Southwest Energy Efficiency Project (SWEEP) position on clean hydrogen

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With the passage of recent federal legislation, there is significant funding and renewed interest in the potential for clean hydrogen to contribute to climate solutions. In the Southwest Energy Efficiency Project's (SWEEP) work to promote energy efficiency, electrification, and other clean energy solutions to climate change in the Southwest states, we will be involved in decisions regarding potential new hydrogen projects in the region, and investments in the Department of Energy's (DOE) proposed clean hydrogen hubs.

SWEEP sees the potential of green hydrogen to contribute to the United States and regional climate goals, if its production and use are prioritized properly. We think it is important to maximize the wise use of renewable electricity resources — for direct use as electricity, or to produce green hydrogen for difficult to decarbonize fuel uses. SWEEP does not support the production of other colors of hydrogen, including blue, with some potential caveats discussed below.

Because clean hydrogen is likely to be an expensive low-carbon fuel, it is important to prioritize its uses to the most difficult to electrify end-uses. Specifically, we think green hydrogen can play a role in decarbonizing high-temperature industrial processes, long-haul trucking, and aviation. On the other hand, SWEEP does not support any use of hydrogen for heating residential or commercial buildings, as there are cleaner and cheaper alternatives such as electrification.

There are two key questions to answer regarding hydrogen: how it's produced and how it's used.

“Clean hydrogen” production

In this section, we provide a brief discussion of methods of producing “clean hydrogen.” Most groups include two main methods: green hydrogen and blue hydrogen.

“Green hydrogen” is produced from electrolysis of water using renewable electricity. Electrolysis itself does not produce any byproducts or emissions other than hydrogen and oxygen. In practice, electrolysis or “power-to-gas” plants can potentially source all of their electricity from renewable sources, either on-site, or from off-site sources, such as through a long-term power purchase agreement (while also relying on the grid for a steady backup power source).

In addition to green hydrogen, some also include “blue hydrogen” in the clean hydrogen category. Blue hydrogen is produced from steam methane reformation (the same process used for traditional “gray” hydrogen), but includes carbon capture and storage — of some/most of the carbon dioxide (CO2) emissions from the production process. Blue hydrogen relies on consumption of fossil fuels: it uses fossil gas as the main feedstock, and consumes additional fuel in the steam reformation process. The process is not energy- or water-efficient, does not reduce use of fossil fuels, and only reduces net greenhouse gas (GHG) emissions if the CO2 from the process is successfully captured and stored.

Some recent studies have found that blue hydrogen production and use results in increased fossil fuel consumption and overall increased GHG emissions compared to directly consuming gas.[1]

For these reasons, SWEEP generally does not support blue hydrogen production. Instead, we would like “clean hydrogen” production to focus on green hydrogen.[2] Rather than referring to “clean hydrogen” as either green or blue, in the rest of this position paper, we only refer to green hydrogen.

Other colors of hydrogen are described below in the Appendix. Both the European Union and Rocky Mountain Institute (RMI) recommend evaluating the emissions benefits of clean hydrogen production (any colors) based on the lifecycle GHG emissions (e.g., including methane leaks in upstream gas production and leakage from captured carbon in the case of blue hydrogen). RMI suggests a minimum threshold for clean hydrogen production of reducing life-cycle GHG emissions by at least 80% compared to gray hydrogen production.[3]

Environmental Justice Issues

[1] “Touted as clean, ‘blue’ hydrogen may be worse than gas or coal,” Friedlander, Cornell Chronicle, August 2021, https://news.cornell.edu/stories/2021/08/touted-clean-blue-hydrogen-may-be-worse-gas-or-coal.

[2] At a minimum, if a blue hydrogen project were pursued, SWEEP strongly suggests requiring a thorough analysis of life-cycle GHG emissions, along with setting an emissions reduction threshold such as 80% compared to gray hydrogen.

[3] “Funding Our Future: Clean Hydrogen Hub Offers Major Opportunity,” RMI, May 2022, https://rmi.org/clean-hydrogen-hub-offers-major-opportunity/.

By focusing on green hydrogen production, which has very little on-site emissions, there will be very few potential health impacts on local communities. For siting of any blue hydrogen production facilities, there are potential environmental and health impacts, which would be important to minimize.

Applications of Green Hydrogen

Best Uses

The following paragraphs provide a list of the best uses of clean hydrogen, roughly prioritized based on applications that are most difficult to electrify and that are likely to have the most impact in the Southwest.

Industrial process heating. There are several important industrial sectors, such as steel and cement, with high levels of fuel use for process heating, which will be challenging to decarbonize. The Southwest region has no integrated steel plants (producing iron from iron ore, using coal and coke),[4] but our region has several cement plants.

In general, the industrial process heating needs that are the most difficult to electrify are those involving temperatures higher than about 200 degrees C.[5] There are also other opportunities for electrifying industrial processes, such as in glass container production.[6] But for many high temperature, difficult to electrify processes, green hydrogen could play an important role in reducing carbon emissions.

Long-haul, heavy-duty transportation. Another sector that is a good application for green hydrogen use is long-haul, heavy-duty transportation. Trucking can be roughly divided into local, regional, and long-haul trucking. While electrification and other strategies are available now for the first two categories,[7] for large, heavy-duty trucking over large distances, there are advantages to using hydrogen fuel cells rather than electric batteries (with current battery technology).

Hydrogen fuel cells tend to be more cost-effective than electrification where the duty-cycle of the vehicle cannot accommodate time off for recharging (e.g., the truck needs to run close to 24 hours a day). This is often the case for cross-country (long-haul) trucking.[8]

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[4] There are two electric arc furnace steel plants, one in Utah and one in Colorado. These produce steel with electricity, using scrap metal as inputs rather than iron ore.

[5] "Industrial Heat Pumps: Electrifying Industry's Process Heating Supply," ACEEE, March 2022, https://www.aceee.org/research-report/ie2201.

[6] "Electrifying U.S. Industry: Technology and Process-Based Approach to Decarbonization," Global Efficiency Intelligence, January 2021, https://www.globalefficiencyintel.com/electrifying-us-industry.

[7] For the first two categories, SWEEP recommends switching to new electric trucks, or, in certain circumstances, converting diesel trucks to LNG, powered by renewable natural gas (RNG). See SWEEP's position paper on best uses of RNG.

[8] "Making Zero-Emissions Trucking Possible," RMI/Mission Possible Partnership, July 2022, ttps://missionpossiblepartnership.org/wp-content/uploads/2022/07/Making-Zero-Emissions-Trucking-Possible.pdf

Aviation fuel. Hydrogen can be potentially used in aircraft propulsion directly, through hydrogen combustion engines or fuel cells, and some work is being done in both of those areas. The other option is to use renewable (green) hydrogen to produce synfuels, which is less energy efficient.[9]

Replace current hydrogen uses with green hydrogen. According to RMI, about 10 million metric tons per year of hydrogen are produced in the U.S., mainly for use in refineries as a chemical feedstock or to produce ammonia for fertilizer. Replacing current gray hydrogen production (from fossil gas, using steam-reformation) with green hydrogen or blue hydrogen has the potential to reduce CO2 emissions by about 100 million metric tons per year.[10]

International shipping. Similar to aviation, green hydrogen-derived fuels could be used to decarbonize international shipping. In the short term, advanced biofuels will play a key role in cutting emissions. In the medium and long-term, green hydrogen-based fuels will be pivotal, making up 60% of the energy mix in 2050. E-methanol and e-ammonia are the most promising green hydrogen-based fuels, with e-ammonia set to be the backbone for the sector's decarbonizing by 2050. Renewable ammonia uses renewable electricity to produce the hydrogen needed for the ammonia production — the hydrogen reacts with hydrogen to produce ammonia. Ammonia emits no carbon dioxide when burned.[11]

Although this application is promising, we have no shipping ports in the Southwest, so if we have a regional clean hydrogen hub, we will not focus on hydrogen uses in international shipping.

Low priority green hydrogen uses

Renewable electricity storage (questionable). Hydrogen can also be used to store excess renewable electricity. The technology involves a "regenerative hydrogen fuel cell." The first step is to use renewable electricity to produce hydrogen through water electrolysis, as described above. Step two is to store the hydrogen, and later feed the hydrogen to a fuel cell to generate electricity.

Some research shows that using hydrogen for storage of excess renewable electricity offers some potential benefits compared to battery storage.[12] However, converting renewable electricity to hydrogen and then back to electricity results in over half of the energy being lost.[13] Therefore, we think it makes

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9 "Hydrogen-powered aviation and its reliance on green hydrogen infrastructure – Review and research gaps," International Journal of Hydrogen Energy, January 2022, https://www.sciencedirect.com/science/article/pii/S0360319921043184.
10 "Policy Memo: Clean Hydrogen Abatement," RMI, 2021, https://rmi.org/insight/policy-memo-clean-hydrogen-abatement/.
11 "Green hydrogen fuels to decarbonize 80% of global shipping," Offshore Energy, October 2021, https://www.offshore-energy.biz/green-hydrogen-fuels-to-decarbonise-80-of-global-shipping/#:~:text=A%20rapid%20replacement%20of%20fossil,Energy%20Agency%20(IRENA)%20finds.
12 "Hydrogen or Batteries for Grid Storage: A net energy analysis," Pellow, Matthew, et al, Energy and Environmental Science, April 2015, https://pubs.rsc.org/en/content/articlelanding/2015/ee/c4ee04041d
13 "EU Hydrogen Policy," https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/689332/EPRS_BRI(2021)689332_EN.pdf, p. 3.

more sense to use renewable electricity directly as much as possible, or to use it to produce green hydrogen for the purposes described above. For short-term renewable electricity storage, for now we think it makes more sense to rely on batteries.

Poor uses of green hydrogen

Some gas utilities are proposing to use clean hydrogen to provide a lower carbon form of gas to their end-use customers, either through producing synthetic gas,[14] or by putting hydrogen directly into pipelines. Given the cost of producing green hydrogen, and the availability of heat pumps and other technologies to electrify residential and commercial buildings, this is not a cost-effective use of green hydrogen. SWEEP agrees with the recent studies by RMI and others, which state that producing green hydrogen for heating buildings is an inefficient and not cost-effective use of renewable electricity.[15] [16]

For residential and commercial buildings in the region, SWEEP will continue to advocate for electrification policies and technologies, and we will oppose efforts by gas utilities in the region to use green hydrogen as a substitute for fossil gas to serve these buildings.[17]

Regional Clean Hydrogen Hubs

The DOE is proposing to fund at least four clean hydrogen hubs in different U.S. regions. The purpose of these regional hubs is to demonstrate clean hydrogen production using different fuels or methods, and for different end-use applications, while measuring the emissions benefits and cost-effectiveness.

SWEEP would like the DOE to keep the research and pilot projects of the Regional Clean Hydrogen Hubs focused as much as possible on green hydrogen production, and we think it makes sense to demonstrate green hydrogen production in regions with large wind and solar resources, which includes the Southwest. For blue hydrogen, DOE should set a maximum threshold for life-cycle GHG emissions of 4 kg

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[14] Synthetic gas is a mixture of carbon dioxide and hydrogen, which can be used as a substitute for traditional fossil gas. See Wikipedia, https://en.wikipedia.org/wiki/Synthetic_fuel#Hydrogenation_processes.

[15] "Low-Carbon Fuels Have a Limited Role in New York's Buildings," RMI, May 2022, https://rmi.org/low-carbon-fuels-have-a-limited-role-to-play-in-new-yorks-buildings/?utm_medium=email&utm_source=spark&utm_content=spark&utm_campaign=2022_06_09&utm_term=text.

[16] Jan Rosenow, "Is Heating Homes with Hydrogen All but a Pipe Dream?" Joule, September 2022, https://doi.org/10.1016/j.joule.2022.08.015.3

[17] Note that the Colorado "Clean Heat Standard" (SB 21-264) allows regulated gas utilities to include clean hydrogen, renewable natural gas, or recovered methane as a pathway to achieve their GHG emission reduction targets. Although allowed as a small component, SWEEP would like to see the gas utilities avoid any use of clean hydrogen in their compliance plans, because it is not a cost-effective use of this resource.

CO_2e per kg of hydrogen produced.[18] In addition, the DOE should emphasize blue hydrogen's role as a transition fuel, until 2030 or so, when the costs of green hydrogen make it more competitive.

We also agree with the goal of demonstrating uses of green hydrogen in regions with different end-use applications, focusing on the priority applications discussed above. In addition to demonstrating the production methods for green/low-carbon hydrogen and the end-use applications, we feel it is important for the DOE to focus on developing and evaluating the hydrogen infrastructure that will make green hydrogen use more cost-effective.

Cost-effectiveness

One of the goals of the DOE Regional Clean Hydrogen Hubs is to evaluate the cost-effectiveness of green hydrogen production and its applications in replacing more traditional fuel uses in the priority sectors discussed above. This will be an ongoing process, and experts expect the cost-effectiveness to improve over the next 5-10 years, through economies of scale, technology improvements, etc.

These evaluations of cost-effectiveness should include:

- Life-cycle GHG emissions from green hydrogen production.
- The social cost of GHG emissions (currently $83/metric ton CO_2e).[19]
- Costs of the competing fuels for each application, including projected price increases.
- Costs of hydrogen infrastructure.
- Other costs relevant to each application.

Currently, about 96% of the world's hydrogen production is gray hydrogen from steam reforming of gas, at a cost of about $1.50/kg H_2. Green hydrogen currently costs about $2.50 - $5.50/kg, and accounts for less than 0.1% of global hydrogen production. Blue hydrogen costs about $2/kg, cheaper than green hydrogen but more expensive than gray.[20] Because electrolysers are expensive, blue hydrogen production is likely to be cheaper than green hydrogen in the short-term. However, some analysts such as Bloomberg predict that green hydrogen will be cheaper than blue by 2030 in all major countries,

[18] This is the maximum GHG emissions threshold for which the Inflation Reduction Act (IRA) provides incentives, and is equivalent to achieving about 60-70% reduction in lifecycle emissions compared to gray hydrogen. The IRA's incentives are greater for hydrogen production processes that result in lower lifecycle emissions, which should help encourage more emphasis on green hydrogen. The IRA offers a production tax credit of 20% for hydrogen production with life-cycle emissions of 2.5 - 4 kg CO_2e/kg H_2, 25% for emissions of 1.5 - 2.5 kg CO_2e/kg H_2, 33.4% for emissions of 0.45 - 1.5 kg CO_2e/kg H_2, and 100% for emissions less than 0.45 kg CO_2e/kg H_2.

[19] "Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide," U.S. Government Interagency Working Group, February 2021, https://www.whitehouse.gov/wpcontent/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf.

[20] "EU Hydrogen Policy," https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/689332/EPRS_BRI(2021)689332_EN.pdf, p. 3.

including the U.S. with its cheap gas prices.[21]

Summary

SWEEP sees the potential of green hydrogen to contribute to U.S. and regional climate goals, if its production and use is prioritized properly. We think it is important to maximize the wise use of renewable electricity resources — for direct use as electricity or to produce green hydrogen for difficult to decarbonize fuel uses.

For the Regional Clean Hydrogen Hubs, the DOE should focus its funding and efforts as much as possible on green hydrogen production, as well as on the highest-value end use applications. We also encourage the DOE to refine its methodologies for evaluating life-cycle GHG emissions benefits of hydrogen production and use, and its cost-effectiveness compared to competing fuels and technologies.

Green hydrogen has the potential to play an important role in decarbonizing long-haul trucking, high temperature industrial processes, aviation, and shipping — all of which do not currently have cost effective low-carbon alternatives. Green hydrogen is not a sensible solution for residential and commercial buildings; electrification technologies such as heat pumps and heat pump water heaters are much more energy-efficient and cost-effective.

Appendix

Colors of hydrogen

Green hydrogen is produced from electrolysis of water using renewable electricity. Electrolysis itself does not produce any byproducts or emissions other than hydrogen and oxygen, except for any indirect emissions associated with using fossil fuels to produce the electricity supplying the power-to-gas plant. Operating an electrolysis or “power-to-gas” plant purely on renewable electricity may not be feasible or cost-effective. However, the power-to-gas plant could source its electricity from renewable sources on-site or from renewables off-site through a long-term (e.g., 10-year) power purchase agreement, while also relying on the grid for a steady backup power source.

- Here’s a basic piece from the U.S. Energy Information Administration on how hydrogen is produced: https://www.eia.gov/energyexplained/hydrogen/production-of-hydrogen.php.

All of the other environmental groups mentioned above agree we should focus on green hydrogen, but the DOE and others may have broader ideas, so here is a look at some of the other colors:

[21] “‘Green’ Hydrogen to Outcompete ‘Blue’ Everywhere by 2030,” Bloomberg NEF, May 2021, https://about.bnef.com/blog/green-hydrogen-to-outcompete-blue-everywhere-by-2030/.

Blue hydrogen captures the CO2 emissions (70-90%)[22] and costs less than green hydrogen (for now). Turquoise hydrogen is at the experimental stage but could be a potential cleaner source of hydrogen in the future. RMI notes that blue hydrogen (steam methane reformation with carbon capture and storage) and green hydrogen are the two primary methods being considered for near-term hydrogen production.

The main questions for any of these colors (especially for colors other than green) are:

- What are the net GHG emissions benefits?
- Are there other emissions or environmental impacts? Are there environmental impacts on disadvantaged communities?
- What are the costs?

Regarding the concern some people may raise about water consumption from green hydrogen, recent research shows that there will actually be a net water savings from green hydrogen production and use, compared to fossil fuel consumption.[23] For blue hydrogen, which consumes no water directly in the production process, the water consumption would be similar to the amount of water consumed in fossil fuel consumption.

The following summary is mainly taken from this source:

- "Hydrogen Color Codes," H2 Bulletin https://www.h2bulletin.com/knowledge/hydrogen-colours-codes/#:~:text=Hydrogen%20itself%20is%20a%20colourless,%2C%20pink%2C%20red%20and%20white.

Gray hydrogen: hydrogen produced from natural gas, using steam-methane reforming.

Steam-methane reforming currently accounts for nearly all commercially produced hydrogen in the U.S. Commercial hydrogen producers and petroleum refineries use steam-methane reforming to separate hydrogen atoms from carbon atoms in methane. In steam-methane reforming, high-temperature steam (1,300°F to 1,800°F) under 3–25 bar pressure (1 bar = 14.5 pounds per square inch) reacts with methane in the presence of a catalyst to produce hydrogen, carbon monoxide, and a relatively small amount of carbon dioxide. Natural gas is the main methane source for hydrogen production by industrial facilities and petroleum refineries. Biomethane, or renewable natural gas, is a source of hydrogen for several fuel cell power plants in the U.S. Petroleum fuels are also potential hydrogen sources.

Brown or black hydrogen: hydrogen produced from coal.

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[22] "Liebreich: Capturing Only 90% of CO2 Emissions in Blue Hydrogen Production 'Ain't Good Enough," Energy Transition, July 2021, https://www.rechargenews.com/energy-transition/liebreich-capturing-only-90-of-co2-emissions-in-blue-hydrogen-production-ain-t-good-enough-/2-1-1034599.

[23] "Does the Green Hydrogen Economy Have a Water Problem?" Beswick, et al, American Chemical Society, August 2021, https://pubs.acs.org/doi/10.1021/acsenergylett.1c01375#:~:text=Green%20hydrogen%20production%20will%20consume,energy%20production%20and%20power%20generation.

Blue hydrogen: gray or brown/black hydrogen, typically from steam-methane reforming, combined with carbon capture and storage/sequestration.

The CO_2 produced from the reforming process is captured and stored underground, or it could also be utilized rather than stored. As mentioned above, many analysts see blue hydrogen as a transition fuel toward eventually relying on green hydrogen, but a recent study from Stanford and Cornell University researchers shows that blue hydrogen may not help reduce emissions compared to burning gas directly.[24]

Pink hydrogen: hydrogen generated through electrolysis of water using nuclear power.

Turquoise hydrogen: hydrogen extracted through methane pyrolysis — the thermal decomposition of methane.

Though at the experimental stage, the process removes the carbon in a solid form instead of CO2 gas. The thermal process could potentially be powered with renewable energy.

Synthetic gas

It is also possible to use hydrogen to produce a synthetic methane gas ("syn-gas").

- See NRDC position paper (also referenced below).

There are pros and cons to this additional step. The potential benefits are that a syn- gas can be more easily used in equipment that uses conventional methane gas, such as boilers or internal combustion engines. The disadvantage is that there are energy consumption and GHG emissions impacts associated with the syn-gas production, in addition to the hydrogen production itself. Note that syn-gas production is not an essential step for many applications, and none of the top uses outlined above require synthetic gas.

Position statements from other groups

- RMI makes some helpful points about best applications, the carbon abatement potential, and how to ramp up clean hydrogen production. RMI includes both green and blue hydrogen as having carbon abatement potential. RMI also makes specific policy recommendations which seem very helpful, including support for some hydrogen transportation and storage infrastructure. See "Policy Memo: Clean Hydrogen Abatement," https://rmi.org/insight/policy-memo-clean-hydrogen-abatement/.

[24] "Blue Hydrogen 'worse than gas' for the climate': Landmark Study's Damning Verdict," Energy Transition, August 2021, https://www.rechargenews.com/energy-transition/blue-hydrogen-worse-than-gas-for-the-climate-landmark-studys-damning-verdict/2-1-1051084.

- Sierra Club's position paper includes helpful information about hydrogen production, potential impacts of colors other than green, and potential uses. See: https://www.sierraclub.org/articles/2022/01/hydrogen-future-clean-energy-or-false-solution#:~:text=The%20Sierra%20Club%20only%20supports,is%20powered%20by%20renewable%20energy.
- NRDC also emphasizes that we should focus on green hydrogen and applications in only the hardest to electrify sectors, and also provides a discussion of synthetic gas production from hydrogen. See https://www.nrdc.org/sites/default/files/pipe-dream-climate-solution-bio-synthetic-gas-ib.pdf.
- The Colorado Energy Office (CEO) sponsored a study for Colorado, Opportunities for Low Carbon Hydrogen in Colorado: A Roadmap. CEO's Director, Will Toor, said that along with the RMI paper above, this is the closest thing to a CEO position on clean hydrogen.