Clean Energy Innovation Roundtable Series

Summary:
Session V: Hydrogen Renaissance?

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On May 20, the Aspen Institute Energy & Environment Program virtually convened the fifth in its 2021 series of Clean Energy Innovation Roundtables. This convening brought together experts to discuss the categories of decarbonized hydrogen, uses for it, and the opportunities for and barriers to its deployment. This summary captures some of the key topics of discussion.

The Hydrogen Color Wheel

Hydrogen is currently produced primarily by gasification of coal or reformation of natural gas. Producing this hydrogen, sometimes referred to as gray hydrogen, is a carbon-intensive process. Existing hydrogen production accounts for a small but significant portion of global carbon emissions.

There are various methods by which hydrogen production can be decarbonized. One, generally referred to as blue hydrogen, involves adding carbon capture, utilization, and storage (CCUS) to the coal gasification or natural gas reformation process. Another, generally referred to as green hydrogen, involves producing hydrogen via electrolysis of water, using zero-carbon electricity. Some consider green hydrogen to include only hydrogen produced using renewable electricity; others include hydrogen produced with electricity from nuclear power, which is sometimes also referred to as pink hydrogen. It is unclear if the green hydrogen label applies only to hydrogen produced directly from clean electricity or if it also encompasses electrolytic hydrogen that is "clean" by virtue of acquiring renewable energy credits; the current fiction of Scope 2 reporting suggests that latter route is plausible. Gasifying or reforming biomass or biofuels and applying CCUS to the processes could result in a net-carbon-negative production process; this carbon-negative hydrogen does not yet have a color designation, though some suggest gold hydrogen.

The color wheel of labels could create confusion in the marketplace, impeding progress and transactions. A color-blind approach is needed to drive the decarbonization of hydrogen, regardless of the particular production pathway. The various "colors" or brands of decarbonized hydrogen matter less than the lifecycle analysis of each type, factoring in all feedstocks and production pathways. It is the carbon that matters. It would be simpler to have labels that just make clear whether the hydrogen production is carbon-negative, carbon-neutral, or carbon-emitting. Some kind of carbon accounting is needed, with both accuracy and flexibility to provide simplicity. That said, some do not want to call all decarbonized hydrogen "clean" or "zero-carbon" because they do not want those labels applied to hydrogen produced with nuclear or CCUS; they oppose those as potential climate solutions. This is what leads to the rainbow of hydrogen labels, as well as other terms such as "renewable hydrogen". There is value in holding discussions and gathering consensus on how to characterize the different types of hydrogen and, if possible, how to merge them into labels focused on greenhouse gas characteristics.

Uses for Decarbonized Hydrogen

Hydrogen can be a decarbonization solution for a range of sectors and uses. Most directly, decarbonized hydrogen could replace existing hydrogen feedstocks, particularly for ammonia production and oil refineries; there really is no other decarbonization solution for existing hydrogen feedstocks. While there may be other potential solutions for hard-to-abate industry sectors, hydrogen is widely seen as being among the most viable. Decarbonized hydrogen is being targeted for use in the iron and steel industry, as well as for use in producing high-temperature heat for industrial processes involving cement, glass, aluminum, and other materials. Hydrogen could also be an input into ammonia for the agricultural sector (and other sectors), as well as part of the petrochemical supply chain.

In the power sector, decarbonized hydrogen could provide either dispatchable zero-carbon electricity or long-term energy storage. Excess local renewable energy can be used to produce green hydrogen, while high-temperature solid oxide electrolyzers can complement nuclear power, enabling existing nuclear plants that are struggling economically to produce electricity when electricity prices are high and to produce hydrogen when electricity prices are low.

In the transportation sector, decarbonized hydrogen could be utilized as a zero-carbon fuel; one exciting thing about hydrogen is that it opens a path from electricity – which is cheap compared to existing liquid fuels – to fuels. In the early 2000s, the transportation sector was the main focus of hydrogen hype, with efforts such as FreedomCAR. Hydrogen appears to have mostly lost out on the light-duty vehicle space, but the situation remains more unresolved with medium- and heavy-duty vehicles. Beyond road vehicles, hydrogen can also be an input for low-carbon hydrocarbons to support aviation. In maritime, hydrogen or ammonia could advance decarbonization, complemented by efficiency efforts and wind propulsion. (Liquefied natural gas is also in the debate mix for maritime fuels, and small thorium reactors could work in cargo vessels.) In addition to hydrogen fuel cell technologies, ammonia engines should be coming out within a couple of years. Ammonia is seen as potentially preferable in shipping because hydrogen must be stored at super-cold temperatures, which is hugely expensive to do on a ship. Ammonia, which is a hydrogen carrier, has much more reasonable storage requirements. Ammonia is also familiar; it is already widely transported by ship around the world. Shipping is global, and there are countries excited about the potential to produce, use, and export hydrogen and ammonia.

Hydrogen can be transported over land or water in liquified form and could, to an extent, leverage existing natural gas networks to be used anywhere gas is currently used. For example, with equipment and infrastructure modifications, hydrogen could be used in the buildings sector to provide heat. Utilizing and repurposing existing infrastructure – whether gas pipelines, maritime engines, or others – can facilitate the use of hydrogen across sectors. While hydrogen's potential uses span sectors, there is an argument to be made that, whether through policy or market pressure, the aim should be to accelerate hydrogen for use in the areas where few other decarbonization solutions are available.

Opportunities for and Barriers to Decarbonized Hydrogen Deployment

Hydrogen has perpetually been "10 years away", but its potential is now on the precipice of being unlocked. Technological advancements, policy shifts, and increased penetration of ever-cheaper renewable energy have all contributed to the present moment. For instance, electrolyzer technologies have improved in efficiency and costs, thanks in part to the success of fuel cells; electrolyzers are basically fuel cells run in reverse. While technologies have improved, decarbonized hydrogen production is still in the early stages and is not yet fully bankable. Technological readiness is just table stakes for deployment; new products also need process integration, capital market support, and policy support, and those are just starting to come together.

At the moment, costs – including not only production costs, but also infrastructure costs for storage and pipeline transport – are something of a barrier to greater deployment of decarbonized hydrogen. Hydrogen has to be cost-competitive with the fuels it is replacing. Some estimate the tipping point for decarbonized hydrogen to be around $2/kg, but that is something like $14-$15/MMBtu, which is far more expensive than $3/MMBtu for natural gas if one is thinking about heating. In contrast, hydrogen as a transportation fuel displaces gasoline or diesel, which are very expensive fuels. A carbon price, of course, would make competitor fuels account for their carbon emissions, which would change the competitive comparison. Beyond emitting competitors, the costs of decarbonized hydrogen also need to come down to be competitive with other technologies and pathways for significantly reducing emissions, including CCUS and electrification. In addition, there will be cost competition among the types of decarbonized hydrogen. Hydrogen produced via fossil CCUS, biomass CCUS, or nuclear could be produced 24/7, which means high asset utilization, unlike hydrogen produced via electrolysis from cheap but variable renewables. Electrolyzer costs are expected to come down substantially over the next decade, though, which means they may not need to run all the time to be economical. Many things are made in factories that do not run 24/7.

While costs may be a hurdle for some, price thus far has not been much of an obstacle for the customers that want hydrogen. Some customers are demanding hydrogen that is generated by co-located renewables. Others want green hydrogen, not caring whether it is direct or through a power purchase agreement and credits (which means renewables are not the actual source of electrons). Others just want hydrogen, not caring whether it is low-carbon or not. Price has rarely been part of the conversation; people decide they want hydrogen, and then within that they want lower costs. At least in some early markets, hydrogen demand does not seem particularly price sensitive, and those early markets will drive down costs for other uses.

Inadequate public policy support has been another hurdle for decarbonized hydrogen. For example, policy is needed to drive change in maritime shipping, but none is evident yet. The International Maritime Organization has a target to reduce shipping emissions by half by 2050, but the United States recently said the goal should be zero by 2050; it remains to be seen what the United States proposes in terms of policies to get there. While maritime shipping is not hard to decarbonize in terms of technology, it seems to be in terms of political will.

The policy picture for hydrogen is starting to change, though, as policy efforts on decarbonization have never been stronger. The EU is leading the way. The European Green Deal is coming in July, with a big focus on hydrogen, and the EU will be putting shipping into its Emissions Trading Scheme. Europe is showing that with the right policies, investments, and implementation, there is significant potential for decarbonized hydrogen. (Japan, too, has always thought of itself as a leader on hydrogen and will be featuring it at the Olympics this year – if they take place.) Public policy in the United States concerning hydrogen is not nearly as mature as it is in Europe, but there are several new legislative proposals addressing almost every component of the burgeoning hydrogen economy, and there is great interest on Capitol Hill, in the Administration, in industry, and among civil society groups.

To get industry moving quickly to bring costs down and boost deployment, beneficial policy tools could include: support for research, development, and demonstration; expansion of the Loan Programs Office's mandate to include all forms of decarbonized hydrogen; technical assistance; codes and standards (e.g., on pipelines and blending); and tax incentives, such as a production tax credit (PTC). A PTC for all the potential "colors" of decarbonized hydrogen could help make their production costs competitive with gray hydrogen. At a minimum, policy should label and incentivize the production of decarbonized hydrogen accurately so the market can react accordingly. This has to be done carefully. For instance, life cycle analysis requirements that set a carbon intensity threshold at super-low levels from the outset could hinder the development of the market for hydrogen and of many forms of decarbonized hydrogen, preventing achievement of scale. Carbon intensity factors should perhaps start with a more achievable threshold (e.g., an 80% reduction of carbon dioxide emissions compared to natural gas reformation) and grow more stringent over time.

The net carbon benefits of hydrogen, though, depend on how it is used and what it displaces. Because hydrogen can be used across sectors and in numerous ways (e.g., for electricity, as a fuel), dealing with it from a policy standpoint can be very complicated; those with compliance obligations are operating under existing sector-specific frameworks. If policies are adopted or reformed to be tech-inclusive – including a new Clean Energy Standard, a modified Renewable Fuel Standard, and a reformed Corporate Average Fuel Economy standard – the policy accounting of hydrogen could take care of itself. Still, there may be a need in the policy realm to separate production from use – to promote hydrogen production on a zero-carbon basis and then provide some separate incentive based on how it is used and what it displaces – with accounting to prevent double-counting. Yet another mechanism may be needed for when hydrogen operates as energy storage. This suite of incentives would allow for a fuller accounting of hydrogen's benefits, though it would be much more difficult and complex than something like the wind PTC or 45Q for CCUS.

Opportunities for hydrogen deployment also lie in the private sector and in public-private partnerships. For example, corporations could move beyond buying renewable energy credits and invest more in other technologies, such as hydrogen, that could have meaningful decarbonization impact. Public-private regional hydrogen demonstrations are also key because manufacturing centers both are centers of job creation and will be impacted by the energy transition. The regional cluster approach to hydrogen development is being implemented successfully in Europe, where there are tangible examples – including in the United Kingdom, Germany, and the Netherlands – of clusters and other industrial projects advancing decarbonized hydrogen. There was also a recent announcement about plans for a hydrogen industrial cluster in the Southern California region. Overall, the market is getting excited about hydrogen. There has been a 20-fold increase in hydrogen projects over the last 18 months, and there are companies pursuing innovations and approaches that will burst the doors open.