications. Existing documents may require revision to formally recognize hydrogen as an approved constituent of the gas stream.
- 2. Equipment Compatibility Assessment:** Organizations should conduct a detailed hydrogen suitability assessment covering meters, flow computers, regulators, valves, pipelines, analyzers, chromatographs, elastomers, seals, and end-use equipment. Evaluations should consider material susceptibility, environmental conditions, and operational stresses to determine replacement or mitigation requirements.
- 3. Procedures and Workforce Training:** Standard operating procedures, maintenance practices, calibration methods, safety programs, and workforce training materials should be updated to address hydrogen-specific requirements and operational practices. **[Insert Graphic]**
- 4. SCADA and Data Integration:** Data acquisition systems should be enhanced to include hydrogen concentration monitoring, new alarm thresholds, updated process logic, and validation testing. Point-to-point testing should be completed before field deployment. **[Insert Graphic]**
- 5. Measurement System Validation:** Measurement systems should be updated with revised physical property tables, heating values, specific gravity calculations, compressibility factors, calibration standards, and reporting methodologies. Verification testing should be completed to ensure acceptable measurement accuracy.

Through implementation, strong project management and cross-functional collaboration among utilities, regulators, manufacturers, and industry organizations are essential for success.

Conclusion

Hydrogen blending represents a practical transitional strategy that enables natural gas utilities to contribute to decarbonization goals while leveraging existing infrastructure investments. This technology is technically feasible at blend levels up to approximately 20% hydrogen by volume, but successful implementation requires careful attention to material compatibility, appliance performance, metering accuracy, operational procedures, workforce readiness, and regulatory compliance. As hydrogen production expands, standards mature, and experience with blending projects grows, hydrogen blending can serve as a valuable bridge between today's natural gas networks and a lower-carbon energy future.

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