WHITE PAPER

Restoring Energy Capacity of Natural Gas Following Hydrogen Blending

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When hydrogen is injected into natural gas, the blended fuel can generate energy with lower CO_2 emissions than natural gas. This could be good news for natural gas transmission and distribution companies seeking near-term ways to decarbonize their operations. But first, they must find cost-efficient ways to restore the heating value lost by blending hydrogen with natural gas. Two options might offer workable solutions.

As the cleanest-burning fossil fuel, natural gas will play a significant role in decarbonizing the world's economy. With more than 3 million miles of natural gas pipelines in the U.S., national gas infrastructure is well-established. Natural gas has helped energy companies and utilities diversify their energy mix and meet emission reduction targets, providing approximately one-third of annual energy in the U.S.

As the pace of decarbonization quickens, organizations seek to further reduce carbon emissions from natural gas. One alternative is using existing infrastructure to blend hydrogen into natural gas. Hydrogen is a clean energy source that does not produce carbon dioxide as a combustion byproduct. A University of Alberta study published in 2023 found that burning a hydrogen and natural gas blend where hydrogen does not exceed 15% to 20% by volume can cut carbon emissions by as much as 5%, compared to burning natural gas alone. This and other studies confirm that emission reduction can be achieved with a relatively low concentration of hydrogen: typically 20% or less.

The Challenge: Reversing Heating Value Loss

Because the heating value of hydrogen is roughly a third of that of natural gas, it reduces the heating value of the blended gas, by volume. For example, studies conducted by the Interstate Natural Gas Association of America found that a 20% hydrogen blend reduces the energy content of natural gas by nearly 14%, compared to 100% natural gas. In other words, the dilution of natural gas with hydrogen lowers its volumetric fuel efficiency and increases the volume of fuel needed to achieve the same level of heat or energy.

Hydrogen blending also impacts the Wobbe index of natural gas, which is used to assess the interchangeability of fuel gases. Dividing a gas's higher heating value (HHV), which expresses energy per standard volume, by the square root of the gas's specific gravity, the Wobbe index identifies gas blends that can be used in most household appliances without affecting their performance or safety.

It is possible, however, to increase the volumetric energy density of hydrogen-blended gas. This white paper explores two promising ways, through an assessment of the impact that hydrogen blending has on the energy in natural gas.

Understanding the Variations in Natural Gas Composition

Natural gas consists primarily of methane with small amounts of ethane, propane, nitrogen, carbon dioxide and other gases. The precise composition of the gas mixture varies, depending on the supply basin.

Natural Gas Composition Variations	Higher Heating Value (Btu/ft^3)	Volume for 1,037 Btu (ft^3)	% Velocity Increase
Enbridge natural gas	1,040	0.998	-0.25%
Gulf Coast natural gas	1,032	1.005	0.52%
Amarillo natural gas	1,030	1.007	0.68%
Ekofisk natural gas	1,100	0.943	-5.74%
CEESI Iowa - natural gas	1,005	1.032	3.17%
CEESI Colorado - high ethane natural gas	1,097	0.946	-5.43%
Pure methane	1,011	1.026	2.57%
Pure hydrogen	325	3.191	219.08%

***Figure 1:** Chemical composition variations for natural gas. Notes: **Higher Heating Value** is a measure of the total energy content of a fuel. It reflects the maximum amount of thermal energy produced when a volume of natural gas is completely combusted and returns to a starting temperature of 25°C/77°F. **Volume for 1,037 Btu** identifies the volume of gas needed to generate 1,037 British thermal units per cubic foot (Btu/ft^3), the current national average for natural gas heat content. **Percent Velocity Increase** represents the percentage by which the flow velocity of the natural gas would need to increase (or decrease) to achieve 1,037 Btu/ft^3 of natural gas.*

Burns & McDonnell compared key metrics on six different natural gas compositions (See Figure 1). The first four illustrate the variation in standard gas composition in different regions of North America. Comparative data is included for the standard gas compositions used by CEESI (Colorado Engineering Experiment Station Inc.) to calibrate flow meters, as well as that of pure methane and hydrogen.

Assessing the Impact of Hydrogen Blending on Energy Content

In a desktop exercise, Burns & McDonnell researchers sought to measure the change in natural gas volume when it is mixed with hydrogen at varying concentrations. These calculations used published data on the standard gas composition for Ontario-based Enbridge Gas, one of North America's largest natural gas storage, transmission and distribution companies. Enbridge was selected because its HHV of 1,040 Btu/ft^3 is closest to the U.S. national average of 1,037 Btu/ft^3.

As Figure 2 illustrates in the following section, the addition of hydrogen in every case decreases the energy content of the natural gas by volume. The more hydrogen in the blend, the lower the HHV and the higher the volume of blended gas needed to deliver energy comparable to pure natural gas. Depending on the ratio of hydrogen to natural gas, the HHV of blended gas can range from 682 Btu/ft^3 to 1,004 Btu/ft^3.

Left unchecked, the lower HHV of a hydrogen blend can adversely impact the operation of appliances, most of which are rated for burning natural gas with a HHV of approximately 1,000 Btu/ft^3.

Restoring the Energy Content of Hydrogen-Blended Natural Gas

Burns & McDonnell researchers studied two ways to restore the energy content lost when hydrogen is injected into natural gas.

Option 1: Increasing Flow Rate of the Blended Gas

Natural gas transmission and distribution companies can compensate for the reduced energy capacity of hydrogen-blended gas by raising its flow rate. This is accomplished by increasing gas velocity through the pipelines that supply natural gas to the customer.

For example, a 20% hydrogen blend can be restored to 1,037 Btu/ft^3 by increasing its flow velocity by 15.65%, according to Burns & McDonnell calculations (See Figure 2). Such a blend would reduce the natural gas's greenhouse gas emissions by approximately 6% to 7%.

Natural Gas Composition Variations	Higher Heating Value (Btu/ft³)	Volume for 1,037 Btu (ft³)	% Velocity Increase
No hydrogen added	1,040	0.998	-0.25%
5% H_2 blend	1,004	1.033	3.30%
10% H_2 blend	968	1.071	7.11%
15% H_2 blend	932	1.112	11.22%
20% H_2 blend	897	1.156	15.65%
30% H_2 blend	825	1.257	25.66%
50% H_2 blend	682	1.520	51.99%

***Figure 2:** Velocity increase needed to restore energy content in blended gas. Note: The impact of hydrogen blending at various concentrations was measured using the natural gas composition for Enbridge gas, which is closest to the U.S. national average of 1,037 Btu/ft³.*

The velocity for blended gas containing up to 20% hydrogen is typically less than 60 feet per second (ft/s) across different types of residential, commercial and small industrial loads, based on average gas consumption and service line size. This falls within the 60-80 ft/s industry standard for natural gas to safely pass through a service line. A velocity of less than 100 ft/s is preferred for the safe and reliable operation of a pipeline system.

Increasing the flow rate of an 80-20 blend of natural gas and hydrogen has other advantages. For example, this gas blend is found to be interchangeable with 100% natural gas on the Wobbe Index, with consumer appliances experiencing no ill effects from the flow rate increase, according to ATCO, which conducted a hydrogen blending project in its Fort Saskatchewan natural gas distribution system in 2022. Some residential and commercial gas meters, however, could be impacted if the flow rate nears or exceeds the meter's maximum capacity. Residential flow meters commonly range in capacity from 200 to 400 ft³ per hour.

Natural gas blends with higher concentrations of hydrogen are problematic. For 30% and 50% hydrogen blends, gas velocity through the pipeline would need to increase to as much as 70 ft/s to restore the energy capacity lost through blending.

While this flow velocity increase does not compromise pipeline integrity or safety, it raises other concerns. For example, increasing flow velocity by 20% or more can create a constant low humming sound in pipelines. This noise could be disruptive to residents, given that portions of service lines are located above ground and on the exterior walls of residences. Care should be taken so that the increased flow velocity stays below the erosional velocity of the pipe material to prevent any integrity concerns and potential material failure.

This study considered only residential and commercial applications for hydrogen blends. Industrial and turbo gas applications require different considerations. Further study is needed to evaluate the use of hydrogen-blended natural gas in these applications.

Option 2: Adding Ethane to Blended Gas

While increasing the flow rate of hydrogen-blended gas can restore the energy lost in blending, adding ethane to blended gas can achieve a similar effect.

A small amount of ethane is present in all variations of natural gas. Adding a greater concentration of this hydrocarbon, which is fully miscible and will not separate, to hydrogen-blended natural gas increases the energy content of the gas and restores it to levels closer to the U.S. national average.

For this study, Burns & McDonnell calculated the percentage of ethane that would need to be added to be added to various concentrations of hydrogen blends to achieve 1,037 Btu/ft³ (See Figure 3). The results indicate that the optimal 20% hydrogen blend would require a 15.83% concentration of ethane to achieve the desired result.

Gas Composition Variations	Higher Heating Value (Btu/ft³)	% Ethane Added
5% H_2 blend with added ethane	1,037	4.25%
10% H_2 blend with added ethane	1,037	8.45%
15% H_2 blend with added ethane	1,037	12.30%
20% H_2 blend with added ethane	1,037	15.83%
30% H_2 blend with added ethane	1,037	22.11%
50% H_2 blend with added ethane	1,037	32.23%

***Figure 3:** Adding ethane to restore energy content for natural gas–hydrogen blends.*

While it could be considered counterproductive to add a carbon-rich fuel source such as ethane back into the natural gas–hydrogen blend, this alternative might be considered a viable, near-term solution for providers with an abundant ethane supply. It is especially reasonable in locations where the ethane is otherwise flared off from existing gas or oil wells.

Using ethane to restore energy content eliminates the need to change flow rate or velocity, but care must be taken to see that the ethane injected into the natural gas–hydrogen blend is within the Wobbe Index interchangeability range so that it may be used without modification to residential appliances.

Next Steps

By adding hydrogen to the natural gas in their existing pipeline infrastructure, natural gas transmission and distribution companies can reduce their CO_2 emissions, compared to pure natural gas. Some Canadian and European organizations seeking to decarbonize their operations have already begun to implement hydrogen blending projects. Similarly, Hawai'i Gas has had 12% to 15% hydrogen in its gas transmission and distribution networks since 1974.

Other U.S. counterparts are following close behind. Some are implementing pilot systems while others await further data and direction on how to restore the energy loss associated with the blending process. The findings from this research should give operators confidence to begin considering the role that hydrogen blending may play in their decarbonized future.

A good next step is an assessment of local hydrogen and ethane availability, along with a review of the blending capabilities at town border stations where most hydrogen injection would be expected to take place. Renewable energy credits and other government-funded incentives may be available to help offset the cost of design and construction.

While the operational changes associated with hydrogen blending pose some challenges, blending may prove to be a good near-term alternative along a path to achieving decarbonization goals.

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