WHITE PAPER

WHAT YOU NEED TO KNOW ABOUT HYDROGEN AND NATURAL GAS BLENDING

The past, present, and future of hydrogen as a sustainable source of energy

SICK
Sensor Intelligence.

Introduction

Hydrogen is steadily emerging as a vital element in the worldwide efforts of decarbonization and electrification. The current economic and socioeconomic climate is driving the hydrogen conversation. Hydrogen is the lightest element and has no entrained carbon in it. When hydrogen burns, water is released which makes it, by definition, a carbon-free fuel. One of the ways to utilize this carbon-free fuel is to blend it with natural gas. This blend of hydrogen and natural gas provides a more sustainable fuel. But what exactly happens when you blend hydrogen and natural gas?

To answer this question, first we will look at hydrogen and its use in clean energy. Finally, we will explore ultrasonic measurement as a reliable way to monitor the amount of hydrogen in the natural gas when it is blended.

The Origin and Availability of Hydrogen

Globally, the current hydrogen demand is about eight exajoules. It is mostly utilized in refining applications, but the projection out to 2050 shows an increase of the hydrogen economy to 78 exajoules.

Hydrogen is defined using a color spectrum. Although it is a colorless gas, it is defined by a rainbow of colors to differentiate between different types, despite there being no visible difference between the types. Currently, the industry still uses grey hydrogen. Grey hydrogen is hydrogen from steam methane reforming of natural gas. From this process, CO2 is produced and eventually released into the atmosphere. Steam methane reforming is common globally in the refining application in areas where there are demands from the refineries for hydrogen. Going forward, hydrogen generation with carbon sequestration will be used, as it is a commercially viable technology.

Continuing into the near future, as the cost decreases and efficiencies increase, renewable hydrogen generation will also increase. Thus, the importance of the different colors of hydrogen will vary depending on the demand and industry needs. It is important to note that hydrogen will not replace natural gas, but only about 8-12%, depending on the study. This is a small portion of the overall energy demand. Fossil fuels will continue to play a role, the role of electrification will increase, and hydrogen will make up a portion of this energy future. However, long term projections show that renewable hydrogen will be dominant through successive/disruptive innovation and significant cost reduction.

Types of Hydrogen

HYDROGEN	DEFINITION
GREEN	• Produced with no harmful greenhouse gas emissions • Combustion produces primarily water vapor • Made using clean electricity from surplus renewable energy sources, such as solar, wind or water. • Currently makes up a small percentage of the overall hydrogen because production is expensive
BLUE	• Produced mainly from natural gas, using a process called steam reforming, which brings together natural gas and heated water in the form of steam • Hydrogen and carbon dioxide are by-products of the process • Carbon capture utilization and storage (CCUS) is essential to trap and store this carbon • Often described as 'low-carbon hydrogen' as the steam reforming process doesn't actually avoid the creation of greenhouse gases
BLACK & BROWN	• Exact opposite of green hydrogen in the spectrum • Most damaging to the environment • Produced using black coal or lignite (brown coal) in the hydrogen-making process • Any hydrogen made from fossil fuels through the process of 'gasification' is sometimes called black or brown hydrogen interchangeably
PINK	• Generated through electrolysis powered by nuclear energy • Nuclear-produced hydrogen can also be referred to as purple hydrogen or red hydrogen. • Very high temperatures from nuclear reactors could be used in other hydrogen productions by producing steam for more efficient electrolysis or fossil gas-based steam methane reforming
TURQUOISE	• New type of hydrogen • Production has yet to be proven at scale • Made using a process called methane pyrolysis to product hydrogen and solid carbon • In the future, may be seen as an option for low-emission hydrogen
GREY	• Most common form of hydrogen production • Created from natural gas, or methane, using steam methane reformation • Does not capture the greenhouse gases made in the process
YELLOW	• Newer type of hydrogen • Made through electrolysis using solar power
WHITE	• Naturally occurring geological hydrogen found in underground deposits created through fracking • No strategies to currently utilize this hydrogen

Hydrogen Timeline

Figure 1 shows a timeline to illustrate the hydrogen production and use as the technologies are available. It will be localized. For example, in a power plant in Utah, hydrogen will be generated for local storage and use. It's going to be a process with steam methane reforming and some electrolysis. In Nebraska, there's a pyrolysis plant making carbon black in hydrogen. This is the near-term vision that uses the existing infrastructure to move hydrogen and generate carbon neutral fuels.

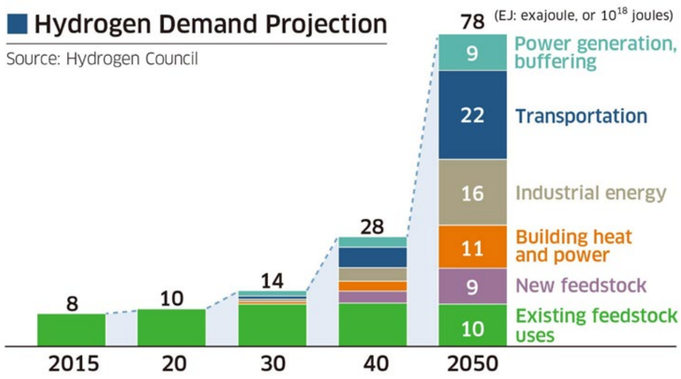

Figure 1: Hydrogen Demand Projection

Long term, past 2030, the industry will move to distributed generation using excess wind and solar. The hydrogen will be blended and transported in the gas pipeline system, and there will be more focus on the green energy electrolysis. Eventually, the hydrogen pyrolysis technologies will go beyond commercial scale and get to 10 to 100 times the generating capacity. Natural gas resources and fossil fuel resources will be used to generate clean burning hydrogen. That is just a brief look at the industry in the future.

The socioeconomic pressure is very real as many major energy producers and refiners are talking of projects soon. Large cement manufacturers are working on carbon sequestration. However, there are still a lot of questions to answer, especially from the pipeline side. There has been significant work in Europe on the process of putting hydrogen into the pipelines, the grid, and supply municipalities with blended fuels. Unfortunately, the United States lags five to seven years behind that work and has more questions than answers. The industry needs to work together to answer those questions.

Hydrogen in Energy

Hydrogen is an energy carrier and can also be a storage medium. It can be produced from fossil fuels, biomass, solar, wind, nuclear, and hydroelectric processes. It's uses right now are mainly in oil refineries, ammonia production, methanol, and some steel applications. Additionally, the transportation industry and transportation markets have become increasing users of hydrogen fuel cells. This is because by weight, hydrogen has three times more energy density than natural gas, meaning that it must be compressed at three times higher a pressure as well. The hydrogen can then be transported in a pipeline as a gas or by liquid. If transporting by a liquid, it must be -423 degrees Fahrenheit, much colder than the requirements for LNG.

Why does hydrogen make sense as a fuel for the transportation industries? Fuel cells are proven, efficient technology with no moving parts. They use the chemical energy of hydrogen or another fuel to cleanly and efficiently produce electricity. Fuel cells work like batteries without running down or needing a recharge. Having such a great energy density makes hydrogen fuel cells an attractive source for heavy industrial or freight transportation. For example, one of the biggest names in diesel and diesel motors has a complete portfolio of fuel cells and electrolysis. To create a much cleaner fuel for moving freight around the world, just remove the diesel engine and use a fuel cell powered by hydrogen.

The near term will be mostly focused on addressing viewpoints and the electrification of vehicles, using hydrogen as the fuel over batteries. There is a challenge in the industry now regarding energy density, batteries, and charging times. However, being able to move freight long distances using a clean energy supply is very attractive for the future.

Hydrogen in Renewable Energy

The current project balance of commercial power producers is heavily weighted toward renewables. Right now, the unsubsidized cost of generating electricity from wind and solar is on par with the cost of natural gas or fire generation. This is huge, which means that power producers are voting with their budgets on how they are going to generate electricity. The challenge is that the density of the wind is predominantly in the Midwest, and the solar density in the South and Southwest. Thus, our population centers are separated from these energy sources.

The energy needs to be able to move long distances to meet the demand. This is a challenge. Electrons can be transported in wires, but a lot is lost in transit. Therefore, putting hydrogen in a pipeline, storing it, or transporting it becomes a way to build a chemical battery. We can use that excess wind and solar when it is not needed to generate hydrogen. Then, we can use that hydrogen to generate electricity where there isn't the sun or wind. There is truly a generation-to-consumption disparity where the excess electricity generation doesn't match the demand. However,

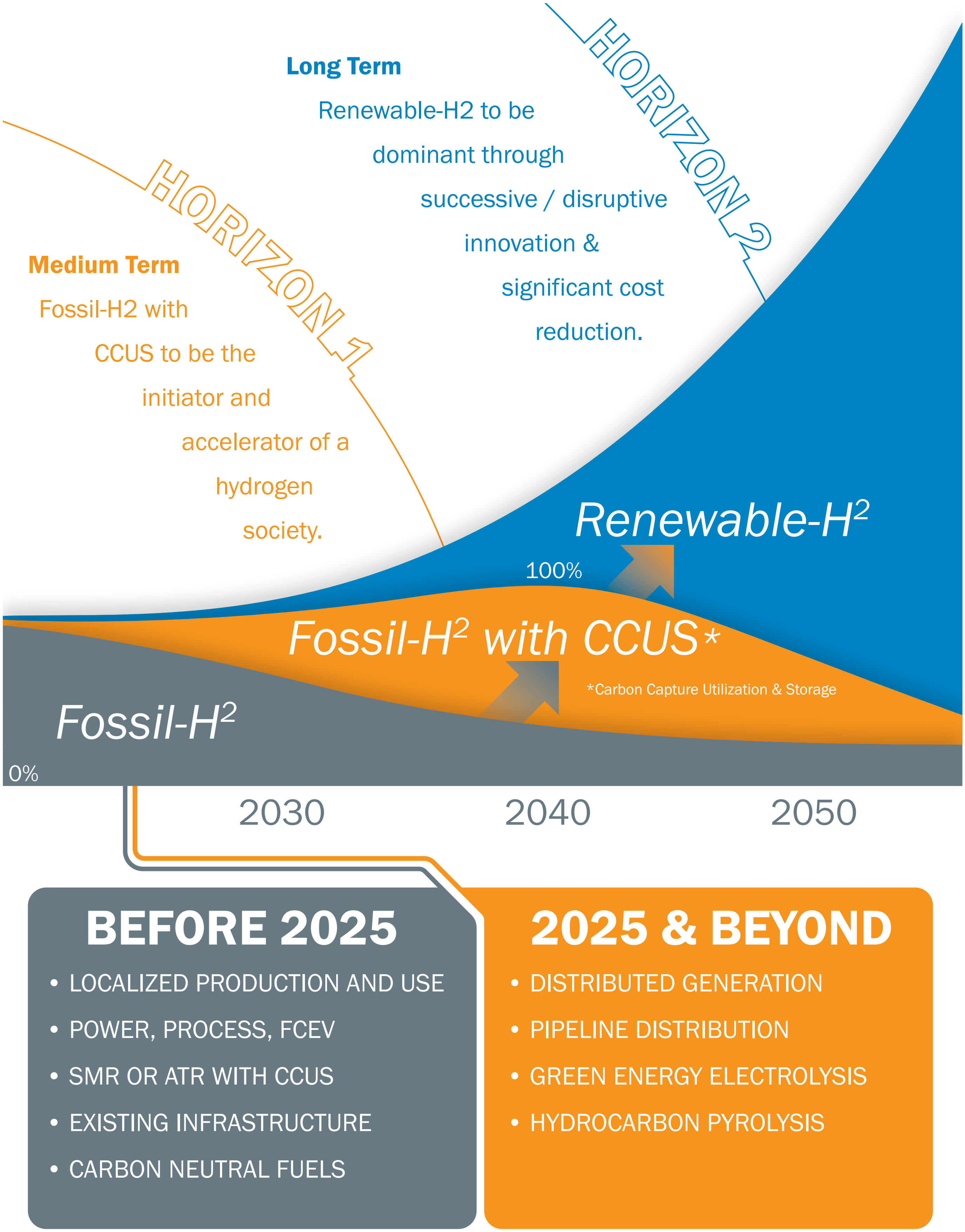

Figure 2: What's on the horizon for Hydrogen

hydrogen can be used to fill that gap.

Blending Hydrogen in Natural Gas

Hydrogen has its own unique characteristics that make it a preferred energy source. Beyond being a carbon-free fuel, hydrogen is eight times lighter than natural gas. It also has three times higher speed of sound than natural gas. The speed of sound in natural gas generally is around 1,394 ft. per second. If that is extrapolated, then the speed of sound of hydrogen is 4,300 ft. per second. Additionally, natural gas is going to run from about 950-1050 BTUs per cubic foot and hydrogen is around 325 BTUs per cubic foot. Just from a physical perspective, there are significant differences when comparing hydrogen to natural gas.

Hydrogen Characteristics

- 8x lighter than natural gas
- 3x higher speed of sound than natural gas
- 3x lower heating value than natural gas
- Lighter BTU per cubic foot

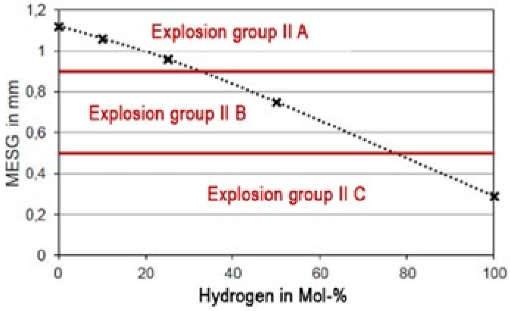

Figure 3: Hydrogen and explosions

One area that can cause challenges is the effect of the blending hydrogen and the explosion protection. The Federal Institute for Materials Research and Testing (BAM) published its report entitled, *Safety properties of natural gas/hydrogen mixtures*, in 2016 looking into the effects of admixing hydrogen with natural gas on explosion behavior and requirements for the explosion group classifications. This report shows that the explosion pressure changes only slightly up to an H2 proportion of 25% by volume. Likewise, a 10% by volume admixture of hydrogen has no significant influence on the standard gap width for the gas group IIA (Fig. 3). The results lead to the conclusion that a 25% admixture of hydrogen by volume, in all likelihood, does not inadmissibility reduce the standard gap width for the gas group IIA.

Already today, a 10% admixture of H2 by volume is possible in Europe with the current rules under consideration of specific applications or restrictions. The new regulation is intended to increase the admixture to 20% by volume. According to the current state of knowledge, this proportion is estimated to be technically feasible.

Acoustics Basics

- Hydrogen content increases -> Speed of sound increases
- Speed of sound increases -> Sound lobe increases
- Sound lobe increases -> Line size limitation increases

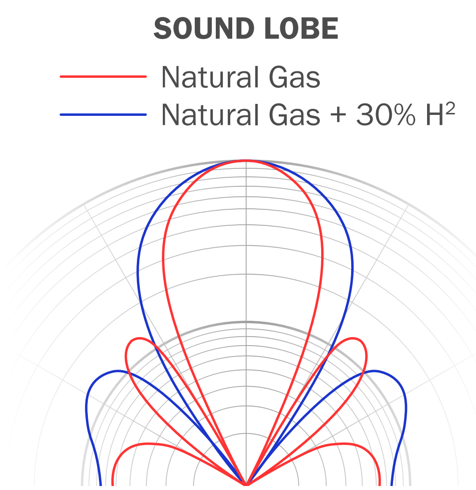

Figure 4: Acoustics Basics

The sound lobe is the curved projection. We see that as the hydrogen content increases, the speed of sound increases. And as the speed of sound increases, the sound lobe increases.

In Figure 4, the red line represents natural gas, and the blue line represents a sound lobe of natural gas blended with 30% hydrogen. With increased admixtures of hydrogen there can be a line size impact with existing ultrasonic measurement equipment.

Therefore, the hydrogen content must be included in the design of the device so that a specific solution can be created. The amount of hydrogen that is going to be incorporated into a specific facility cannot be ignored.

Ultrasonic meters and blended gas

SICK has participated in research on ultrasonic meters since the first installation in 2005. Since 2005, SICK has been involved in the implementation of pure and mixed gases in the process industry. There has been a wealth of implementations where the meters have measured from one percent, five percent, 10 percent, up to 30% hydrogen and a number of pure hydrogen applications. These applications are continuing to be monitored and researched, while also continuing to ensure measurement integrity for natural gas, blended natural gas with hydrogen, and pure hydrogen.

Ultrasonic meters have everything needed to meet the demands of a future network operation. The proof of measurement, reliability, and accuracy with IP-based communication allows for 24/7 remote access. Another feature of ultrasonic meters is the ability for real-time diagnostics to support operational controls. The industry is not going to operate with static conditions, the conditions are going to be dynamic. With those dynamic conditions, operators are going to require near real-time access to monitor and control processes. An ultrasonic meter can deliver those values. Advanced diagnostics allow lessons from the past to inform the process when managing future challenges and changes. Additionally, the speed of sound as a second measurement value allows for decentralized gas quality control.

The ultrasonic meter diagnostics indicate the hydrogen content in real-time and can act as a backup providing reliability for data that would be coming from a gas chromatograph. This can ensure integrity of the pipeline system. Ultrasonic meters can detect a wealth of anomalies, so why not explore the benefit of incorporating meter diagnostics for hydrogen?

Benefits of Blended Natural Gas and Hydrogen Measurement with an Ultrasonic Meter

- Real time hydrogen content monitoring
- Backup for process gas chromatograph (PGC)
- Detection of hydrogen peaks /bubbles withing you pipeline system
- Cost efficient monitoring of customer specs in gas supply

Conclusion

Hydrogen is a large focus in research and development, not only for SICK but around the world. It is important to understand hydrogen and its potential in the energy industry. It is also important look ahead to the future and see what technologies are available for use when incorporating these developments into facilities and processes. Through research, the ultrasonic principle for measuring gas flow has stood out as an effective way to measure hydrogen and it will be a reliable measurement tool as we move forward to a more sustainable world. Ultrasonic technology from SICK is ready to take on the challenges of blending up to 30% hydrogen and we are committed to continuing to learn about the uses and applications of hydrogen.

Contact Us

For more information about hydrogen blending applications, contact SICK at info@sick.com or visit our website at www.sick.com.