A Position Paper on Hydrogen For New Mexico

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350 Santa Fe

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Executive Summary

The US makes about 10 million tonne/yr of industrial hydrogen using the Steam Methane Reforming process (SMR). The industry is a major contributor to methane and carbon dioxide emissions that 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' produced either via the electrolysis of water using renewable energy or by accessing the potential of geologic hydrogen reserves.

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 has high disposal costs, while electrolysis has only useful byproduct oxygen. For fossil fuel hydrogen to succeed, it requires an efficient and cost effective carbon capture and sequestration (CCS) step. Claimed unprecedented levels of performance of over 90% capture have not yet been demonstrated at scale. Realistic industrial performance[1] is more like 55% and as low as 11% when upstream losses are accounted for. There is no profit to be made from CCS as it's a pure operating cost.

The full potential of co-produced oxygen from the electrolytic process to make renewable ('green') hydrogen continues to be ignored. Electrolyzers produce 8 kg of oxygen for every kg of hydrogen. Medical oxygen can be priced around $10/kg and up. Such a potential economic impact requires serious evaluation, taking into account the needed infrastructure to capture, store and transport oxygen.

Geologic ('white') hydrogen is now found, often via seepage, in certain geological formations. Hydrogen reserves have now been identified with purity levels over 90%. Since such hydrogen isn't manufactured and occurs naturally, all the water demands from either electrolysis or the SMR process go away. Geologic reserves have also shown no decline in production. Minimal water and energy usages will stem from the initial drilling activities. Since geologic processes can allow these reserves to be continuously productive, geologic hydrogen may be an inexhaustible resource. Serious prospecting efforts are needed and private industry is beginning to take notice.

Renewable ("green" or "white") hydrogen is also needed to replace the 55% of fossil fuel hydrogen that is used to make ammonia, a feedstock for fertilizer manufacturing. It was estimated[2] in 2016 that 3.5 billion people on the planet were sustained by foods grown with

[1] https://phys.org/news/2019-10-carbon-capture.html - "Study Casts Doubt on Carbon Capture" - Phys.org - Taylor Kubota - October 25, 2019

[2] https://ourworldindata.org/how-many-people-does-synthetic-fertilizer-feed - "How many people does synthetic fertilizer feed? - Our World in Data - Hannah Ritchie - November 2017

ammonia based fertilizers.. Renewable hydrogen using renewable energy can make renewable ammonia and hence move towards renewable fertilizers. While internationally, companies are aggressively installing electrolyzers and developing green hydrogen opportunities there is reluctance in the US.

Fossil fuel hydrogen only benefits the Oil and Gas industry by expanding the sales of natural gas and delaying potent methane emissions reductions. Any expansion of fossil fuel hydrogen only adds to our greenhouse gas emissions and is widely opposed.

Renewable energy businesses will offer many profitable 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 and gas economy to a renewable energy economy, every effort should be made to transition to renewable hydrogen - green and white - and away from fossil fuel hydrogen.

We recommend incentives be provided to businesses willing to pursue renewable hydrogen opportunities; as an energy carrier (with oxygen, electrolyzers, storage and fuel-cells), as an energy source (geologic hydrogen), and in applications of hard to decarbonize industries and heavy-duty transportation.

(NB. This paper is based on our extensive research and sources documented in our 350santafe.wiki Hydrogen Background article. We encourage readers to visit our wiki http://www.350santafe.wiki/index.php/Hydrogen_Background for supporting information, background and references.)

350 Santa Fe, March 2024

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Preface

In the ongoing discussions about the pros and cons of hydrogen's role in New Mexico, we decided to write a position paper based on well-researched and reliable sources that paints a pragmatic picture against which polices and plans can be developed. Our aim here is to explore how non-fossil fuel hydrogen helps to decarbonize human activity as rapidly as possible, to drive down our greenhouse gas emissions.

Some of this is motivated by what appears to be a rise in ideology as a basis for decision making - a popular national trend in the 2020s. In solving the climate crisis. we believe all options should be on the table. If it looks like it might stop the burning of fossil fuels or cuts potent greenhouse gas (GHG) emissions, it is fair game. Pragmatically, pursuit of effective solutions will ultimately have to prove themselves in the market place. Jump starting promising ideas with state and federal funding can play a big role.

There are problems with many paths to a fast and just transition. Whenever there are novel forms of concentrated energy, be it electrical, chemical, kinetic or potential, there are always risks. Understanding these risks and expeditiously finding solutions is something at which humans are good at. Believing today's problem is a death knell to a particular solution biases the pursuit away from potential break-throughs. Such breakthroughs might be in the basic sciences or how a solution is engineered or how a process is optimized and managed. Even breakthroughs in agency rules, regulations and management systems may play a part. Such breakthroughs, big and small, may come from interdisciplinary thinking and creative imaginations. In the face of the disastrous consequences of a 2, 3, or 4 deg. C global temperature rise, now is the time to seriously act on all fronts and not to get too choosy.

Much of the basic problems with, and consequences of, the climate crisis require both some understanding of environmental science, and of the technical and economic solutions. We encourage the curious to visit our growing on-line resources in our Wiki (350santafe.wiki) and in particular on the "Hydrogen Background" material.

We hope readers find this review useful in speaking to what hydrogen is about, what might need to be done and how best to take advantage of available opportunities in our quest to mitigate or perhaps even reverse the worst effects of global warming.

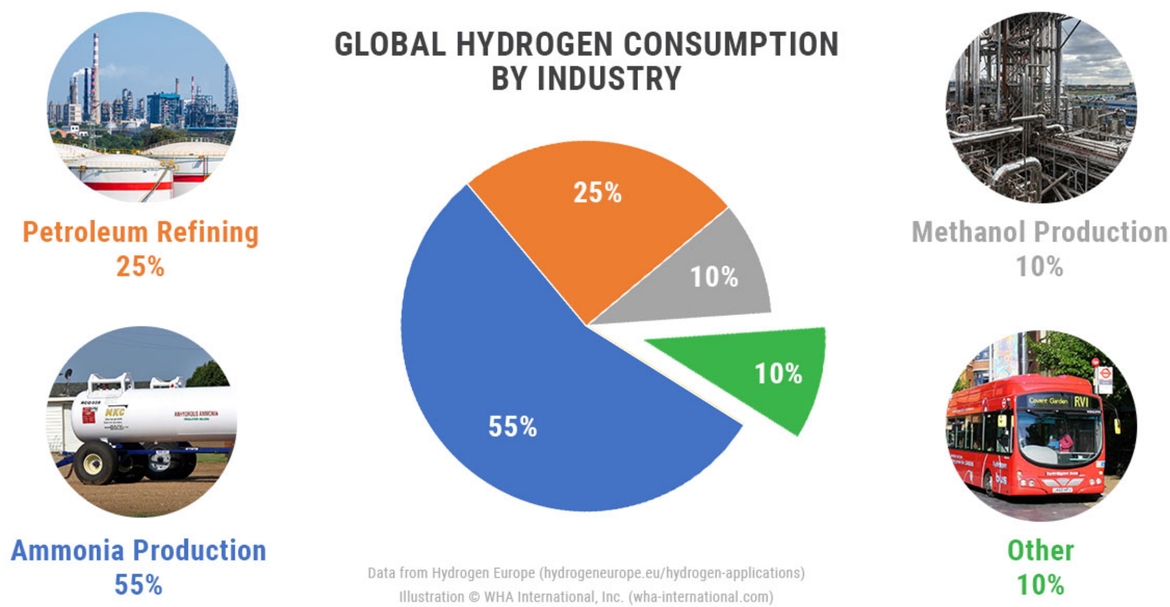
Robert Cordingley, Matthew Hecht, James Eagle
350 Santa Fe, March 2024

So What's The Story?

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 40-50 Mtpa by 2050. 90-95% of US hydrogen is currently 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 small fraction currently goes into fuel cells to generate electricity or is burned directly in air for propulsion. Ammonia is important since it, in turn, is used to make fertilizers, that 3.5 billion of the planet's population depend on for food[3].



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

[3] https://ourworldindata.org/how-many-people-does-synthetic-fertilizer-feed - "How many people does synthetic fertilizer feed? - Our World in Data - Hannah Ritchie - November 2017

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, it is critical to recognize that the reported leakage rate is 3-9% from well-head to user. It is 'low hanging fruit' when addressing the climate crisis. The fossil fuel hydrogen industry based on methane, therefore, should not be expanded but instead needs to be phased out and replaced with renewable hydrogen.

Hydrogen 'colors' can easily obfuscate.

There has been much discussion of hydrogen, some ideological, in terms of 'colors'. But hydrogen 'colors' can disguise the different impacts GHG emissions can have 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 (SMR) 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 or Gold - hydrogen found in naturally-occurring geological formations.
- Orange - hydrogen made in geological formations by the direct injection of water.
- Purple - hydrogen made from biomass fermentation (our proposal, an unused color)

Semi-technical terms aren't much better.

Meanwhile, '**clean' hydrogen** is mostly 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 still significant CO_2 emissions, compared to fossil fuel hydrogen. The Department of Energy specifies 'clean hydrogen' as hydrogen produced on-site with less than 2kg of CO_2/kg hydrogen. While the US Inflation Reduction Act specifies a lifecycle target for 'qualified clean hydrogen" of less than 4kg of CO_2/kg hydrogen. The (on-site) SMR process typically produces 7kg of CO_2/kg hydrogen.

'**Low carbon hydrogen'** is another ambiguous term with no agreed international standards on what this or 'clean' hydrogen means.

Renewable hydrogen – a term we prefer – is made from renewable energy and water or sourced from geologic hydrogen reservoirs. 'Yellow', 'green', 'white' and 'orange' hydrogen fall into this category.

Fossil fuel hydrogen – a term we prefer – 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 emissions.

Is 'white' hydrogen our white knight that saves us?

White hydrogen, often referred to as geologic hydrogen, may be a sleeping giant!

> *"There might be enough natural hydrogen to meet burgeoning global demand for thousands of years, according to a U.S. Geological Survey (USGS) model that was presented in October 2022 at a meeting of the Geological Society of America."* [4]

Very pure finds in Africa and France have ignited some in the industry, with companies like Denver CO based Natural Hydrogen Energy LLC (NHE) deliberately prospecting for hydrogen. As with the geothermal energy industry the same prospecting, exploration and drilling assets can be employed in what might be the next 'gold rush'. We note that fracking isn't needed and depths required are unexceptional.

NHE CEO Viacheslav Zgonnik is author of a 2020 survey[5] of literature on geologic hydrogen in which Zgonnik bemoans the fact that most geologic hydrogen was found accidentally, no one was really looking. It's also reported that geologic hydrogen in some instances is being continually renewed by the migration of natural water into the right geologic strata where minerals react with the water stripping the oxygen and leaving the hydrogen.

'Green' hydrogen 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 SMR to make hydrogen from that methane. Then additional water is required to operate the generally unproven carbon capturing and deep well injection process promoted by the fossil fuel industry.

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[4] https://www.science.org/content/article/hidden-hydrogen-earth-may-hold-vast-stores-renewable-carbon-free-fuel - "Hidden Hydrogen", Science February 2023

[5] https://www.sciencedirect.com/science/article/abs/pii/S0012825219304787?via%3Dihub - The occurrence and geoscience of natural hydrogen: A comprehensive review - Earth Science Reviews - April 2020

Electrolysis takes about the same amount of water per kg of hydrogen as SMR. An EnergyPost report[6] 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).
>
> In SMR (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.
>
> 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[7] 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 costs can be minimal. Depending on the geology and the dissolved components, the produced water which occurs naturally in oil and gas formations also has to be purified. Complicating matters, produced water recovered from fracked wells will also be contaminated with the fracking water ingredients.

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[6] https://energypost.eu/hydrogen-production-in-2050-how-much-water-will-74ej-need/: "Hydrogen production in 2050: how much water will 74EJ need?" Jan 2021

[7] https://www.ceres.org/resources/reports/hydraulic-fracturing-water-stress-water-demand-numbers : "Hydraulic Fracturing & Water Stress: Water Demand by the Numbers" - Ceres - February 2016

If water is available for the SMR process in NM to make fossil fuel hydrogen then it is also available to make renewable hydrogen, since it's about the same amount. 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.

But then there is useful byproduct oxygen.

High school chemistry tells us 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 useful byproduct compared to the costly waste carbon stream from the SMR process. The economic impact of oxygen and how it can be utilized is often overlooked and thus needs to be included 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. Electrolyzer oxygen is a suitable source for medical grade or high purity oxygen. Medical grade oxygen sells widely around \$10/kg O_2 and sometimes twice that in the US. Income from coproduced oxygen could then amount to \$80/kg H_2 (cf: SMR hydrogen costs around \$1-2/kg H_2). Incidentally, retail oxygen packs, available in your local grocery store, cost almost \$2,000/kg O_2!

'Diverting' renewable energy to green hydrogen may not be a good idea?

Calculating the efficiencies of delivering energy from renewable sources, through electrolysis and back again through storage and fuel cells to electricity looks discouraging. However, whether that's a real concern depends on a wide number of factors, including:

- Is it part of a storage strategy where long term power shortages need to be accommodated using excess power in 'good times'? With a recent (March 2024) federal grant of \$500k, Kit Carson Electric is evaluating just such a project to ensure 100% renewable power 24/7 covering those periods when solar and wind are falling short. For them it's cheaper than battery options.
- Does using local energy infrastructure to make green hydrogen prolong the operation of fossil-fuel power plants already scheduled for closure? Where do the power and water come from and where is the hydrogen and oxygen going to go? Specific geographical locations bear heavily on such assessments.
- Is there water available for electrolysis anyway? Water electrolyzed by renewable energy to make hydrogen to then use in fuel cells can recover around 60% of the 'original' water.

- Locally, how well is basic infrastructure built out to take advantage of any proposal? Will it serve the local population, does it work as a stand-alone facility?
- How much does it cost compared to other green energy options?

In our capitalist economy, the strong determinant will be costs. Inefficiencies will present opportunities for technical developments to engender competition. As Bill Gates recounts in his book *"How to Avoid Climate Disasters",* reducing 'Green Premiums' (the incremental cost of going green) must be an area of technological research and development.

Increasing electrical demand risks keeping fossil fuel power on-line longer.

Use of renewable energy in any new electrochemical process (e.g. green hydrogen or green cement) increases the demand for power. Against the backdrop of increasing worldwide demand for more power, electrification that is directed towards decarbonization of industry, transportation and agriculture, all have the potential of prolonging fossil fuel power generation.

Meanwhile, artificial intelligence, cryptocurrencies and data center applications are driving the demand to electrify faster than new generating facilities are being built (Washington Post, march 7, 2024, "Amid explosive demand, America is running out of power").

It's not clear how power allocations should or even could be prioritized in the face of electrification and the growing demands of so many aspects of our lives and industry. Such issues will need evaluating at the state or city level on a case by case basis, incorporating local needs and addressing local environmental justice concerns.

Carbon Capture and Sequestration (CCS) doesn't work well enough.

In order to make palatable the production of hydrogen from natural gas via the SMR process, some form of carbon capture and sequestration is almost always included by the fossil fuel industry. The cited clean hydrogen targets almost make it imperative.

Industry however has made many claims of successful carbon capture from effluent streams of up to 95%. Most claims are based on the local carbon material balance and don't include losses from say well-head to customer. As reported in Phys.org, Mark Z. Jacobson[8] at Stanford University:

"calculated all the emissions associated with [the coal] plants that could contribute to global warming, [and] converted them to the equivalent amount of carbon dioxide in order to compare

[8] https://phys.org/news/2019-10-carbon-capture.html - "Study Casts Doubt on Carbon Capture" - Phys.org - Taylor Kubota - October 25, 2019

his data with the standard estimate. He found that in both cases the equipment captured the equivalent of only 10-11 percent of the emissions they produced, averaged over 20 years." "Even without accounting for upstream emissions, the equipment associated with the coal plant was only 55.4 percent efficient over 6 months, on average"

Enhanced Oil Recovery (EOR) is not Carbon Capture and Sequestration.

The fossil fuel industry also hopes to store waste carbon dioxide streams from the SMR process underground using 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 biosphere than is actually stored. Not only that but the security of the underground storage isn't guaranteed in the long term. EOR CO_2 may well find its way back into the atmosphere as easily as abandoned and orphaned wells leak natural gas.

Are there other problems and opportunities with hydrogen?

Contemporary concerns over widespread use of hydrogen are mostly overstated. Here is some perspective on four common ones.

Hydrogen Tanks

Hydrogen storage standards have been specified for different types of tanks from metallic pressure vessels to impervious, wrapped and lined types. Hydrogen as the smallest molecule is susceptible to permeation without the proper tank design. Equivalent energy losses become comparable to other energy storage and energy carrier options.

Hydrogen embrittlement

Hydrogen embrittlement in steel piping can be caused by improperly laid welds. The presence of hydrogen atoms (not molecular) is also a factor. Steels susceptible to embrittlement (hardened tool steels) are not used in pipelines. 1000 miles of hydrogen pipeline on the Gulf Coast attests to proper management of the phenomenon. In the absence of reports of pipeline failures and the underlying metallurgy, this problem seems to be solved

Hydrogen as a fuel

Hydrogen use as a fuel can produce NO_x emissions in much the same way as any fuel burned in air. Air is 78% nitrogen so at high temperatures burning fuels in air will coincidentally generate some NO_x. Three-way catalytic converters can cut CO, hydrocarbons and NO_x by over 99% if the air to fuel ratio is accurately controlled. So the problem is largely solved except perhaps in aviation applications where such a device would interfere with propulsion demands.

Hydrogen Energy Density vs Ammonia

Hydrogen stored either as a gas or liquid has some engineering challenges but when 'converted' to anhydrous ammonia it can act as a more useful energy carrier. Ammonia has a zero GWP, a much higher energy density than hydrogen and when burned produces only water and nitrogen. Ammonia while toxic, has been around a long time so its safety precautions are well known.

Basaltic rock storage of CO_2 can work if we knew where.

A project in Iceland that includes Direct Air Capture (DAC), injects a mixture of water and carbon dioxide in basaltic rock formations. After about two years the carbon has combined with minerals to form primarily calcium carbonate, a solid, like limestone. The solid can be seen in veins in rock samples. The carbon is thus locked up for all eternity.

New Mexico is known for its past volcanic activities. Basaltic rocks are visible in ancient lava flows. So far the extent of suitable basaltic rock formations that could be used for carbon storage is not yet known. We encourage any efforts to identify the extent, accessibility and potential capacity of these geological formations.

Note such storage is different from EOR operation in which CO_2 is reinjected into depleted oil and gas fields. It is also different from storage in salt domes or caverns were underground space is created by dissolving salt deposits with water that is then returned to the surface as brine.

Companies are building 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[9]:

- 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 Power 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, for example, to fuel over 1,000 heavy-duty class 8 trucks.

[9] https://www.utilitydive.com/news/developers-enter-largest-green-hydrogen-ppa-in-us-with-345-mw-of-wind-to-po/603366/ : Developers enter largest green hydrogen PPA in US with 345 MW of wind to power facility - Utility Dive - July 2021

- 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[10] 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/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.

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. According to a Dec 2021 ReCharge article: "*'Producing green hydrogen for $1/kg is achievable in some countries by 2030': WoodMac*", quoting a Wood Mackenzie analyst. 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.

More recently, US startup and Colorado based NovoHydrogen Holdings LLC[11] has received a $20 million equity investment from Modern Energy Group LLC to develop 'green' hydrogen production plants across North America.

So what do other think tanks think about hydrogen?

[10] https://www.rechargenews.com/energy-transition/iberdrola-and-cummins-announce-plans-for-europes-fourth-hydrogen-electrolyser-gigafactory/2-1-1014743 : Iberdrola and Cummins announce plans for Europe's fourth hydrogen electrolyser gigafactory - Recharge May 2021

[11] https://novohydrogen.com/news/in-the-news-colorado-startup-novohydrogen-secures-20m-commitment-role-in-doe-regional-energy-hub/ : Colorado startup NovoHydrogen secures $20M commitment, role in DOE regional energy hub - Nov 2023

For the most part with perhaps a couple of exceptions, we consider the positions of the following think tanks to largely be in alignment with our analysis. There are two significant exceptions which we think are conspicuous by their absences:

1. the emerging significance of white hydrogen
2. the economic benefits of potentially useful byproduct oxygen from the electrolysis of water.

There is universal agreement on:

1. 'blue' hydrogen should be avoided at all costs,
2. hydrogen has an important role in the transition from fossil fuels,
3. CCS even if it works is an expensive option in the transition to clean energy.

Bullet points are transcribed from the corresponding organizations' reports or webinar.

IEEFA Position (https://ieefa.org)

In February 2022. the Institute for Energy Economics & Financial Analysis (IEEFA) published their analysis on hydrogen in their report *"Blue Hydrogen: Technology Challenges, Weak Commercial Prospects and Not Green".* Key takeaways were:

- Blue hydrogen requires methane; production is energy-intensive.
- Blue hydrogen requires carbon capture and storage (CCS).
- Commercial CCS projects have never achieved the industry target rate over time, despite years of efforts.
- CCS projects have been very costly.
- Cleaner competition has big head start, investments.
- Must play catch-up to other technologies, especially batteries.
- Blue hydrogen markets likely to shrink due to green competition.

UCS Position (https://www.ucsusa.org/)

The Union of Concerned Scientists (UCS) shared their thoughts in a February 2024 webinar *"Getting Hydrogen Policy Right".* Some highlights:

- Hydrogen extends the reach of renewables.
- 'Blue' hydrogen needs to be excluded.
- 'Diverting' renewable energy to the production of hydrogen in a way that extends fossil-fuel use has to be avoided

- Misuse of the Inflation Reduction Act 45V tax credit might counter-intuitively drive up emissions.
- Pipeline hydrogen mixtures with natural gas are limited to 5-20% hydrogen. [We dispute this since Hong Kong uses town gas with 50% hydrogen. There may be an impact on residential burner requirements at the higher hydrogen concentrations.]
- Hydrogen as a combusted fuel produces NO_x. [We dispute this is a problem since there are technical solutions in catalytic converters as used in ICE automobiles today specifically for NO_x emissions.]
- Hydrogen has a role in hard to decarbonize industries.

RMI Position (https://rmi.org/)

The Rocky Mountain Institutes (RMI) published their Hydrogen Insight Brief in Jan 2020 "*Hydrogen's Decarbonization Impact for Industry"* with the following key insights:

- When considering what a global energy system on a 1.5°C or 2°C pathway will look like by 2050, hydrogen consistently plays a critical role as a low-carbon fuel. In fact, for several of the hydrogen application areas discussed in this Insight Brief, there are no other viable pathways to decarbonization.
- The abatement impact of hydrogen depends strongly on both the specific use case where it is implemented and the way it is produced.
- Hydrogen produced with grid power at the global average carbon intensity – or even with coal gasification – could be used to reduce carbon emissions in steelmaking today.
- Despite lower CO_2-intensity than most power grid-based hydrogen sources, there is no long term role for steam methane reform (SMR) in decarbonizing industry sectors unless successfully fitted with carbon capture and storage (CCS).
- In the near-term, electrolysis using Chinese and Indian grid power is less CO_2-effective than coal gasification, and EU and US grid power is less efficient than SMR.
- In natural gas-based economies like the United States, the predominantly SMR-based existing hydrogen production plants are quickly on track to become less CO_2-efficient than electrolysis.
- Because electrolysis production with grid power will be at parity with SMR within the next 5-year period, EU and US policy should exclusively focus on electrolysis until CCS is a viable and scalable technology.
- Given the long lifetime of hydrogen generation assets, even in coal-heavy economies (such as China and India), any build-out of coal gasification has to be motivated with the belief in CCS retrofit in the 2030 – 2040 timeline.

- Near- and medium-term outlooks for power grid CO_2 intensity should be leveraged and implemented as a leading indicator for hydrogen policy.
- The alignment of high-potential for CO_2 reduction and the large-scale of off-takers in sectors like steel and shipping, where demand is naturally aggregated in ports, provides a pathway for policy makers to achieve demand at scale. This can significantly accelerate the cost reduction of electrolysis technologies.

Recommendations

We thus encourage:

- the technical development of hydrogen and coproduced oxygen made in the electrolysis of water using renewable sources of energy,
- promoting the prospecting for and development of geologic hydrogen.

For clarity in formal documents, we encourage the use of the terms ‘fossil-fuel hydrogen’ and ‘renewable hydrogen’ to reflect how the hydrogen is sourced as against the use of obfuscating colors. Colors can be useful in mainstream media when communication with the public.

We recommend the fossil fuel industry, demonstrate the economic and technical feasibility of any publicly funded fossil fuel hydrogen and carbon capture and sequestration proposal, first at a pilot plant scale, with strict performance standards and professional independent oversight. The state agencies and tax payer interests will then be best served to determine if scaling up such proposals is a prudent step. Implementation at scale risks stranding 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 energy plan:

- Encourage overbuilding of renewable wind, solar and storage to support grid reliability, and where appropriate to provide capacity for electrolytic production of hydrogen and oxygen.
- Survey the state for suitable geological formations for geologic hydrogen reservoirs and basaltic rocks for carbon storage.
- Use excess renewable power to generate and store ‘electrolytic’ hydrogen to integrate with a) renewable (aka 'green') ammonia and other industrial uses where such downstream uses are available and b) to provide a supply for startups pursuing locally developed hydrogen technologies.
- Encourage and evaluate the clean-up and diversion of hydraulic fracturing (fracking) water and clean-up of excess produced water for electrolysis purposes.

- Working with the State Investment Council, fund economic development plans in support of technologies for electrical transmission lines, renewable energy, electrolyzers, fuel-cells, hydrogen (‘green’ and ‘white’) along with the multitude of other energy storage options (e.g. metal hydride storage), and the hard to decarbonize industry and transportation applications.
- Provide incentivizing tax breaks for such endeavors.
- Explore public private partnerships with companies to build gigawatt scale electrolyzer factories where the jobs are needed in NM.
- Promote the SpacePort as an infrastructure hub for the support, development and testing of hydrogen fuel-cell and hydrogen fueled aviation opportunities.
- Geography, infrastructure and community impacts must be considered in any renewable energy project.

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

Incentives for renewable energy for electrolytic hydrogen or prospecting for geologic hydrogen should be carefully crafted especially where there are no better pathways to decarbonization than using hydrogen.

Addenda

Sources:
- Sierra Club and Friends NM Hydrogen Policy Letter October 2021

References are listed in our 350santafe.wiki pages
- Hydrogen Background
- Carbon Capture and Sequestration

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