A Position Paper on Hydrogen For New Mexico

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Executive Summary

The US makes about 10 million ton/yr of industrial hydrogen using the Steam Methane Reforming process (SMR). With the attendant methane and carbon dioxide emissions this industry cannot be ignored, especially since demand for hydrogen is expected to grow four-fold by 2050. The industry needs to and should transition from existing 'fossil fuel hydrogen' to 'renewable hydrogen' made via the electrolysis of water using renewable energy.

The 'color' terms used for hydrogen obfuscate how it's made. We prefer terms like 'renewable hydrogen' (instead of 'green') or 'fossil fuel hydrogen' (instead of 'blue'). The climate impacts of the processes then become much clearer.

Both SMR and electrolysis processes use similar amounts of water, net per kg of hydrogen. The major difference is that SMR has a waste carbon stream that is costly to dispose of, while electrolysis has only valuable byproduct oxygen. For fossil fuel hydrogen to succeed, it requires a successful and effective carbon capture and sequestration (CCS) step. Claimed unprecedented levels of performance of up to 97% capture have not yet been demonstrated at scale. Realistic industrial performance is in the 40-50% range. There is no profit to be made from CCS it's a pure operating cost.

Renewable hydrogen is also needed to replace the 55% of fossil fuel hydrogen that is used to make ammonia, a feedstock for fertilizer manufacturing. Without ammonia based fertilizers it is estimated that a billion people on the planet would starve. Renewable hydrogen plus renewable energy can make renewable ammonia and hence renewable fertilizers.

Fossil fuel hydrogen only benefits the Oil and Gas industry by expanding the sales of natural gas. At best it delays potent emissions reductions. Any expansion of fossil fuel hydrogen only adds to our greenhouse gas, notably methane, emissions.

Renewable energy businesses will offer many profitable business opportunities as the costs of wind, solar and storage continue to fall. As part of a broader statewide strategic plan to move from an oil & gas economy to a renewable economy, every effort should be made to transition to renewable hydrogen from fossil fuel hydrogen and to incentivize all the business opportunities hydrogen has; as an energy carrier, with electrolyzers and fuel-cells, in decarbonizing other industries and in transportation. Such moves are driven by the need to avoid stranded Oil and Gas assets, the drive for positive climate action and in the end by the economics.

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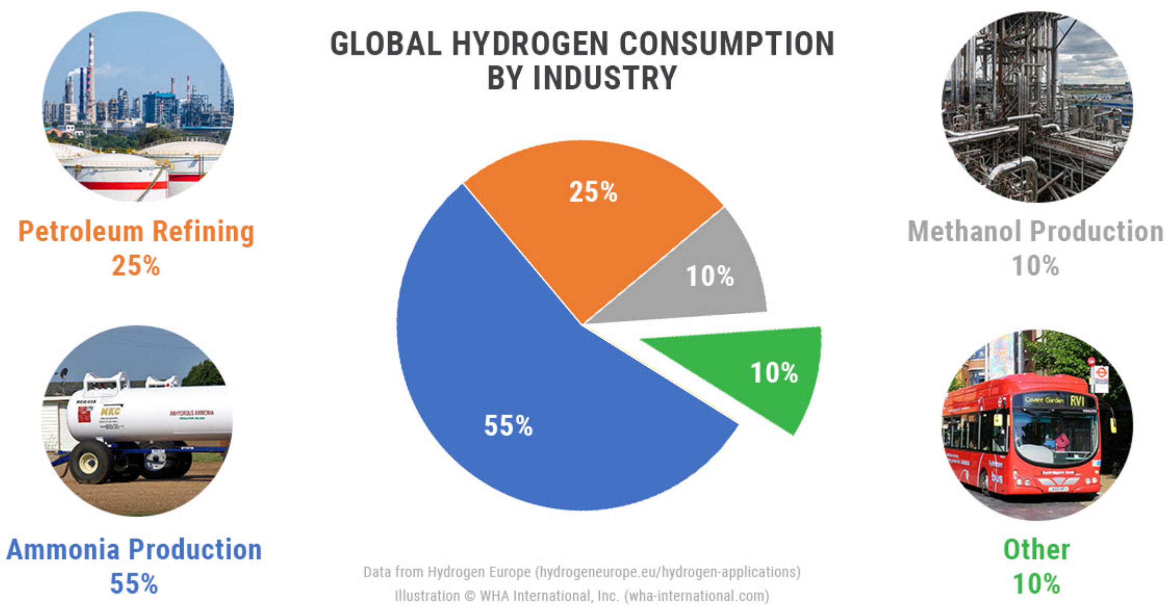
Hydrogen is here to stay

Hydrogen, while the most abundant element in the universe, is a little elusive on Earth. Because of its very low density under normal conditions, it has been used in lighter-than-air dirigible aircraft with some spectacular failures. Let loose and it rapidly rises in the atmosphere and dissipates.

Currently it's estimated the US makes 10 million tonnes per annum (Mtpa) of hydrogen. This is expected to grow to 40 Mtpa by 2050. 90-95% of US hydrogen is made from the methane in natural gas using the Steam Methane Reforming (SMR) process. About 55% of the hydrogen produced is used to make ammonia, 25% goes back into petroleum refining, 10% goes into methanol production and 10% goes into miscellaneous uses such as metallurgical processes. A fraction currently goes into fuel cells to generate electricity. Ammonia is important since it in turn is used to make fertilizers, without which it has been estimated that 1 billion of the planet’s population would starve.



ref: https://wha-international.com/wp-content/uploads/2020/09/Hydrogen-Industry-Breakdown.jpg

Given that methane is such a potent greenhouse gas (GHG) with a global warming potential (GWP) in the first 20 years following release that is 86 times that of carbon dioxide, and it seems to have a leakage rate of anywhere from 3-6% of production where ever it's used, it is a ‘low hanging fruit’ when addressing the climate crisis and dangerous temperature increases. The fossil fuel hydrogen industry based on methane, therefore, doesn't need to be expanded but instead needs to be decarbonized.

Hydrogen 'colors' only obfuscate

There has been much discussion of hydrogen, some ideological, in terms of 'colors'. But hydrogen 'colors' disguises the impact GHG emissions have with hydrogen production from different manufacturing processes. The **hydrogen color spectrum** can be summarized as:

- Green - hydrogen made from renewable sources, essentially the electrolytical processes, using water and renewable energy such as wind, solar and geothermal.
- Gray - hydrogen made from the methane in natural gas and other oil and gas products, mostly using Steam Methane Reforming process.
- Blue - gray hydrogen with carbon capture and sequestration processing added.
- Brown - hydrogen made from coal mostly via Coal Gasification.
- Pink - hydrogen made via electrolysis of water using energy from nuclear power.
- Turquoise - hydrogen made using an unproven process called methane pyrolysis to produce hydrogen and solid carbon.
- Yellow - hydrogen made through electrolysis using only solar power.
- White - hydrogen found in naturally-occurring geological formations.

Meanwhile, '**clean' hydrogen** is an ambiguous phrase meant to refer to any hydrogen production that has a net-zero or better GHG emissions 'footprint'. Sometimes it is used to refer to hydrogen made with low but not insignificant CO_2 emissions, compared to fossil fuel hydrogen.

'**Low carbon hydrogen'** is another ambiguous term sometimes meant to mean any hydrogen production that doesn't exceed emissions of 2 kg equivalent-CO_2/ kg hydrogen produced. Part of the problem is that there are no agreed international standards on what the term means, let alone a US standard.

Renewable hydrogen is made purely from renewable energy and water. 'Yellow and 'green' hydrogen fall into this category.

Fossil fuel hydrogen or fossil-hydrogen is predominantly made from methane in natural gas and other oil and gas products. 'Blue', 'gray', 'brown' and 'turquoise' hydrogen fall into this category.

Note, until all manufacturing, storage and transportation industries have been decarbonized, all hydrogen production will have some life-cycle carbon footprint.

It may all come down to water

Hydraulic fracturing (fracking) takes lots of water to get natural gas out of the ground. Even more is needed to run Steam Methane Reforming (SMR) to make hydrogen from that methane. Then additional water will be required to operate the generally unproven carbon capturing and deep well injection process promoted by the fossil fuel industry.

Electrolysis takes about the same amount of water per kg of hydrogen as SMR even before the complication of carbon waste streams disposal is taken into account. An EnergyPost report on research into how much water will be needed in the production of hydrogen through electrolysis can be summarized as:

> It appears that total water use involved in producing hydrogen by electrolysis is about 32 kg H_20/kg H_2 and 22 kg H_20/kg H_2 when produced using electricity from photovoltaic cells or wind turbines, respectively (including electricity production, water purification and the electrolytic reaction itself).
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> In Steam Methane Reforming (methane reacting with water under heat and pressure), total water consumption from the water consumed in the reaction itself as well as water use during production of natural gas to heat the reaction, ranges from 7.6-37 kg H_20/kg H_2, with an average of about 22 kg H_20/kg H_2. The higher water consumption figure results, at least in part, when the natural gas used (for both methane for the reaction and to power the reaction) is derived from (fracked) shales.
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> From a chemistry standpoint, SMR produces twice as much hydrogen per molecule of water consumed than does electrolysis, but it takes a substantial amount of water to produce the methane used in the process, so the net water use is not that different. But, electrolysis produces no CO_2 whereas SMR does, both in the chemical reaction itself and in burning fossil fuels to generate heat to drive the reaction. Hence the need for extensive (and currently unachievable) levels of carbon sequestration to make 'gray' hydrogen 'blue'.

A 2016 Ceres Research Paper reports that around 100 billion gals/yr of water are consumed by the fracking process in the US. This is over four times what would be needed to meet the current demand for 10 Mtpa hydrogen using electrolysis. New Mexico fracking water has been reported by the US Geological in 2019 to run around 14 billion gals/yr.

Water that is suitable for electrolysis has to be relatively clean, otherwise contaminants can interfere with the catalytic action on modern electrolyzer electrodes. Brackish water for example has to be purified by reverse osmosis to remove excessive salts. Reports indicate such purification has a minimal cost.

If water is available for the SMR process in NM to make fossil fuel hydrogen then it is also available to make renewable hydrogen. It is however unclear how much of the US hydrogen market New Mexico would like to capture. Only a small fraction would be needed to jump start the development of 'green' businesses derived from renewable hydrogen.

Valuable byproduct oxygen

High school students are (or should be) taught that for every 1 kg of hydrogen produced by the electrolysis of water, 8 kg of oxygen, an important industrial and medical gas, is also made. Oxygen is a valuable byproduct compared to the costly waste carbon stream from the SMR process. The economic impact of oxygen and how it can be utilized needs to be explicit in the discussions of the economics of renewable hydrogen.

Oxygen gas has many medical, health and recreational uses. Industrially, oxygen is used in the smelting of iron ore, in the production of chemicals, in welding and many other essential applications.

Carbon Capture and Sequestration doesn't work well enough

Some form of carbon capture and sequestration is included in proposals for the fossil fuel industry to dispose of the waste carbon stream from the SMR process and parasitic energy demands. Air Products has estimated that current carbon capture technology is only capable of capturing 40% of such waste carbon. Claimed 95% capture rates have not yet been demonstrated as scale.

Enhanced Oil Recovery is not Carbon Capture and Sequestration

The fossil fuel industry likes to claim that waste carbon dioxide streams from the SMR process might be stored underground using Enhanced Oil Recovery (EOR). EOR uses the gas to pressurize the oil and gas reservoirs to increase production levels. Much more carbon bearing materials are thus returned to the bio-sphere than is actually stored. Not only that but the security of the underground storage isn't guaranteed in the long term as it is with basaltic rock carbonation. EOR CO_2 may well find it's way back into the atmosphere as easily as abandoned and orphaned wells leak natural gas.

Electrolyzer projects

A week doesn't go by when there isn't another announcement of investors planning to build renewable hydrogen plants connected to wind or solar farms. In July 2021, Plug Power announced:

- Hydrogen technology company Plug Power has entered into a 345 MW wind power purchase agreement (PPA) with Apex Clean Energy. The energy from the wind farm, which Apex believes will be the first and largest wind-powered hydrogen project in the U.S., will power one of a series of liquid hydrogen plants Plug plans to build by 2025.

- The new hydrogen plant, which will draw power directly from one of Apex's wind farms under development in Texas, will be capable of producing 30 metric tons of liquid hydrogen per day, which Plug Power estimates is enough to fuel over 1,000 heavy-duty class 8 trucks.

- The plant's 30-ton capacity will be enough to supply three-fourths of Plug Power's current hydrogen demand, according to company Chief Strategy Officer Sanjay Shrestha, but is only a first step toward the company's goal to "make hydrogen ubiquitous."

In May 2021, Recharge reported Iberdrola and Cummins announce plans for Europe's fourth hydrogen electrolyzer gigafactory and the project in central Spain follows in the footsteps of gigafactory announcements earlier this year by ITM Power, Nel and McPz:

- US-based power company Cummins announced it is to build a hydrogen electrolyzer gigafactory in Spain in partnership with Iberdrola, it was announced on Monday morning.

- The €50m ($61m) proton exchange membrane (PEM) electrolyzer plant will start up in 2023 in the central region of Castilla-La Mancha, near Madrid, as a 500MW-a-year facility, "and will be scalable to more than 1GW/year", according to Cummins.

- It is the fourth electrolyzer gigafactory to be announced in Europe this year, following in the footsteps of the UK's ITM Power, Norway's Nel and France's McPhy.

- Denmark's Haldor Topsoe has also unveiled plans for a 500MW plant producing high-efficiency high-temperature solid-oxide electrolyzers.

The Economics

Dramatic drops in the price of electrolyzers, combined with low-cost renewable energy, can enable 'green' hydrogen to be the cheapest form of hydrogen by the end of the decade, analyst says according to a Dec 2021 report by ReCharge: 'Producing green hydrogen for $1/kg is achievable in some countries by 2030': WoodMac. Such price curves suggest there's only a short window when fossil fuel hydrogen might be competitive assuming tax payers fund the carbon capture step. Beyond that SMR facilities will become stranded assets.

Recommendations

We are thus committed to promoting the development of renewable hydrogen made from the electrolysis of water using renewable sources of energy.

For clarity we recommend use of the terms 'fossil fuel hydrogen' and 'renewable hydrogen' to reflect how the hydrogen is made as against the use of obfuscating colors.

We recommend private industry, i.e. the fossil fuel industry demonstrate the economic and technical feasibility of fossil fuel hydrogen and carbon capture and sequestration processes at a pilot plant scale. Such a step minimizes the economic risk while also answering many of the technical issues before scaling up to commercial adoption. With strict performance standards and professional independent oversight, the state agencies and tax payer interests will be best served to determine if scaling up is a prudent step. Implementation at scale risks stranded assets given how long projects take to implement.

Meanwhile, strategically, we believe it is clear that, as fast as we can, New Mexico should take the following steps as part of a statewide strategic plan:

- apply for and secure one of the infrastructure hydrogen hub $2 billion grants based on renewables, given our extensive solar and wind resources,
- overbuild renewable wind, solar and storage that's needed for a reliable grid,
- use the excess renewable power to generate the renewable hydrogen to make renewable (aka 'green') ammonia or for licensing novel and locally developed technologies,
- develop systems to pursue sales of the byproduct oxygen,
- divert a fraction of hydraulic fracturing (fracking) water for electrolysis,
- working with the State Investment Council, fund economic development plans in support of technologies for electrical transmission lines, renewable energy, electrolyzers, fuel-cells, hydrogen and the multitude of other energy storage options (e.g. metal hydride storage, gravity storage etc.),
- provide incentivizing tax breaks for such endeavors,
- explore public private partnerships with companies like Cummins to build one or two of their GW electrolyzer plants where the jobs are needed in NM,
- promote the SpacePort as an infrastructure hub for the support, development and testing of BEV and FCEV planes.

We insist on a strategic plan for NM that integrates all that's happening in the 'green revolution', that cuts fossil fuel usage and dangerous climate warming emissions, that encourages jobs around green businesses and brings the attendant economic benefits, especially to disadvantaged communities.

Sources:
NM Hydrogen Policy Letter
Hydrogen Background

Abbreviations

BEV – battery electric vehicle
CCS – carbon capture and sequestration
FCEV – fuel cell electric vehicle
GHG – greenhouse gas
GWP – global warming potential relative to carbon dioxide
kg – kilogram
Mtpa – million tonnes per annum
SMR – Steam Methane Reforming process