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Is Hydrogen the Future of Clean Energy for Business?

We're in the very early days of hydrogen adoption. We're de-risking technology, de-risking business models and initiating markets so that others who have less risk tolerance can enter the space, which means growth for the industry and progress for a society that values decarbonization.

— JOE SAWA, PROJECT MANAGER, SHELL PLC

Case Synopsis

By 2023, companies of all sizes and across multiple industries had started to create and publicly announce Net Zero climate commitments that included hydrogen power as a source of clean energy. However, there was no technology available at scale to achieve widespread adoption of hydrogen power. Further, there was no globally recognized body guiding the regulation or implementation of hydrogen technology, leaving companies to set their own standards.

As a result, many questions about the feasibility of hydrogen use and the implications for climate change were left unanswered. For example: Did it make sense for a company to include hydrogen as a renewable energy source in their Net Zero strategy without widespread production of hydrogen? What were the implications when a company incorporated hydrogen technology into its climate commitment?

How Does Hydrogen Fit into a Clean Energy Future?

Hydrogen was not an energy *resource* that could be mined from the earth, like oil or coal. All the hydrogen on Earth was chemically bound to other atoms, meaning that chemical bonds had to be broken to produce free, unbound hydrogen gas (H_2). Free H_2 is an energy *carrier* – a substance in which energy was able to be stored for later use. H_2 was such a compressed substance that a small 1 kg tank of compressed H_2 held enough energy to move an automobile over 100 km without recharging.

The process of separating H_2 from other atoms was very energy intensive. Hydrogen could be derived from a variety of resources, including water or biomass, using renewable energy such as solar and wind power. When produced in this manner, the H_2 produced was very climate-friendly. However, in

Professor Andrew M. Isaacs prepared this case study with Natàlia Costa i Coromina (UC Berkeley, Master of Development Practice 2023), and with assistance from Case Writer Aviva Legatt, as the basis for class discussion rather than to illustrate either effective or ineffective handling of an administrative situation.

2023, most of the hydrogen produced in the US was produced from fossil methane (natural gas), using a method that contributed to climate change[1].

Joan Ogden, Professor Emerita at University of California, Davis suggested that incumbent energy companies could play "a major role" in the transition away from fossil fuels toward hydrogen. "As the biggest hydrogen producers in the world, oil and gas companies know this technology better than anybody, and are moving toward decarbonization and green hydrogen production. They have incredible technical depth and resources…they're very good at making molecules at a large scale and at storing them. If a large hydrogen demand develops serving industry, transport and heating needs, there's going to be hydrogen producers with names we recognize from the current energy sector."

One key question was whether corporate net zero climate commitments that incorporated clean energy and renewable fuels such as hydrogen were realistically able to keep their promises. The Hydrogen Council reported that the global pipeline of *planned* hydrogen projects was growing, but the *construction* of those projects was not deploying at the same pace[2].

A zero-carbon future may include hydrogen someday, but at present, hydrogen use was doing very little to address climate change. However, as a renewable, versatile energy carrier, H_2 was considered a promising element in a clean energy future.

What is the demand for hydrogen?

Joe Sawa, a Hydrogen Project Manager at Shell, said that as recently as 2019 hydrogen technology was "a sleepy side project outside of a few active market regions such as California, Japan, and Germany. Other than a small core of advocates, most were skeptical that the market would ever amount to much… and now it's kind of the inverse." Sawa cited "changing societal values" in shifting hydrogen to a higher priority and the public "getting passionate and aware of climate change which has also led to game changing policies such as the Inflation Reduction Act (IRA) which incentivizes the supply-side of the hydrogen market in the US."

"The main customers for green hydrogen and other low-carbon hydrogen, such as grey hydrogen from renewable natural gas or turquoise forms, have largely been in the transport and mobility sector where retail consumers have a willingness to pay higher prices due to their values," said Sawa. "These consumers value decarbonization, whereas corporates and industrial companies tend to just look at the economics of energy." In addition to market forces, limitations of supply, demand and scale were holding back the adoption of zero-carbon or low-carbon hydrogen on a large scale. Recent policy (e.g. the IRA) was expected to push the supply curve for green and blue hydrogen outwards, which will increase adoption for passenger vehicles and heavy-duty mobility applications, and it will also make hydrogen economical for industrial producers of ammonia and methanol, refiners, energy storage developers, among others.

What are the pros and cons of using hydrogen as a renewable fuel?

Hydrogen was an attractive renewable fuel for the following reasons:

[1] https://afdc.energy.gov/fuels/hydrogen_production.html
[2] https://hydrogencouncil.com/en/hydrogen-insights-2022/

- **Space-efficiency.** Compressed hydrogen gas carried a lot of energy in a small volume, making it attractive for use in fuel cell-powered electric vehicles[3]. "The sweet spot for hydrogen will also be in heavier duty transportation applications, for example, trucking, shipping, and ferries," said Sawa.
- **Multiple means of production from multiple resources.** Hydrogen can be produced from a variety of resources including fossil methane (natural gas), biomass, and water.[4] "Brown" methods of producing hydrogen were common in 2023, but those methods emitted more GHG than was eliminated. The supply of green hydrogen generated in a zero-carbon process was still very limited. "Green hydrogen is an immediate plug-in to decarbonize industry," said Sawa.
- **Use of current technology.** No new technology needed to be developed, only scaled up.[5]

However, there were limitations to widespread adoption, including the following:

- **Difficulty to transport over long distances.** As Ogden points out: "Think of how pervasive the electric grid or the natural gas grid is. We don't have anything like that with hydrogen. We have instead big users and big producers that are pretty much next to each other. Localized hydrogen pipeline networks have been built in a few highly concentrated industrial/refining areas like the Gulf Coast. We also have a small fraction of hydrogen that gets trucked around right now, a little bit of it piped in to be used in specialty chemicals and making glass and metals and things like that. Getting hydrogen out to truck stops or to filling stations is a new thing. There's not a system that's already in place. However, projects are underway to build optimized networks of hydrogen stations serving zero emission fuel cell vehicles in California, Japan and Europe." As a highly flammable gas, there were also safety concerns with transporting the hydrogen over long distances. Several thousand miles of long-distance high-pressure hydrogen transmission pipelines were in commercial operation to serve industry needs. Studies were underway assessing the viability of repurposing natural gas lines for service with hydrogen blends or pure hydrogen.
- **Lack of public awareness.** Lack of widespread public awareness about hydrogen and hydrogen-powered vehicles due to regional concentrations of hydrogen fueling stations.
- **The policy and regulatory environment.** Due to the variation in laws and government incentives available for producing clean hydrogen, the ability to adopt hydrogen as a renewable fuel was location-dependent[6].

What are the business implications for hydrogen?

The business implications for hydrogen were largely impacted by regulatory and policy environments across the world. "With renewable energy directives in Europe, we're going to see decarbonization fairly quickly in industries that already use hydrogen," predicted Ogden.

Within the United States, California had implemented incentives for clean vehicle adoption and manufacturing and invested heavily in the development of a hydrogen fueling infrastructure.[7] This

[3] https://www.sciencedirect.com/topics/engineering/hydrogen-energy-storage
[4] https://www.energy.gov/eere/fuelcells/hydrogen-fuel-basics
[5] https://www.nature.com/articles/d41586-022-03699-0
[6] https://www.ieahydrogen.org/annual-reports/
[7] https://ww2.arb.ca.gov/our-work/programs/hydrogen-fueling-infrastructure

infrastructure made it easier for consumers to adopt hydrogen fuel cell vehicles, which played a significant role in the growth of the market for these vehicles in the state. Of the 58 hydrogen fueling stations open to the public in the US, 57 were located in California one on Hawaii, but none elsewhere. This made the use of hydrogen as a fuel impractical in most of the US.

The following examples show how businesses were adopting hydrogen initiatives in 2023.

Case 1: Toyota with BMW

Toyota had made a commitment to achieve net zero emissions across its entire business by 2050 and hydrogen was a key part of its strategy, including a partnership with BMW to produce hydrogen fuel cells beginning in 2025. Toyota was considered a leader in producing hydrogen-powered fuel cell automobiles, however hydrogen vehicle sales had been slow. From 2021 to 2022, there had been an 82% drop in sales of Toyota's Mirai hydrogen-powered vehicle, with consumers apparently preferring electric vehicles instead[8].

Case 2: Shell

Shell had made a commitment similar to Toyota's to become Net Zero by 2050, and identified hydrogen as essential in meeting that goal. Shell planned to build Europe's largest green hydrogen plant and limit its oil and gas production while becoming a clean energy company[9]. Backed by a $40.8 million grant from the California Energy Commission, Shell recently opened 9 new hydrogen stations in California, though none in other states. In addition, Shell rolled out green hydrogen initiatives in other parts of the world, including medium-duty fuel cell trucks and a vehicle leasing program in Germany, and shipping and aviation initiatives in China and the UK[10].

Case 3: Chevron and Partners

A Chevron initiative with Pertamina and Kippel Infrastructure planned to explore green hydrogen projects, though the specifics were not identified[11]. Chevron, together with Japan's Itawani Corporation, planned to build 30 hydrogen fueling stations in California by 2026[12]. The company also planned to invest $2.5 billion in green and blue hydrogen projects by 2028. Chevron's overall goal was to produce 150,000 tons of hydrogen annually by 2030, but this included grey hydrogen produced from unabated methane[13].

Case Discussion Questions

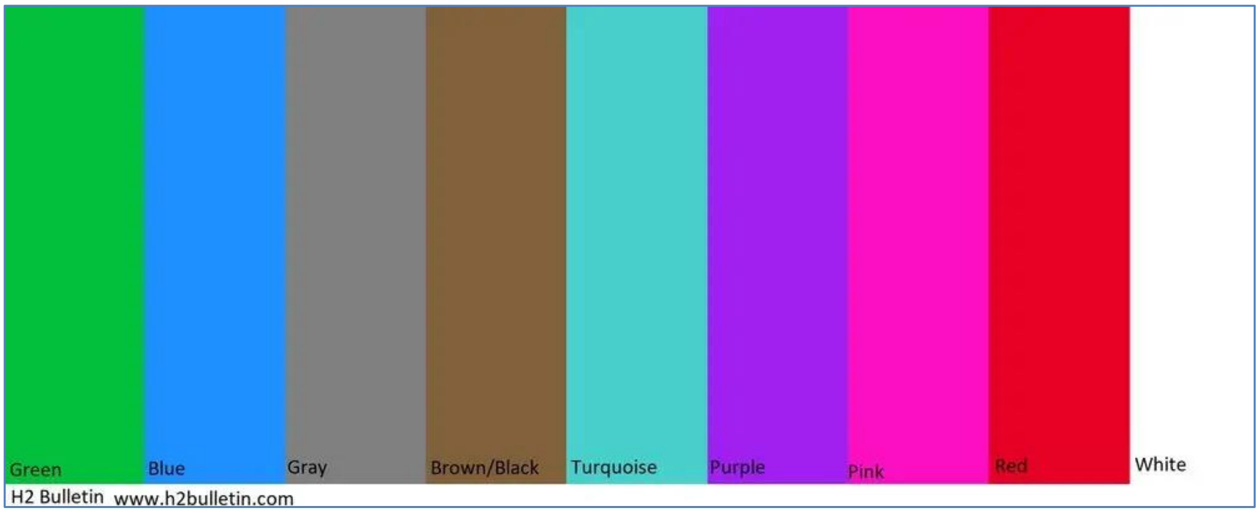
1. What are the enablers and barriers to implementing hydrogen as a renewable fuel?
2. What are the business, social and economic issues associated with corporate climate commitments that incorporate hydrogen as a renewable fuel?

[8] https://www.hydrogenfuelnews.com/fuel-cell-car-sales-us/8555667/
[9] https://seekingalpha.com/article/4543607-shell-is-betting-on-green-hydrogen-to-replace-upstream-loss
[10] https://www.shell.com/energy-and-innovation/new-energies/hydrogen.html
[11] https://www.chevron.com/newsroom/2022/q4/pertamina-keppel-and-chevron-sign-agreement
[12] https://www.chevron.com/newsroom/2022/q1/chevron-iwatani-announce-agreement-to-build-30-hydrogen-fueling-stations-in-california
[13] https://www.rechargenews.com/energy-transition/chevron-to-invest-2-5bn-in-green-and-blue-hydrogen-by-2028-reveals-senior-executive/2-1-1240852

Appendix.

Exhibit 1. Hydrogen Colors.[14]

Hydrogen itself is a colorless gas, but industry uses nine "color codes" to identify how the hydrogen in commercial use is produced. At present, these codes are: green, blue, grey, brown or black, turquoise, purple, pink, red and white.



- Green hydrogen is produced through electrolysis of water by using only renewable electricity. It is called green because there are no CO_2 emissions during production. (Electrolysis is a process which uses electricity to decompose water into its constituent hydrogen and oxygen.)

- Blue hydrogen uses fossil hydrocarbons as the source material, usually fossil methane gas (CH_4), often referred to as "natural gas". However, the CO_2 produced in the process is captured and stored underground (geological sequestration). Companies are also trying to utilize the captured CO_2, referred to as "carbon capture, utilization and storage (CCUS). Utilization is not essential in order for the hydrogen produced to qualify as blue hydrogen. Since no CO_2 is emitted, the blue hydrogen production process is considered carbon neutral.

- Gray hydrogen is produced from fossil fuel and commonly uses steam methane reforming (SMR) method. During this process, CO2 is produced and eventually released to the atmosphere.

- Black or brown hydrogen is produced from coal. The black or brown color code refers to the type of coal used as source material: bituminous coal = black, and lignite coal = brown. This is a very polluting process, and both CO_2 and carbon monoxide (CO) are produced as by-products which are released to the atmosphere.

- Turquoise hydrogen can be extracted by through the pyrolysis of methane. The process, though at the experimental stage, removes carbon from the methane in a solid form instead of as CO_2 gas.

[14] https://www.h2bulletin.com/knowledge/hydrogen-colours-codes/

- Purple hydrogen is made using heat from a nuclear power plant to pyrolyze water.
- Pink hydrogen is generated using electricity from a nuclear power plant to pyrolyze water.
- Red hydrogen is produced through the high-temperature catalysis of water using heat from a nuclear power plant.
- White hydrogen refers to naturally occurring hydrogen – of which there is very little on Earth.