Hydrogen May Heat up the Engineering Job Market

BY KAT FRIEDRICH, ***WISCONSIN ALPHA '00***

Above image: Hydrogen supply system at DLR Cologne
Credit Wikimedia Commons: DLR

There's been plenty of enthusiasm recently about the nascent hydrogen economy in the United States. What should engineers know about employment in this emerging market?

"I'm really bullish," said Frank Wolak, president of the Fuel Cell & Hydrogen Energy Association (FCHEA). "My comment to anyone in the technical space is that this career path in energy, especially in clean energy and hydrogen, is a great reward. I would encourage anyone who looks at this pathway to see it as an opportunity to expand their own knowledge, make a difference, and also find very gratifying and financially rewarding activities."

When Wolak was in engineering school, he viewed energy from a nontraditional vantage point. He has since worked for oil and gas companies, fuel cell companies, energy efficiency companies, and other organizations before settling down at the FCHEA.

"I came of age in the aftermath of the oil crisis in the '70s and '80s," Wolak said. "I started out many years ago interested in the evolution of the subject of alternative energy. I'm really excited about the long-term prospects of hydrogen, both as an engineer as well as the head of the FCHEA. I think this is a very interesting place for younger engineers, for those who want to change their career paths and make a meaningful impact on decarbonization and employ their skills in a way that can be very gratifying and interesting."

Ashley Samuelson, vice president – STEM at the corporate recruiting company Airswift, said she sees this job market is growing throughout the United States. Hiring managers are looking for engineers with transferable skills, including soft skills and design abilities. They are interested in candidates who are adaptable, are willing to learn, and stay informed about the latest news in the field. The industry is looking for experience with "energy integration in chemical engineering, energy storage, safety and risk management, and project management."

"Airswift is seeing an uptick in the demand for jobs throughout emerging markets, and the hydrogen industry is definitely trending upwards," Samuelson said. "The expansion of these hydrogen projects and initiatives is creating so many job opportunities."

There is excitement surrounding clean energy initiatives, Samuelson added. Ordinarily, people pick industries and stay with them throughout their careers, but her company is seeing candidates moving into these emerging markets.

"The hydrogen industry is shown to be such a big piece of the puzzle within clean energy," Samuelson said. "If you take a look at the dollars behind the projects, there's already a handful of these projects in construction, with so many more that are in the conceptual phases and looking at the feasibility. So the dollars behind it are saying that this is going to continue to be a growing market."

"What we're seeing right now on the ground in Louisiana is a lot of transferability between our existing energy industry and the skillsets, the expertise, the knowledge that we gleaned from generations of doing oil and gas work, into the hydrogen economy," said Lacy McManus, executive director of future energy at Greater New Orleans, Inc.

Engineers from many different educational backgrounds can participate in the hydrogen economy, Wolak said. Civil engineers can help to design the architecture for hydrogen systems. Electrical engineers can work on the integration of new hydrogen infrastructure with the electric grid. Mechanical engineers can design process equipment.

"For example, if you're working in the chemical industry as a process engineer, you have very easy transferability into more of a pure hydrogen industry, whether it's fuel cells or hydrogen," Wolak said. "If you've got manufacturing engineering skills, those may be different components being built and different processes, but if you have good experience in those areas, they're transferable."

During a typical day on the job, Wolak said, an engineer working on hydrogen might collaborate with a team to improve a process, cut costs, or evaluate new materials. An electrical engineer might consider the interface with the electric grid, reference code or utility requirements, or design power control interfaces. Manufacturing engineers might look at ways to optimize product quality while reducing costs and working with supply chains. Engineers installing hydrogen equipment might design facilities, develop plans, or deliver equipment.

Wolak is not sure exactly how much new hiring is taking place, but said that one of his association's member companies has "gone from a handful of employees to several thousand." Electrolysis factories are being built by major players such as Cummins Inc. These factories typically have hundreds of jobs, some of which are in manufacturing. Startup companies such as Electric Hydrogen are also expanding their operations.

The job market has changed dramatically due to COVID, Wolak said. Right before the pandemic began, policymakers recognized in many countries that hydrogen was important for decarbonization. The pandemic put efforts on hold, but then when the public health situation improved, the industry accelerated.

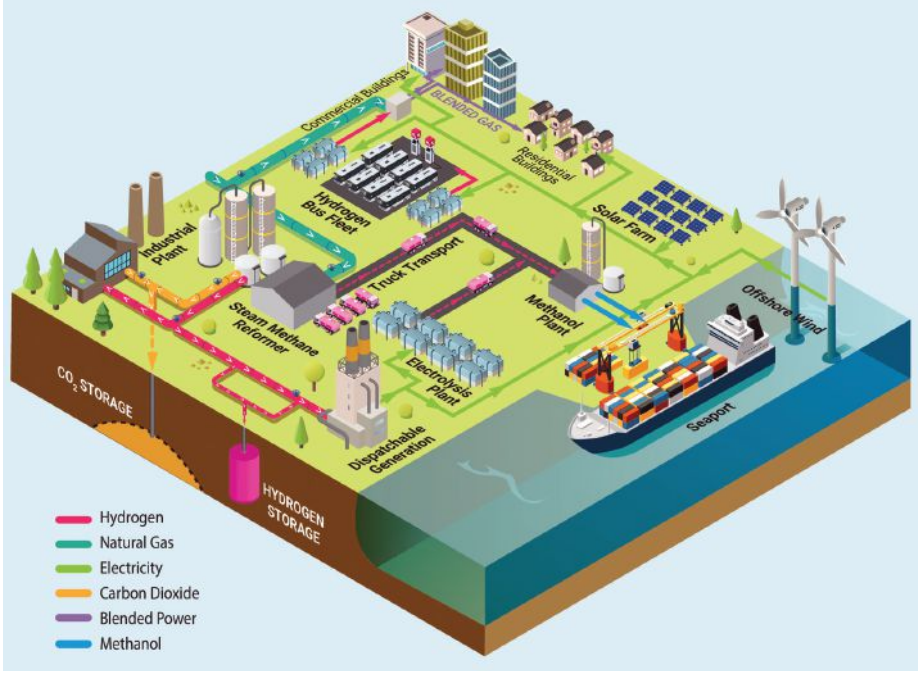
Although most hydrogen produced now is "gray" hydrogen, which is produced from steam reforming of natural gas,[1] the technologies that are leading to strong interest in this industry relate to "green" hydrogen, which is produced using renewable energy, or "blue" hydrogen, which is similar to gray hydrogen but is created with a carbon dioxide sequestration process.[2] According to Gizmodo, this sequestration process does not always work.[3]

According to a 2022 guide from the Society of Environmental Journalists,[4] some other "colors" of hydrogen include "turquoise," which is made starting with methane in a thermal plasma-electrolysis process;[5] "pink," which is made using nuclear power (and is sometimes called "purple" or "red"); "brown," which is made using gasification of brown coal;[6] and "black," which is made via gasification of black coal.[7]

Carbon Brief also noted that there is no agreed-upon color for biomass-fueled hydrogen production.[8] In addition, nuclear-powered hydrogen may be referred to as "pink," "purple," or "yellow." Online sources differ on what "yellow" hydrogen means, but it often is solar-produced green hydrogen.

Less than one percent of hydrogen that is industrially produced is green, according to the Society of Environmental Journalists.[9]

Hydrogen "is the main ingredient of stars, including 90 percent of our sun, and a thin mist of it is scattered through space — sometimes, in giant interstellar gas clouds," wrote Marco Alverá in his 2022 book "The Hydrogen Revolution: A Blueprint for the Future of Clean Energy."



Hydrogen Economy Integration Across Multiple Sectors and Production Pathways:

A regional hydrogen hub can provide pathways to decarbonize multiple sectors and use multiple production and transport pathways.

In this example, hydrogen is produced by a steam methane reformer that uses carbon capture and several electrolysis facilities. Hydrogen is transported by both pipe and truck and used in the industrial, electric power, mobility, buildings, and shipping sectors.

Electrolysis facilities use power from the bulk power supply as well as dedicated renewable resources.

Credit: The Energy Futures Initiative from "The Future of Clean Hydrogen in the United States: Views from Industry, Market Innovators, and Investors" report.

"Hydrogen's story goes back 13.7 billion years to a time when the universe was newborn and very hot... Hydrogen emerged from the primordial furnace in far larger quantities than any other element, and even today, it dominates the cosmos."[10]

Physically speaking, hydrogen is odorless, colorless, nontoxic, and highly flammable. Its energy content by weight is nearly three times that of gasoline, but it has a low energy density by volume if it is at a standard temperature and atmospheric pressure, according to a report by the UN Environment Programme.[11]

According to a 2022 article from *IEEE Spectrum*, the cost of gray hydrogen is around $2/kg in the United States. The U.S. Department of Energy has established a goal of lowering the cost of low-carbon hydrogen to this same price without incentives by 2026 and bringing it to $1/kg by 2031. Europe is rushing to develop hydrogen resources due to a fossil fuel crisis.[12]

"I see the gray hydrogen clearly declining," Wolak said. "It's mostly industrial. The growth in green hydrogen is certainly on the radar screen because I think, in some ways, it's the one that gets the most attention. If I look at the activity of engineers, there's much more of a potential to be involved in many green hydrogen projects than in pink or blue."

Wolak said jobs related to blue hydrogen will be concentrated around large carbon capture and storage projects. Roles related to pink hydrogen will be concentrated where nuclear plants are located.

Policy is driving growth of the hydrogen economy in the United States and internationally. Here, the Inflation Reduction Act (IRA) has created new incentives to produce green and blue hydrogen, according to Wood Mackenzie. It reintroduced a production tax credit known as the 45V. This allows qualifying production facilities to receive a 10-year tax credit for qualified hydrogen that is up to $3/kg.[13]

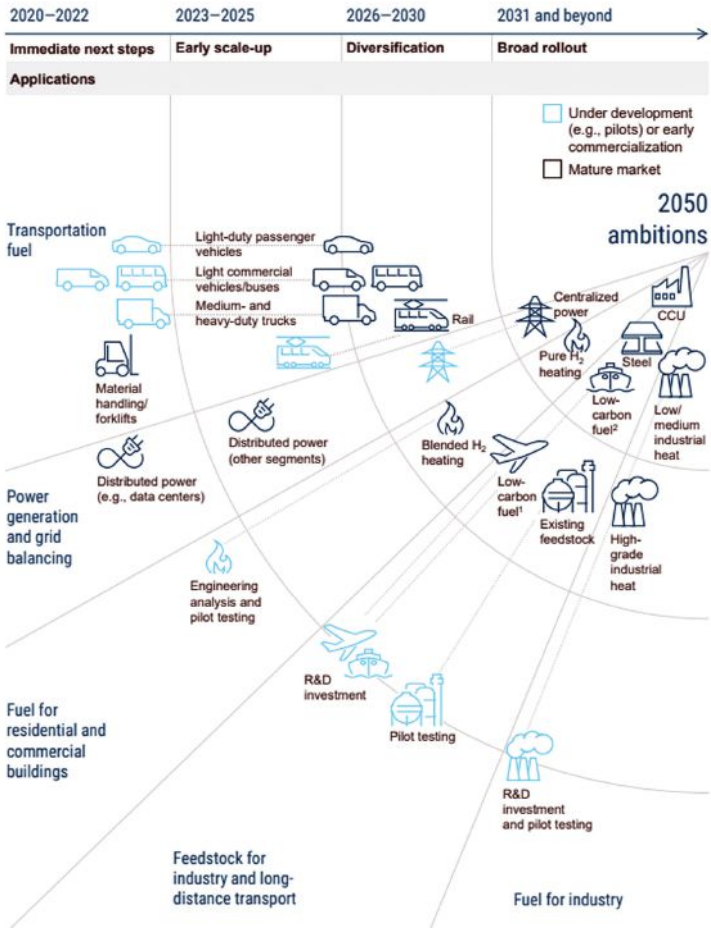
"The IRA's been absolutely catalytic and totally game-changing, building out the demand for green hydrogen and blue hydrogen as well," McManus said. "The shift we've seen in our landscape cannot be understated. Beyond the IRA, we're seeing market pressures as well. When you have those market pressures coupled with public policy like the IRA, you're starting to see a true paradigm shift."

"The U.S. DOE has had a longstanding role as the champion of the development of hydrogen," Wolak said. "The U.S. national labs have looked at hydrogen as a complement to the buildup of renewable resources to decarbonize. And what we're seeing today is the U.S. DOE taking all of that historical knowledge and presence and really being a driving force to help define how best to use hydrogen."

"We have an amazing set of tools in our national labs with engineers and technology specialists and scientists who have been looking at the best ways to employ hydrogen," Wolak said. "They're at the edge of looking at technical innovation, dealing with materials issues, supply, raw materials, advancements in fuel cells. I really see the DOE as coming of age in some ways, being able to unleash its resources around hydrogen and really take the leading role and define how the United States can employ hydrogen."

The DOE has put out a call for proposals to develop hydrogen hubs at various locations nationally, Wolak said. According to the Center for Strategic & International Studies, there were 22 prospective hubs being promoted as of July 2022, although the DOE had not announced the funding opportunity yet.[14]

According to a 2022 report by the Energy Futures Initiative, the Infrastructure Investment and Jobs Act earmarked $8 billion over five years to develop four regional hydrogen hubs. The hubs would include hydrogen from fossil fuels, nuclear power, and renewable energy. Hubs would also focus on the industrial and mobility markets, residential and commercial heating, and the electricity sector. The act also budgeted $1 billion for hydrogen



Hydrogen Applications Road Map from a report on the hydrogen economy by the Fuel Cell & Hydrogen Energy Association (FCHEA).

demonstration projects that would include power systems integration, large electrolysis facilities, and storage techniques.[15]

By the standards of this legislation, hydrogen is considered clean if under 2 kg of carbon dioxide are emitted for every kilogram of hydrogen produced, according to the Center for Strategic & International Studies. The hydrogen can be produced from a variety of sources. One of the goals is to establish "a network of clean hydrogen producers, potential clean hydrogen consumers, and connective infrastructure located in close proximity" for each hub. Initial responses recommended ten regional clusters: California, Appalachia, the Southwest, the Pacific Northwest, the Great Lakes, New England, the Central United States, Alaska, Hawaii, and the Gulf Coast.[16] Independent research from the Great Plains Institute suggested 14 regional clusters.[17] The DOE wrote in June 2022 that it would probably target six to ten proposals to advance.[18]

Proposals were submitted in the spring of 2023, said Mike Ciotti, VP of product at PDC Machines. "If you look at any of the Inflation Reduction Act... just the general scope of what we're trying to do with the overall economy to reduce the overall temperature of the planet, this is going to be a big deal for many years to come."

"There's a tremendous amount of concentration of knowledge in California right now because (almost) all of the (hydrogen) vehicles are there," Ciotti said. "This has to filter through the rest of the country. California has between 13,000 and 15,000 hydrogen fuel cell cars on the road. Outside of California, there are less than 200 (hydrogen) vehicles on the road."

Around one third of future hydrogen jobs will relate to fuel cells, according to an article from *Energy Monitor* that cited the Hydrogen Europe Roadmap.[19] A study by *Navigant* in 2019, mentioned in the same article, said that half of the jobs upstream would involve producing renewable energy.[20] Green hydrogen could create up to 1.5 million of these jobs in the EU by 2050.

The 2016 Toyota Mirai, introduced in 2014, was the first hydrogen fuel cell car sold commercially. The car itself emits only water. However, hydrogen has to be produced and distributed for these cars. As there are a few hydrogen fuel stations at the moment in the Netherlands, the possible use of this technology is still limited. Credit flickr user harry_nl

A 2020 road map report by the FCHEA predicted that by 2030, this sector could generate $140 billion per year in revenue in the United States, supporting 700,000 local jobs throughout its value chain. By 2050, growth could reach $750 billion per year in revenue, with 3.4 million cumulative jobs. This would result in hydrogen helping to meet 14% of U.S. final energy demand in 2050.[21]

McKinsey research predicted that total hydrogen demand globally could go up to 600-660 million tons by 2050. This would abate over 20% of global carbon emissions.[22]

"The introduction of hydrogen on a large scale would require a radical transformation of the global energy-supply system," the UNEP report said. This is still true, even though the report was published in 2006. "A vast infrastructure to produce, transport, store and deliver hydrogen, as well as to manufacture fuel cells, would need to be built. And consumers would need to invest in hydrogen fuel cell vehicles and related equipment.[23]

According to Alverá, hydrogen and ammonia can be used as ways of transporting electricity from renewable energy sources and other energy sources. Being able to transport renewable electricity around the globe removes the necessity of having the renewable sources close to the destinations where the power is used. This could stimulate economies in desert locations that are having financial difficulties currently, such as North Africa or parts of the Middle East. It is important that energy development in Africa support the local populations' well-being rather than being simply extractive.[24]

"As with any radically new technology, hydrogen could face the classic chicken-and-egg conundrum: the lack of a market in the first place deters investment, preventing the market from developing," the UNEP report said. "Put another way, why develop hydrogen cars when there is no distribution network, and why develop a distribution network if there are no hydrogen cars?"[25]

Achieving critical market mass is essential to the creation of a hydrogen economy, the UNEP report said. The market must be able to demonstrate to potential users and participants that hydrogen is safe, affordable, and reliable as an alternative to conventional fuels. Seeing hydrogen-fueled vehicles on the road would give consumers confidence. The network of fueling stations would have to be developed quickly, since they are essential for marketing and performance.[26]

"Developing economies have at least as much to gain from a move toward the hydrogen economy as industrialized ones,

"WE HAVE AN AMAZING SET OF TOOLS IN OUR NATIONAL LABS WITH ENGINEERS, TECHNOLOGY SPECIALISTS, AND SCIENTISTS LOOKING AT THE BEST WAYS TO EMPLOY HYDROGEN." — FRANK WOLAK, FCHEA

since they generally suffer more from urban pollution and their economies tend to be more energy-intensive," the UNEP report said. "Yet the transition will probably start later in most developing nations, as they are less able to afford to participate in R&D and the financial incentives needed to kick-start the process. The rich world must be ready to support developing economies in making this happen."[27]

There are many potential uses for hydrogen, according to the FCHEA 2020 report.[28]

In buildings, hydrogen can be used as a replacement for gas if companies blend it into the gas network. They can also put fuel cells in buildings to generate electricity and use the heat from their operations. To put this in perspective, 47% of U.S. homes have natural gas space heating; 3-8% use liquified petroleum gas heating.

Transportation uses of hydrogen are very versatile. Fuel cell electric vehicles can provide transportation with zero emissions and can store more energy onboard than battery electric vehicles. Fuel cells are especially useful for heavy loads, long trips, quick refueling, and frequent driving.

Industrial markets that are difficult to decarbonize, such as refining, steel-making, and chemical production, can use hydrogen. Companies engaged with refining, methanol and/or ammonia are already using substantial amounts of gray hydrogen and should transition to green hydrogen, the report said. Industrial operations are responsible for around 20% of carbon emissions in the United States.

Hydrogen can provide backup or off-grid power for locations such as hospitals, military bases, and data centers. Remote and/or critical facilities may benefit from this power source, which can help communities and organizations handle power outages that might otherwise lead to hardships or emergencies.

In the electric power grid, hydrogen production can be used to reduce the impact of the variations in energy supply from renewable sources. Utility data shows that grid loads fluctuate continually; renewable energy is available at some times more than others. To store this power, electrolyzers that generate hydrogen can be used flexibly to respond to changes in wind and solar energy, helping to even out the performance of the grid. The stored hydrogen can be used to power fuel cells or to fuel gas turbines at power stations.

Making sure that hydrogen is used safely is, of course, essential. The FCHEA report stated that hydrogen flames produce relatively little radiant heat compared to hydrocarbon fires. Hydrogen is less flammable than gasoline. However, there are safety risks due to its high pressure and very low temperature. Important safety measures will include robust leak-detection systems, good safety valves, and secure storage tanks. The industry is working to improve its codes and standards, which need to be stronger internationally. And emergency responders need to learn how to handle hydrogen-related safety hazards.[29]

"This is an engineering-driven industry," Wolak said. "Engineers will be at the core of defining the technologies and the best practices. Unlike finance or medical areas where engineering isn't as much of a core, hydrogen is at its heart made up of engineered systems, and engineers have a strong role to play in its success."

"There's not enough qualified people in this industry," Ciotti said. "They certainly need more engineers. There's just work everywhere. It's exponential. I wish we had more people coming out of school with more skills so I could hire them right away."

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Works Cited

1. World Economic Forum. (2021, July 27). *Grey, blue, green – why are there so many colours of hydrogen?* World Economic Forum. https://www.weforum.org/agenda/2021/07/clean-energy-green-hydrogen/
2. Kindy, D. (2021, August 17). *"Blue" hydrogen may not be a very "green" energy source after all*. Smithsonian Magazine. https://www.smithsonianmag.com/smart-news/blue-hydrogen-20-worse-burning-coal-study-states-180978451/
3. Taft, M. (2022, January 21). *Shell CCS plant emits more greenhouse gases than it's captured*. Gizmodo. https://gizmodo.com/shell-ccs-carbon-capture-1848401554
4. Davis, J. A. (2022, Feb. 2). *Hydrogen rainbow may dazzle, but journalists should eye it warily*. Society of Environmental Journalists. https://www.sej.org/publications/backgrounders/hydrogen-rainbow-may-dazzle-journalists-should-eye-it-warily
5. Jones, J. S. (2021, December 20). *Turquoise hydrogen – an emerging variety in the colour spectrum*. Enlit. https://www.enlit.world/hydrogen/turquoise-hydrogen-an-emerging-variety-in-the-colour-spectrum/
6. Brown, F., & Roberts, D. (2021, May 27). *Green, blue, brown: The colours of hydrogen explained*. CSIROscope. https://blog.csiro.au/green-blue-brown-hydrogen-explained/
7. Brown, F., & Roberts, D. (2021, May 27). *Green, blue, brown: The colours of hydrogen explained*. CSIROscope. https://blog.csiro.au/green-blue-brown-hydrogen-explained/
8. Evans, S., & Gabbatiss, J. (2020, Nov. 30). *In-depth Q&A: Does the world need hydrogen to solve climate change?*. Carbon Brief. https://www.carbonbrief.org/in-depth-qa-does-the-world-need-hydrogen-to-solve-climate-change/
9. Davis, J. A. (2022, Feb. 2). *Hydrogen rainbow may dazzle, but journalists should eye it warily*. Society of Environmental Journalists. https://www.sej.org/publications/backgrounders/hydrogen-rainbow-may-dazzle-journalists-should-eye-it-warily
10. Alverá, M. (2022). *The hydrogen revolution: A blueprint for the future of clean energy*. Hodder Studio.
11. UN Environment Programme. (2006). *The hydrogen economy: A non-technical review*. https://www.unep.org/resources/report/hydrogen-economy-non-technical-review
12. Zorpette, G. (2022, August 17). 2022 - *The year the hydrogen economy launched?*. IEEE Spectrum. https://spectrum.ieee.org/hydrogen-economy-inflation-reduction-act
13. Douglas, M. (2022, October 5). *What will REpowerEU and the Inflation Reduction Act mean for hydrogen?* Wood Mackenzie. https://www.woodmac.com/news/opinion/what-will-repowereu-and-the-inflation-reduction-act-mean-for-hydrogen/
14. Higman, M., & Zacarias, M. (2022, July 14). *Hydrogen hubs proposals: Guideposts for the future of the U.S. hydrogen economy*. Center for Strategic & International Studies. https://https://www.csis.org/analysis/hydrogen-hubs-proposals-guideposts-future-us-hydrogen-economy
15. Moniz, E., Kizer, A., DiStefano, J., Breckel, A., Britton, N., Comello, S., Green, T., & Maranville, A. (2021, September). *The future of clean hydrogen in the United States: Views from industry, market innovators, and investors*. Energy Futures Initiative. https://energyfuturesinitiative.org/wp-content/uploads/sites/2/2022/03/The-Future-of-Clean-Hydrogen-in-the-U.S._Report-1.pdf
16. Majkut, J., Nakano, J., & Zacarias, M. (2022, July 29). *Making hydrogen hubs a success*. Center for Strategic & International Studies. https://www.csis.org/analysis/making-hydrogen-hubs-success
17. McFarlane, D. (2022, January 31). *GPI releases carbon and hydrogen hubs atlas for US decarbonization*. Great Plains Institute. https://betterenergy.org/blog/gpi-carbon-and-hydrogen-hubs-atlas/
18. U.S. Department of Energy. (2022, June 2). *DE-FOA-0002768: Notice of intent to issue funding opportunity announcement No. DE-FOA-0002779 - Bipartisan Infrastructure Law: Additional clean hydrogen programs (Section 40314): Regional clean hydrogen hubs*. Office of Clean Energy Demonstrations. https://oced-exchange.energy.gov/Default.aspx#FoaId4e674498-618c-4f1a-9013-1a1ce56e5bd3
19. Van Renssen, S. (2021, October 12). *Hydrogen tests climate policymakers with its job potential*. Energy Monitor. https://www.energymonitor.ai/tech/hydrogen/hydrogen-tests-climate-policymakers-with-its-job-potential/
20. Navigant Consulting. (2019). 2019 *Gas for Climate employment study*. Gas for Climate. https://gasforclimate2050.eu/publications/
21. Fuel Cell & Hydrogen Energy Association. (2020). *US hydrogen road map*. https://www.fchea.org/us-hydrogen-study
22. McKinsey & Company. (2022, November 23). *The clean hydrogen opportunity for hydrocarbon-rich countries*. https://www.mckinsey.com/industries/oil-and-gas/our-insights/the-clean-hydrogen-opportunity-for-hydrocarbon-rich-countries
23. UN Environment Programme. (2006). *The hydrogen economy: A non-technical review*. https://www.unep.org/resources/report/hydrogen-economy-non-technical-review
24. Alverá, M. (2022). *The hydrogen revolution: A blueprint for the future of clean energy*. Hodder Studio.
25. UN Environment Programme. (2006). *The hydrogen economy: A non-technical review*. https://www.unep.org/resources/report/hydrogen-economy-non-technical-review
26. UN Environment Programme. (2006). *The hydrogen economy: A non-technical review*. https://www.unep.org/resources/report/hydrogen-economy-non-technical-review
27. UN Environment Programme. (2006). *The hydrogen economy: A non-technical review*. https://www.unep.org/resources/report/hydrogen-economy-non-technical-review
28. Fuel Cell & Hydrogen Energy Association. (2020). *US hydrogen road map*. https://www.fchea.org/us-hydrogen-study
29. Fuel Cell & Hydrogen Energy Association. (2020). *US hydrogen road map*. https://www.fchea.org/us-hydrogen-study