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Hydrogen Blending Well into Climate Change Discussion

By **Richard Nemec,** Contributing Editor

The venerable international energy conference, CERAWeek, returned as a live, week-long venue in Houston the second week of March, touting its usual lineup of speakers from around the globe and its topics from A to Z in the energy space.

Notable was the fact that among this vast array of subject matter were 10 separate programs devoted to hydrogen, covering three of the conference's five days. Discussions featured various questions about hydrogen's mobility, adaptability, flexibility and safety as a substitute for diesel in transportation and for natural gas in homes and businesses.

Meanwhile, as CERAWeek ploughed through its formidable schedule, plans for an industrial-scale green hydrogen hub in South Texas were unfolding by a trio of organizations, Apex Clean Energy LLC, Epic Midstream Holdings LP and the Port of Corpus Christi Authority, as part of a memorandum of understanding (MOU) signing. Apex CEO Mark Goodwin calls the proposal "green fuel production at gigawatt scale, reaching levels not yet seen in the United States."

The MOU calls for Apex, an Ares Management Corp. portfolio company, and its partners to explore developing green fuels infrastructure extending from West Texas to the Corpus Christi area. The partners envision producing unprecedented volumes of green hydrogen and other derivative green fuels that would be powered by Apex solar and wind facilities.

In a second MOU unveiled at the same time, four western states preliminarily agreed to create a hydrogen hub – the Western Inter-State Hydrogen Hub – which plans to apply for part of an $8 billion U.S. Department of Energy (DOE) program for creating a national network of hydrogen hubs. Colorado, New Mexico, Utah and Wyoming have joined together to seek some of the funding at DOE designated in the $1.1 trillion federal Infrastructure and Jobs Act passed last year.

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As part of the DOE's sprawling portfolio of research and development (R&D), there is an ambitious, multidisciplinary effort under way called "HyBlend." It intends to address technical barriers to blending hydrogen in natural gas pipelines by examining materials compatibility R&D, techno-economic analysis and life-cycle analysis, leading to the development of publicly accessible tools characterizing the opportunities, costs and risks of blending. This effort supports DOE's "H2@Scale" vision for clean hydrogen use across multiple sectors in the U.S. economy.

Across the country operators in various parts of the natural gas sector are working to get ahead of the curve on the possibility of a hydrogen economy emerging, seeking answers to various technical and economic questions. Concerns range widely from the differences in chemical makeup to hydrogen's potential long-lasting impact on steel pipe's material integrity. Operators want to know if mixing hydrogen with gas will change the effectiveness of various safety and maintenance programs.

"We believe that hydrogen is a zero-carbon energy carrier that can do everything that natural gas can do without carbon emissions," said Andrew Hegewald, gas development business manager for Dominion Energy in Salt Lake City. Dominion is in the midst of a four-phase, multiyear hydrogen development and testing program called Therm H2. "That's why hydrogen should definitely be an important tool in our **decarbonization ()** tool kit. At 5% hydrogen blend, we don't expect to make any changes to the grid. At higher blends, there may need to be some modifications, specifically to appliances. Higher blends are 10%, 15% and higher."

On a hydrogen-related webinar hosted in mid-March by the Gas Technology Institute (GTI), the moderator, Paula Gant, GTI's senior vice president for strategy and innovation, asked Scott Tinker, what word comes to mind when he hears "energy transition." Tinker, director of the 250-person Bureau of Economic Geology, a professor holding the Edwin Allday Endowed Chair in the Jackson School of Geosciences at The University of Texas (UT) at Austin, the State Geologist of Texas and energy thinker, said he immediately thinks "emissions because we're not so much in an energy transition as an emissions transition."

Eventually, that could mean a hydrogen economy, but Tinker approaches the energy future from a global and broad-based perspective grounded in air, land, water and atmospheric considerations.

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"If you look globally at energy, there is nothing going away, although in the U.S. and Europe, we see coal use decreasing," said Tinker, whose biography indicates he has worked to bring industry, government, academia and nongovernmental organizations together to address major societal challenges in energy, the environment and the economy. "The rest of the world is still building coal, so taken together, coal use is going up as are oil and natural gas. We're not leaving anything behind yet, but what we are looking at is the need for a transition away from high emissions. It doesn't mean getting rid of a bunch of fuels, but more precisely getting rid of a bunch of emissions." He notes it won't be easy because it must be done without harming the environment.

Tinker notes that only about half the world's population needs energy critically to sustain current lifestyles. A quarter of the globe's people have no energy, and the other quarter is just beginning to become more energy dependent.

"You really need to get right with the idea that we're going to be using dense energy resources forever," he said, adding that this will include moving away from coal to natural gas and away from carbon toward hydrogen/methane, and eventually mostly hydrogen and uranium. "That transition away from carbon to hydrogen and others will continue to happen," he thinks. "The denser forms of energy – dispatchable – will be supplemented by wind and solar along the way."

Tinker is the son of a geologist born in Centralia, Ill. He worked in the E&P sector for several years before joining Marathon Oil Corp.'s Petroleum Technology Center for more than a decade (1988-1999), eventually leaving the industry to head the Bureau of Economic Geology at UT.

"Hydrogen is all around us, and the cheapest form comes from methane, and most of it produced today comes from methane," Tinker noted. "If we can get hydrogen from probably either methane or water it is a combustible and is an energy carrier that can be used in vehicles. It's an electricity carrier as a fuel cell."

Tinker sees subsurface expertise from the fossil fuel sector will be valuable to the future hydrogen development. Hydrogen and compressed air storage are viable, but still need a lot of development.

Tinker and other researchers are examining potential changes in the natural gas infrastructure that will be needed to accommodate hydrogen. In California, two of the nation's largest gas utilities, PG&E Corp.'s Pacific Gas and Electric Co. (PG&E) and Sempra's Southern California Gas Co. (SoCalGas), are testing various infrastructure and blending combinations leading to mixing hydrogen in their natural gas streams.

PG&E is taking the position that there are still many unknowns about the impact of hydrogen blending on the natural gas infrastructure. According to spokesperson Melissa Subbotin, "While there are still a lot of knowledge gaps, the gas distribution system has the least gaps, and underground gas storage has the most [porous reservoirs specifically]."

SoCalGas has successfully blended up to 20% hydrogen through a closed-loop natural gas system complete with natural gas residential appliances, and it has been working for a number of years with researchers at the University of California, Irvine (UCI), and its National Fuel Cell Research Center (NFCRC). SoCalGas is blending hydrogen to fuel a test household system and appliances at its Engineering Analysis Center and Centralized Training Facility.

As part of the testing, technicians are measuring the performance of common household appliances like stoves, wall heaters and forced-air furnaces when they are fueled with a blend of hydrogen and natural gas.

"We continue to work with SoCalGas on transforming several parts of its gas system for introducing some percentage of hydrogen initially and transforming it for eventually carrying all hydrogen," said Jack Brouwer, UCI engineering professor and hydrogen fuel cell research director. UCI's work with Sempra's SoCalGas utility involves determining what impacts hydrogen-natural gas blends would have on various gas-fired appliances and end-uses. "We've found these appliances can handle blends of up to 30% hydrogen with no problem, and in most cases with reduction of nitrogen oxide (NOx) emissions," Brouwer said.

Brouwer and UCI also are working with SoCalGas on its "Angeles Link" project. The project's goal is to partner with California state regulators to begin exploring the introduction of hydrogen into existing pipelines and building new dedicated hydrogen infrastructure using existing rights-of-way – either adjacent to existing natural gas pipelines or inserted into existing gas lines. "There are some really interesting things that could happen over the next decade or so," Brouwer said.

What Brouwer and his fellow researchers have discovered so far is that the distribution pipeline systems will need little or no changes because they are nearly 100% plastic – not steel – piping.

Related distribution equipment, such as pressure regulators and customer meters, will need changes. The high-pressure steel transmission pipelines will need significant investment in modifications.

"The distribution pipelines likely will need little or no modifications even if the fuel is 100% hydrogen," Brouwer said. "Polyethylene or plastic pipes are already known to be able to handle hydrogen as well as natural gas."

Nevertheless, a switch to hydrogen will still require added investment in changes in the overall distribution system.

"In the transmission system, there is definitely a need to modify compressor stations," he said. "Current compressors are not going to be directly applicable from my perspective. We already have hydrogen compressors that work and with similar reliability, so we know there is a fix, but it is going to have to be invested in at compression stations."

A lot of transmission line piping is made of stainless steels, and the high-carbon steels have embrittlement problems with hydrogen. Thus, over time, if they are to carry pure hydrogen, those pipelines need to have a retrofit coating to handle high throughputs.

Brouwer, the California gas utilities and various national energy research organizations, such as DOE's Colorado-based National Renewable Energy Laboratory (NREL) and the Virginia-based Pipeline Research Council International (PRCI), are investigating both the production and transportation of hydrogen. PG&E's engineers emphasize that there are still many unknowns about the impact of hydrogen blending on the natural gas infrastructure. They note that blending, when it is done, should start off targeted and well controlled.

GTI has completed in-depth hydrogen blend studies for a consortium of natural gas operators as well as a key player in the HyBlend project, NREL, focusing on the life-cycle assessment of hydrogen blending as well as the safety, leakage, durability, integrity, end-use and environmental impacts.

A project at the Institute of Gas Innovation and Technology (IGIT) at the State University of New York, Stony Brook, helped provide the impetus for a larger project at NREL to perform R&D and evaluate the potential impacts of hydrogen blending into existing gas infrastructure. This $12.6 million project began last year with a two-year time frame, supported by 22 participants, including six national laboratories, GTI, IGIT and the multistate utility National Grid.

The project will make use of recent R&D on the potential impact of hydrogen on gas infrastructure as well as customer appliances, sponsored in part by National Grid, GTI, and the NYSEARCH program at the Northeast Gas Association.

In today's push for **decarbonization ()** of the energy stream to mitigate the impacts of climate change, the attraction and challenges of hydrogen are exposed in its chemical facts as the first element in the periodic table (H).

Scientists describe hydrogen as the "simplest and most abundant" element, consisting of only one proton and one electron. It does not typically exist by itself in nature and must be produced from compounds that contain it, such as water (H2O).

Production comes by splitting water molecules with renewable energy, nuclear energy or other sources of energy. Hydrogen can also be produced by splitting natural gas molecules through reforming. Like natural gas, hydrogen can store and deliver usable energy, but it is unique because it has zero carbon emissions when used. Hydrogen gas can be transported via pipelines to end-users, which today are typically industrial and chemical users. Therefore, it can reduce the emissions footprint inherent in traditional energy use.

Chemical differences surface in areas such as leak detection testing, based on the difference in molecules between natural gas and hydrogen. Hydrogen is a much smaller, faster molecule. Operators like Dominion Energy have found that the same technology used for gas can detect hydrogen leaks.

"We tested a variety of units, and some worked better than others, and that was exactly what we were trying to determine," said Dominion's Hegewald.

Similarly, hydrogen has a quarter to a third of the heating value of natural gas. "It is much less volumetrically dense than methane, so that lowers the overall heating value of your gas stream even in a 5% hydrogen environment," Hegewald said.

Dominion sought to assure that even with the lower heating values the blend would be within the overall pipeline specifications. "And indeed, we were," he said. "That's important to know because we want to determine if as we increase the hydrogen amounts, are we going to increase the time various customers need to boil water or make steel or dry clothes."

Various hydrogen advocates contributing to this *P&GJ* report make clear that besides chemical considerations, hydrogen's future is somewhat clouded by gaps in national research, economic factors, investment challenges and uneven handling at times by state and federal government agencies. PG&E engineers list at least eight "knowledge gaps" in the ongoing development of hydrogen, including pipeline integrity, metering, hydrogen-natural gas separation and underground storage, among others.

Subbotin notes that both the U.S. DOE HyBlend program and new California Energy Commission (CEC) programs should help address some knowledge gaps through laboratory testing, along with the DOE H2 Hubs program that will address some knowledge gaps at a commercial scale.

"What may be needed are investments to facilitate the transition from laboratory testing to small-scale pilots to large-scale pilots and then finally to commercial operations," the utility spokesperson said.

PG&E envisions the need for more small- to large-scale hydrogen blending pilots to obtain hands-on engineering and operational experience. "These can start with blending into an isolated pilot and cover the full value chain from H2 production with excess renewable electricity to blending and injection into the gas grid to utilization by customers [power generation, industrial customers, H2/compressed natural gas (CNG) fueling stations, etc.]," Subbotin said.

In addition, she adds that state and federal programs should do a better job providing funding and incentives for R&D work to close knowledge gaps like the HyBlend initiative and pilots that can evolve into H2 hubs.

In its recent studies on hydrogen, NREL has concluded that "any introduction of a hydrogen blend concentration would require extensive study, testing and modifications to existing **pipeline ()** monitoring and maintenance practices [integrity management systems]. Additional cost would be incurred as a result, and this cost must be weighed against the benefit of providing a more sustainable and low-carbon gas product to consumers."

According to NREL researchers:

"Blending hydrogen into natural gas **pipeline ()** networks also has been proposed as a means of delivering pure hydrogen to markets, using separation and purification technologies downstream to extract hydrogen from the natural gas blend close to the point of end use.

"As a hydrogen delivery method, blending can defray the cost of building dedicated hydrogen pipelines or other costly delivery infrastructure during the early market development phase. This hydrogen delivery strategy also incurs additional costs, associated with blending and extraction, as well as modifications to existing **pipeline ()** integrity management systems, and these must be weighed against alternative means of bringing more sustainable and low-carbon energy to consumers."

In the **decarbonization ()** sphere, hydrogen presents a variety of possibilities, particularly for the nation's multibillion-dollar energy pipeline network. It offers brown, gray, blue, pink, and green versions, based on the source of the hydrogen and whether it is combined with carbon capture and sequestration (CCS) systems.

Brown comes from coal or solid waste gasification, gray/blue are derived from natural gas via steam methane reformation, pink comes from nuclear-based electrolysis, and green comes from electrolysis using renewable-based electricity. Brown and gray hydrogen can be turned blue using CCS.

Advocates like Dominion's Hegewald anticipate that future technology advances are likely to come in terms of CCS and electrolysis. After being around for decades, brown, gray and green hydrogen are now attracting more attention and investment, according to Hegewald.

In California, UCI researchers and others are focused on advancements in electrolysis using solid oxide cells, which promise to be a new way of making hydrogen, according to Brouwer. Working with a maker of solid oxide fuel cell systems, San Jose, Calif.-based Bloom Energy, UCI is attempting to transform fuel cell technology into solid oxide electrolysis technology, which Brouwer said can "dramatically increase the efficiency" of hydrogen production from electricity and water using the solid oxide cells.

"A key to solid oxides is that you can make hydrogen at higher efficiencies, but it is a high-temperature electrolysis system, so it is not easy to ramp it up and down," Brouwer said. "It's a steady-state, continuous production, and the other cool thing about it is that at these temperatures you can take industrial waste heat streams and have the heat also make hydrogen. This is not possible with low-temperature hydrogen production."

Another technology that hydrogen advocates are tinkering with is methane steam reforming (MSR), generally thought of as the most common and cost-effective method for hydrogen production, contributing about 50% of the world's hydrogen production.

Although MSR is a mature technology, researchers note that it has significant disadvantages such as mass- and heat-transfer issues and coke deposition during the reaction.

"In industrial applications, the MSR reaction is carried out in conventional reactors and, in order to obtain a highly pure hydrogen stream, several steps are necessary, such as the reduction of carbon monoxide content in the reformate stream by water gas shift reactors, pressure swing adsorption, and further hydrogen separation/purification devices," according to a research abstract by Italian scientists Angelo Basile, Luisa Di Paola and others.

Researchers like UCI's Brouwer and others agree that today's efforts, bolstered by the multibillion dollars for hydrogen advancement in the 2021 federal infrastructure bill, should advance technology and lower the overall costs of a transition to hydrogen.

Brouwer is bullish about the prospects, but also concerned, as are others, that there are funding and technological gaps to be filled, particularly in systems engineering. Noting that the United States lags behind the rest of the industrialized world on hydrogen, Brouwer is hopeful the DOE's announced "hydrogen energy earth shot" will help close this gap, including addressing the systems engineering issue.

Brouwer argues for more attention on the "un-cool," more mundane part of hydrogen R&D, the overall systems engineering requirements.

"While electrocatalyst and cell innovations are relatively well supported, there is insufficient funding devoted to electrochemical systems engineering of individual products and hardware," he said. "But two higher levels of systems engineering also are receiving scant attention in the R&D world."

These include local utility-scale sets of hardware and dispatch concepts to meet the dynamics of demand in a region (for example, decarbonizing Southern California by 2045).

"To do that also requires systems engineering to modify the electric grid, possibly decarbonize the gas grid and invest in networking various regions like the Western Electric Coordinating Council to begin regional transformation immediately. There is currently no research funding to address this," Brouwer said.

In the meantime, Brouwer indicates he will be busy discussing this with his colleagues at DOE who will be doling out funds that will help determine hydrogen's future.

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