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WHITE PAPER

7 Questions to Consider About Hydrogen Hubs

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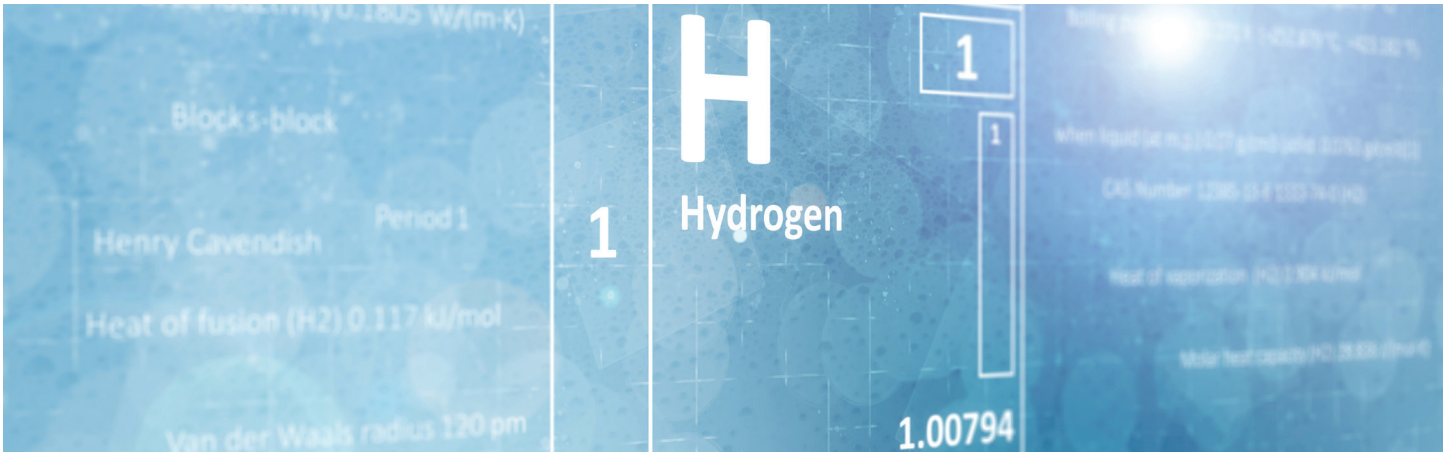
Hydrogen is poised to become a crucial part of the decarbonization equation as countries work to reach net zero carbon emissions. To date electrification has been the primary focus for decarbonization. The increasing use of electric vehicles is a clear example of that. While there are many instances of how electricity can be used to decarbonize, it is not applicable in every sector or industry. Hydrogen offers yet another alternative for decarbonization where electrification is not as suitable.



Hydrogen already helps power our world and is most commonly used in petroleum refining, petrochemicals, fertilizer production and in other industries. As new ways of producing hydrogen with little or no carbon dioxide (CO_2) emissions are developed, transportation, industrial users and utilities could become high-priority markets.

Currently, blue hydrogen is considered the most viable option for economical low-carbon production. It's produced by using a steam methane reforming process that converts natural gas into primarily hydrogen, water and CO_2. Blue hydrogen is considered a low-carbon process because the CO_2 is captured on the back end and routed to geological storage or use in enhanced oil recovery.

Green hydrogen is another low-carbon hydrogen solution, using electrolysis to divide the water molecule H2O into its hydrogen and oxygen elements. While green hydrogen production is more energy-intensive than blue hydrogen production, it can be less carbon intensive if the electricity needed for the electrolysis is provided solely by solar, wind or hydroelectric power. Pink hydrogen is similar to green hydrogen in that it's generated by electrolysis but produced using low-carbon electricity caused by nuclear power.

Clean hydrogen sources like these are being reimagined by investors like Goldman Sachs, utility companies, communities, states, regions and even the federal government as a fuel source for various industries. Each method of low-carbon hydrogen production has its own benefits and challenges,

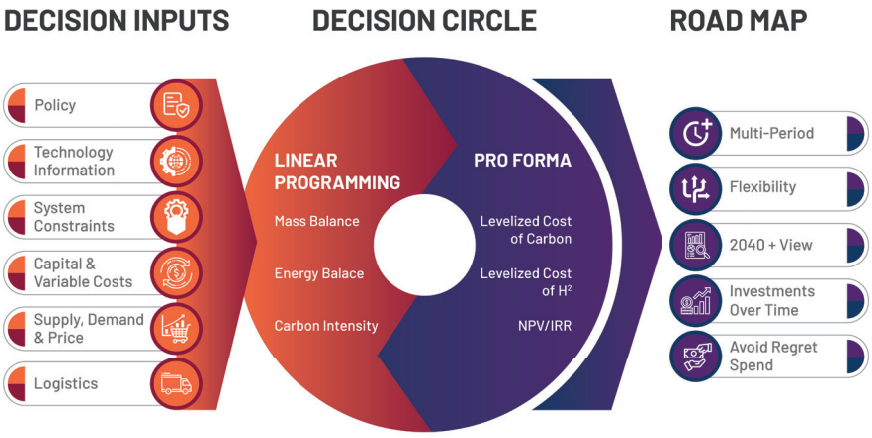


***Figure 1:** Numerous elements are involved in the establishment of a U.S. hydrogen hub economy. This figure outlines factors that should be considered by potential hub participants.*

and all are attracting interest because of their potential to reduce greenhouse gas emissions.

One of the many initiatives the federal government is embracing is the development of a nationwide hydrogen hub network. Congress appropriated $8 billion through the Department of Energy (DOE) for the establishment of 6-10 regional hubs, dubbed H2Hubs, to provide DOE grants for clean hydrogen in the United States under the Infrastructure Investment and Jobs Act (IIJA). In simple terms, each hub will receive between $500 million and $1 billion of DOE funding in the form of cooperative agreements and other incentives.

The development of H2Hubs is intended to be the first step toward the creation of a national network of clean hydrogen producers and customers that could help facilitate the emergence of a clean hydrogen economy.
To kick off the effort, in September 2022, the DOE Office of Clean Energy Demonstrations issued DE-FOA-0002768 entitled "Regional Clean Hydrogen Hubs." This funding opportunity announcement (FOA) called for proposals from prospective hubs.

Seventy-nine hydrogen hub proposals were submitted, with 33 of them getting an "encourage" stamp of approval from DOE to move forward in the application process. 1898 & Co. actively supported two regional hydrogen hubs in the process.

Though there is broad agreement on the need for a robust clean energy economy that includes hydrogen hubs, there is much to be considered. Here are seven key questions that industry players are considering as the clean hydrogen industry develops:

How is a hydrogen hub defined?

Each hydrogen hub is a network of clean hydrogen producers, potential consumers and connective infrastructure. A detailed work process is needed in order to navigate the feasibility of hydrogen. See an example work process in Figure 1.

The mission of a hydrogen hub is to provide clean and affordable hydrogen-based energy. It's a new opportunity for states to garner investment, whether it is through generation, end use or logistics. An optimum hub is one where all the producers and consumers are within a 200-mile radius and work in a precise balance to produce, store and convert hydrogen into usable energy sources to help meet regional needs.

While it may be reasonable to assume that certain areas have a lock on securing hydrogen hub status, the reality is that all regions of the country are on equal footing to participate in the hydrogen economy. To help realize this outcome, DOE has included an environmental justice component to its program to encourage participation from all types of communities and regions.

Among the 40 environmental justice guidelines issued by the DOE, nine burden metrics are in place to enable the department to determine disadvantaged communities. None of these metrics is based on population density. Instead, the metrics are designed to see to it that disadvantaged communities are not disproportionally affected in a negative way by the incremental deployment of new infrastructure.

What does a hydrogen hub energy future look like and what needs to happen to get there?

The energy sector continues to look for opportunities for expansion and diversification to secure a clean energy future. Innovation in any industry is the long-term key to success and early adopters in most industries are rewarded. They are often the ones that shape an industry's path. As with any new industry endeavor, early adopters who take risks could be rewarded, while late adopters could lose out on capturing new markets.

DOE is providing up to 50/50 cost share incentives, tax credits and other enticements to help advance the hydrogen hub sustainability model. When hub incentives are layered on top of each other, it helps drive hydrogen production costs down, making the undertaking more viable and competitive with existing energy sources.

Historically, the government has driven decarbonization efforts through incentives and legislation that allow emerging technology to be competitive. By defraying some of the risk that private investors could incur, momentum is created for a broad-based system that will drive needed economies of scale. When economies of scale occur, the market can take advantage of costs being spread out across many participants. As technology and supply chain innovation evolve, market costs will come down, opening new pathways for adopting hydrogen as a major clean energy source. It will just take time.

How are hubs established and what are the different types?

It is important to begin hub development with the element that is creating demand and then working upstream. Two prime examples of demand leading hydrogen development could be an airline committing to a long-term agreement to purchase sustainable aviation fuel (SAF) from a production facility that sources clean hydrogen from a hub; and an agricultural enterprise that sources clean ammonia from a hub. In these instances, demand fuels the need for SAF and low-carbon ammonia. These market forces drive the concerted efforts of hydrogen hub entities to deliver these essential components of SAF and ammonia.

With a solid demand, the next step would be to consider a hub's existing resources and how to leverage them to produce, transport and use hydrogen. When it comes to hub development, there are endless options, and much depends on resources within a given area. Some hubs are being established around state and municipality resources and some are being established around public/private industry resources. Successful hubs will likely be a hybrid of both.

The availability of regional resources and end users will drive the economics and decision-making regarding hydrogen production and hub logistics. Geography and an area's electricity mix, including renewable energy resources, play a significant role. Production that results in end uses like renewable diesel, SAF, methanol or ammonia works well from a logistics standpoint that relies on trucks, rail yards and pipelines. Some hubs may choose green hydrogen production instead of blue because they don't have the geography or pipeline access to sequester CO_2. Numerous potential underground storage sites, both geological and enhanced oil recovery, are located along the Gulf Coast and Upper Midwest so hubs there might focus on blue hydrogen production because of the capability for storing CO_2.

In states such as California, Louisiana and Texas, there are unique infrastructure assets that already exist that may be successfully converted for use in a hub network. These may include pipeline and port facilities. In some situations, significant hydrogen producers in these states could negotiate agreements from end users for more than 50% of their production output or they could conceivably integrate customers directly into their regional hubs. No matter where a potential hub participant is in the country, the more it leverages its assets and partnerships, the more successful the overall hub endeavor is likely to be.

What are some challenges hydrogen hub participants face?

States, municipalities and companies must look at their appetite for risk when considering participation in a hydrogen hub. There are a multitude of moving parts involved and, as a result, many challenges may arise. The availability of renewable feedstocks to fuel the whole hydrogen economy is a major concern, as is the abundance, or potential lack of end users. One other key challenge is that the cost of producing hydrogen through electrolysis is approximately 70% driven by the cost of power, which raises some concern.

Additionally, for hubs trying to establish new CO_2 pipelines, a not-in-my-backyard mentality could be a barrier. This has proven to be a pervasive factor in many regions, and opposition could emerge anywhere in the country. For hub primes — the primary hub contractor — there is also the question of whether or not necessary funding will materialize. Plus, for primes who are the originators of hubs, there's the concern about liability. What happens if a project within the hub loses money or doesn't meet project standards approved by the DOE or other funding sources? What is the recourse for perceived failed and/or mismanaged projects in the hub network?

One other significant challenge is that hydrogen hubs are a new concept for the DOE. The DOE usually has stringent accountability standards and reporting mechanisms over the lifetime of a grant or loan. For hydrogen hubs, the funding opportunity announcement from DOE provides a brief overview of DOE's process for analyzing emissions during the selection phase. But there is ambiguity when calculating emissions during the planning stage, and the DOE has yet to define what tracking and evaluating of emissions should look like once projects are fully established and operating.

Another issue is the Buy America stipulation, which requires all hub producers to source steel, iron, manufactured products and construction materials from U.S. producers. This restriction only applies to nonfederal institutions including state and local governments, tribes, universities and nonprofit groups as identified by the Office of Management and Budget's Uniform Guidance. H2Hubs that are run by the private sector and don't have to abide by this restriction will likely benefit in terms of lower costs.

What is key to remember is that hydrogen hubs won't take shape overnight. They will take time to develop and evolve. National Environmental Policy Act (NEPA) reviews, state and other permitting, right-of-way, land ownership, and carbon capture sequestration issues could take years to navigate. With the potential for changing government administrations, funding and political will can ebb and flow. But as is the case with most industries, in time the details will work themselves out, making this a highly viable solution for entities to add to their greenhouse gas reduction portfolio.

What infrastructure is needed to support a hydrogen hub system?

Hubs are a sophisticated and intricate ecosystem that spans the full supply chain, as seen in Figure 2. Hydrogen hub developers seek to utilize electrolyzer requirement energy from zero- or low-carbon sources to maximize greenhouse gas emission reductions. One way this can be achieved is by entering into purchase agreements, connecting directly with renewable energy generators or using book-and-claim mechanisms like renewable energy credits.

Logistically, to transport hydrogen, a buildup of hydrogen economy infrastructure is needed and should include transportation via rail, truck and pipeline as well as compression and storage operations.

Because the hydrogen economy build-out will require an abundant supply of renewable and decarbonized energy, there needs to be an abundant supply of renewable energy resources such as wind, solar, geothermal, hydrogen or others considered low carbon. This is challenging, since at its best wind power is available on average only 50% of the time and solar a little less than that. With these capacity factors, a hydrogen plant may be forced to run intermittently, or augment its power supply with energy storage or another clean energy source.

Who will manage the hydrogen hub system and regional interconnection?

The Regional Clean Hydrogen Hubs program is funded by Congress and run by DOE. The program's purpose is to aid in

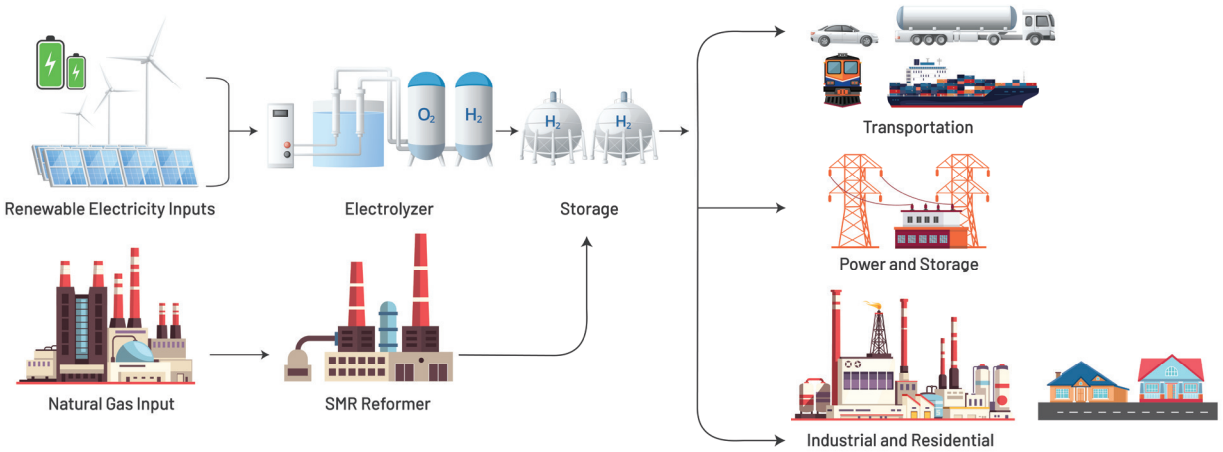


***Figure 2:** From raw materials and feedstocks at the front end to final consumers at the back end, hubs are connected through one or more central hydrogen production facilities and an associated network.*

the generation, handling, distribution, storage and use of clean hydrogen throughout the country. The program is noteworthy as it has the potential to significantly transform energy policy.

The federal government has allocated $9.5 billion in funding for hydrogen projects, including $8 billion for hydrogen hubs. This is intended to jump-start the clean hydrogen economy, with tax incentives helping hydrogen become a competitive solution in hard-to-decarbonize industries. These subsidies include 45V tax credits where the value of credits is based on life-cycle emissions. Additionally, tax credits are available for carbon capture and sequestration efforts, (section 45Q of the tax code). Each of these tax credits can reduce the price difference between clean hydrogen and more carbon-intensive energy alternatives. As part of the 45V tax credits for hydrogen production, the U.S. Department of the Treasury will establish rules for calculating life-cycle emissions in determining the value of the tax credit. DOE also has issued a proposal for a Clean Hydrogen Production Standard that is based on life-cycle emissions. The IIJA requires that hubs meet this standard.

It remains to be seen what government involvement and support will look like as the hydrogen economy takes shape. But ultimately, as with all free-market economics, it will take regional hubs talking to and working together to optimize interconnectivity and the success of this sustainability model.

What role do consultants play in the development of hubs?

Every firm is different, and a thorough assessment of a firm's capabilities is critical. As an example, 1898 & Co. offers a holistic, evergreen approach to evaluating multistate hydrogen production and end-use pathways. The approach leverages strong technical, financial and policy resources with a tool set that supports clients as they work to establish their overall hub vision, understand short-term and long-term hub feasibility, and capture potential market opportunities.

When working with a hydrogen hub consultant, entities should look for firms that can handle technical studies, permitting, financing, grant writing, technical economic analysis and life-cycle analysis. A knowledgeable firm can help determine both the technical operations of the hub and the financial sustainability of the hub inclusive of how federal policy will impact short- and-long-term viability. Most importantly, the consultant should be able to determine the strategy and structure of the hub based on determining how to leverage all assets, including regional partnerships.

Companies interested in considering a hydrogen-hub-related investment need fit-for-purpose techno-economic and life-cycle analyses. Considerations should include developing time-adjustable investment plans, which identify optimum configurations and the right mix of feedstocks, products, technologies and supporting infrastructure to achieve hub goals (e.g., decarbonization, profitability, long-term viability, etc.). Financial outputs, including levelized costs of hydrogen production and the costs of hydrogen earmarked for transportation, cement or steel production, as well as products derived from hydrogen such as renewable diesel, sustainable aviation fuel, methanol and ammonia should all be a key part of the analysis. In instances where hub development moves forward, working with a consultant that not only can advise on the hub's development, but can also help with its design and construction offers a clear advantage.

The pathway to hydrogen hub success

The process of establishing a hydrogen hub can be a daunting and complicated one. But it's becoming ever-more critical as energy providers and others search for ways to achieve a cleaner energy future. Finding a partner with the appropriate technical, financial and policy experience is essential. In addition to helping potential project owners determine when a hub doesn't make sense, a knowledgeable consultant should be able to identify alternatives for achieving sustainability goals.

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