IISD
International Institute for Sustainable Development

Background Paper

IISD Virtual Forum on the Hydrogen Economy

INTRODUCTION

This background paper accompanies the International Institute for Sustainable Development's (IISD's) 2020 Virtual Forum on the Hydrogen Economy. It is designed to summarize the key trends, potential, and debates around the increasing use of hydrogen as an energy carrier and industrial feedstock. This paper aims to frame discussions during the forum around some of the most pressing questions on the role of hydrogen facing the energy system today.

A growing consensus recognizes the need to target net-zero emissions by 2050 in order to limit a global temperature increase of 1.5 degrees Celsius above pre-industrial levels. To get there, we must find a way to replace the fossil fuels that now generate four fifths of our energy. Paramount to achieving net-zero emissions is increased electrification of certain transport and industrial sectors (globally, 64% of electricity is generated from fossil fuels).[1] According to the International Renewable Energy Agency (IRENA), to reach climate targets, the share of electricity in total final energy consumption must double—from 20% to 40%—between 2015 and 2050.[2] As electricity use increases, with a rising proportion from renewable energy, electricity storage, potentially through storage of hydrogen, could help to smooth demand and supply.

Certain transport sectors, such as heavy-duty vehicles and shipping, and energy-intensive industries such as steel and cement, cannot feasibly be electrified with current technology. For this "toughest third," a replacement must be found for fossil fuels, and hydrogen is emerging as the most suitable candidate.

---

[1] International Energy Agency (IEA). (2020, July). *Electricity information: Overview.* https://www.iea.org/reports/electricity-information-overview

[2] International Energy Agency (IRENA). (2020). *Global Renewables Outlook: Energy Transformation 2050.* *https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Apr/IRENA_GRO_Summary_2020.pdf*

Hydrogen can be used as an industrial feedstock, a fuel converted to electricity through fuel cells, or burned as a heat source. According to Bloomberg New Energy Finance (NEF)[3] hydrogen could meet up to 24% of the world's energy needs by 2050. Currently, hydrogen is mainly produced from natural gas and coal, and associated CO_2 emissions are significant. Clean hydrogen, however, either made by electrolysis (green hydrogen) or using carbon capture (blue hydrogen) is quickly gaining ground as a viable alternative to fossil fuels. Bloomberg NEF estimates the cost of green hydrogen could fall to roughly USD 1/kgH_2 by 2050, a price that would make it competitive with conventional fuels for many end uses.[4] Governments have taken note, with a score of national hydrogen strategies released in the past year as countries look to chart paths toward net-zero economies.

The aims of the forum include addressing the following key questions:

1. How will hydrogen move from a niche industrial feedstock today to a means to achieve net-zero CO_2 across the energy sector?
2. Which countries will secure the global leadership role on hydrogen? Which feedstocks will dominate the coming decade? When will large-scale international trade in hydrogen become a reality?
3. How are industrial players overcoming technological risks as well as cost and policy uncertainty?

Further relevant questions and background information are highlighted throughout this document organized around hydrogen demand and supply. These questions will be used to guide discussions at the forum.

DEMAND

Globally, by 2018 the demand for pure hydrogen was roughly 70 million tons per year, compared to less than 20 million in the 1970s.[5] By 2050, Bloomberg NEF projects this could grow by 10 times to 696 million tons per year if countries adopt policies to encourage the development of hydrogen.[6] The market for hydrogen as an industrial feedstock is already established. Current demand for pure hydrogen is mostly for the production of ammonia and oil refining, which together account for over two thirds of hydrogen use.[7] Already, projects are underway to produce ammonia using clean hydrogen, including one led by Yara, a global fertilizer company, with the potential to reduce emissions by 100,000 tCO_2 annually.[8]

[3] Bloomberg NEF. (2020). Hydrogen economy outlook: Key messages. https://data.bloomberglp.com/professional/sites/24/BNEF-Hydrogen-Economy-Outlook-Key-Messages-30-Mar-2020.pdf

[4] Bloomberg NEF, 2020, p. 2.

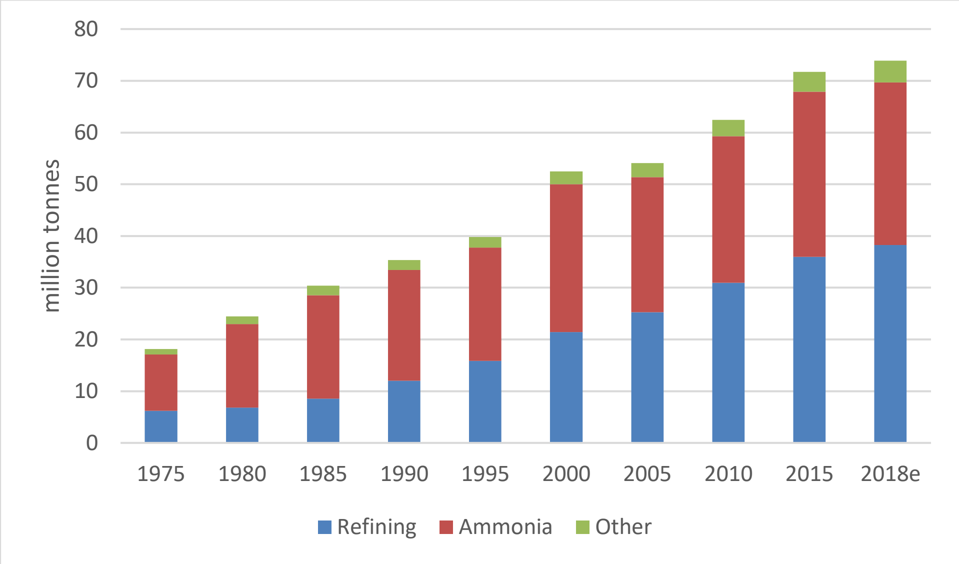
[5] IEA. (2019, June). The future of hydrogen: *Seizing today's opportunities.* https://www.iea.org/reports/the-future-of-hydrogen

[6] Bloomberg NEF, 2020.

[7] IRENA. (2019). *Hydrogen: A renewable energy perspective*, p. 9. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Hydrogen_2019.pdf

[8] Ørsted and Yara join forces to generate renewable hydrogen with which to make fertilizers from carbon neutral ammonia. (2020). *InfoAgro*. http://agriculture.infoagro.com/news/2020/-rsted-and-yara-join-forces-to-generate-renewable-hydrogen-with-which-/

Figure 1. Global annual demand for pure hydrogen



Source: IEA, 2019. See note 5.

Which Sectors Can Hydrogen Help Decarbonize?

For the heating and transport sectors, hydrogen is still in its infancy, and financial and technical barriers to its widespread use remain. Still, hydrogen can be burned for both industrial and building heating. Major industrial heating applications include the production of cement and steel—industries which both now use coal. Swedish and German firms have been experimenting with "green steel," heated using clean hydrogen, with the first successful trial occurring earlier this year in Sweden.[9] At USD 1/kgH_2, such "green steel" could become competitive with traditional steel with a carbon price of USD 50/tCO_2.[10]

What Role Will Hydrogen Play in Building Heating?

For building heating, some proposals suggest blending hydrogen with natural gas for transport and then reseparating the gases near the point of use or consuming them in blended form. A question for regulators is whether existing blending limits for hydrogen in natural gas networks can be increased without danger to infrastructure and end-use appliances. Hydrogen blended at 20% with natural gas—a level considered safe for existing infrastructure—could reduce CO_2 emissions from heating by 6%.[11] Further proposals have considered the possibility of a wholesale conversion of the gas network to hydrogen. One feasibility study determined

[9] Frangoul, A. (2020, May 1). *In Sweden, hydrogen has been used to heat steel in a bid to boost sustainability*. CNBC. https://www.cnbc.com/2020/05/01/hydrogen-has-been-used-to-heat-steel-in-a-bid-to-boost-sustainability.html; Varriale, L. (2020, August 28). *Germany's Thyssenkrupp to build DRI plant run on hydrogen for green steel production*. S&P Global. https://www.spglobal.com/platts/en/market-insights/latest-news/metals/082820-germanys-thyssenkrupp-to-build-dri-plant-run-on-hydrogen-for-green-steel-production

[10] Bloomberg NEF, 2020, p. 1.

[11] Institution of Engineering and Technology. (2019). *Transitioning to hydrogen: Assessing the engineering risks and uncertainties*. p. 30. https://www.theiet.org/media/4095/transitioning-to-hydrogen.pdf

the existing natural gas network in the north of England, connecting 3.7 million meter points, could be converted to hydrogen with minimal disruption to consumers at a cost of GBP 2.2 billion (USD 2.84 billion), around GPB 600 (USD 775) per household.[12] It is estimated that in most regions, given the proper infrastructure, hydrogen would be competitive at a price of USD 1.50–3.00/kgH_2.[13]

What Role Will Hydrogen Play in Passenger and Commercial

Hydrogen is being explored as a replacement for fossil fuels in transportation and electricity generation. In transportation, much attention has been given to passenger hydrogen fuel cell electric vehicles (FCEVs). Japanese and South Korean automakers, especially, have been investing heavily in the development of passenger FCEVs, and the South Korean government offers generous purchase subsidies to induce FCEV demand.[14] However, in the short term, battery electric vehicles (BEVs) appear to have developed a significant lead in the North American and European passenger vehicle markets. Passenger BEVs are currently being sold at significant and growing rates and have the benefit of pre-existing charging infrastructure. The near-term opportunities for FCEVs in North America may therefore be found in larger commercial vehicles where there is less established competition.

Fuel cells may have an advantage over batteries in larger commercial vehicles for two reasons: batteries' weight is compounded with marginal increases in energy storage, and the charging time for batteries represents lost income ("lost miles") to commercial vehicles that operate around the clock. North American manufacturers have therefore shown a growing interest in hydrogen fuel cells for long-haul trucking. If infrastructure were in place, fuel cell trucks using hydrogen delivered at a cost of USD 1/kgH_2 would already be competitive with conventional trucks.[15] In the mining sector, fuel cell-powered vehicles are under development.[16] Despite the challenges, particularly related to fuel supply, Canadian fuel cell manufacturer Ballard has partnered with mining firm Anglo American for a demonstration project using mining FCEVs at a South African mine.[17] They hope this will be the first step in creating a carbon-neutral mine.

---

[12] Sadler, D., Cargill, A., Crowther, M., Rennie, A., Watt, J., Burton, S., & Haines, M. (2018). *H21 North of England*. Northern Gas Networks, p. 392. https://www.northerngasnetworks.co.uk/wp-content/uploads/2017/04/H21-Report-Interactive-PDF-July-2016.compressed.pdf; Institution of Engineering and Technology, 2019, p. 30.

[13] IEA. 2019, p. 148.

[14] Nagashima, M. (2018). *Japan's hydrogen strategy and its economic and geopolitical implications*. Institut français des relations internationales, p. 69. https://www.ifri.org/en/publications/etudes-de-lifri/japans-hydrogen-strategy-and-its-economic-and-geopolitical-implications; Kan, S. (2020). *South Korea's hydrogen strategy and industrial perspectives*. Institut français des relations internationales, p. 2. https://www.ifri.org/sites/default/files/atoms/files/sichao_kan_hydrogen_korea_2020_1.pdf

[15] Bloomberg NEF, 2020, p. 6.

[16] Government of Canada. (2014). *Doing business the Canadian way: A strategy to advance corporate social responsibility in Canada's extractive sector abroad*, p. 2. http://www.international.gc.ca/trade-agreements-accords-commerciaux/assets/pdfs/Enhanced_CS_Strategy_ENG.pdf

[17] Ballard to supply fuel cells for Anglo's trucks. (2019). *Canadian Mining Journal*. https://www.canadianminingjournal.com/news/power-ballard-to-supply-fuel-cells-for-anglos-trucks/

Shipping has also been explored as an opportunity for hydrogen. Storage of hydrogen on ships presents a technical challenge due to the immense amounts of fuel required onboard and hydrogen's low density. One proposed solution is green ammonia, manufactured from clean hydrogen, which could serve as a higher-density renewable fuel. According to Bloomberg NEF at USD 1/kgH_2, a carbon price of USD 145/tCO_2 would still be necessary to make the switch from heavy fuel oil to green ammonia economical for shipping firms. [18]

How Can Hydrogen Reduce Local Air Pollution?

One area where FCEVs have already achieved significant market penetration is in forklifts. Largely because of indoor air quality regulations, businesses have moved to using electric forklifts in warehouses. In this application, hydrogen fuel cells, with their short refuelling time, are competitive against battery-powered forklifts. In remote regions, mini-grids play an important role in providing energy access. For example, the territory of Nunavut in Canada's North derives 100% of its electricity from diesel generators.[19] In some contexts, diesel generation is an important source of local air pollution.

Will Countries Build Hydrogen Capacity to Strengthen Their Energy Security and Support Renewable Penetration?

Hydrogen is proposed as an energy storage technology to shift variable renewable energy generation to match demand. Energy can be stored in the form of hydrogen for frequency response, demand balancing over the course of a day, or potentially even extend to seasonal storage in regions with sufficient storage capacity, such as salt caves.[20]

Linked to consumer demand for hydrogen is the desire at the state level to strengthen energy security. Whereas fossil fuels are geographically dependent, hydrogen can be produced with electrolysis anywhere. This appeals to countries whose access to energy is currently vulnerable to political conflict.

SUPPLY

Hydrogen's role in a low-carbon economy depends on its production method. The main methods of producing hydrogen are often categorized as black, grey, blue, yellow, and green. Black hydrogen, produced by coal gasification, and grey hydrogen, produced by steam methane reforming (SMR) of natural gas, are both carbon intensive. Most analysts do not consider that the cost of changing from fossil fuels to black or grey hydrogen would be justified, as there would be little to no reduction in GHG emissions.

[18] Bloomberg NEF, 2020, p. 6.
[19] Government of Canada. (2020, July 2014). *Electricity facts*. Natural Resources Canada. https://www.nrcan.gc.ca/science-data/data-analysis/energy-data-analysis/energy-facts/electricity-facts/20068
[20] Bloomberg NEF, 2020, p. 3.

How Can Consumers Ensure Their Supply of Hydrogen Is Clean?

The discussion around hydrogen in a low-carbon future therefore centres on blue, yellow, and green hydrogen. Given the imperative to reduce emissions and the myriad technologies available, increased use of hydrogen will need to be accompanied by the development of a scheme to certify the carbon intensity of various hydrogen production pathways. As the end product—pure H_2—is identical regardless of the production pathway, a strong international certification scheme will be needed before clean hydrogen can be marketed as a differentiated product.

Blue hydrogen is produced in much the same way as grey hydrogen, using SMR, but with carbon capture and storage. Theoretically, blue hydrogen could be carbon neutral, but in practice the technology does not entirely prevent leakage of CO_2. For example, the Boundary Dam power plant carbon capture project in Saskatchewan, the world's largest carbon capture project at the time of its construction, achieved an overall CO_2 capture rate of only 51%.[21] The extent to which leakage can be reduced is a subject of debate.

Yellow hydrogen is produced using electrolysis powered by nuclear energy. While new large-scale nuclear projects are not politically feasible in many regions, countries with existing nuclear capacity have announced plans to use this energy to produce hydrogen. France recently unveiled a EUR 7 billion hydrogen strategy that will likely draw from its nuclear power to reach 6.5 GW of carbon-free electrolysis capacity by 2030.[22] Russia is also developing nuclear-powered electrolysis of hydrogen to maintain its position as an energy exporter to Europe if the EU increases tariffs on natural gas imports.[23] To overcome the political gridlock around new nuclear power plants, the nuclear industry has been pushing small modular reactors, a technology supported by the Canadian Government in its 2020 Small Modular Reactor Action Plan.[24] The technology has been proposed as a pathway for producing hydrogen, especially in remote environments.[25]

Green hydrogen is produced using electrolysis powered by renewable energy. Electrolyzers employ similar technology to fuel cells, using electric current to split hydrogen from water, and manufacturers are competing to develop the most efficient designs. Methods include alkaline electrolysis (AE), proton exchange membrane (PEM) electrolysis, anion exchange membrane (AEM) electrolysis, and solid oxide electrolysis (SOE).

---

[21] Sanderson, H. (2019, August 20). Coal industry stakes survival on carbon capture plan. *Financial Times*. https://www.ft.com/content/52552bf8-c024-11e9-89e2-41e555e96722

[22] Radowitz, B. (2020, September 9). France's €7bn hydrogen strategy could feature role for nuclear. *Recharge*. https://www.rechargenews.com/transition/frances-7bn-hydrogen-strategy-could-feature-role-for-nuclear/2-1-872014

[23] Murphy, J. (2020, August 13). Letter from Moscow: Russia reluctantly explores hydrogen. *Petroleum Economist*. https://www.petroleum-economist.com/articles/low-carbon-energy/energy-transition/2020/letter-from-moscow-russia-reluctantly-explores-hydrogen

[24] Government of Canada. (2020, July 20). *Canada's small modular reactor action plan*. Natural Resources Canada. https://www.nrcan.gc.ca/our-natural-resources/energy-sources-distribution/nuclear-energy-uranium/canadas-small-modular-reactor-action-plan/21183

[25] Desai, H.S. (2020, August 20). *Here's why hydrogen is a great partner for nuclear—and the planet*. NEI. https://www.nei.org/news/2020/why-hydrogen-great-partner-nuclear-energy-planet

Currently, 76% of hydrogen is derived from natural gas and 23% from coal, while less than 1% is green hydrogen produced through electrolysis using renewable energy.[26] Electrolyzer capacity for green hydrogen, however, has grown exponentially in recent years, seeing a 50-fold increase since 2015.[27] China is now the world's largest hydrogen producer, making 22 million tons per year—nearly a third of the global total—mostly through coal gasification.[28] Canada is among the top 10 producers, supplying 4% of the global total, mostly through natural gas SMR.[29]

Table 1. Comparison of production pathways

Production pathway	Carbon intensity[30] ($kgCO_2/kgH_2$)	Current cost[31] (2019 USD/kgH_2)	Projected cost 2050 (2019 USD/kgH_2)
Coal gasification (black)	19	1.6-2.0*	1.6-2.0*
Natural gas SMR (grey)	8	1.00-1.75	1.00-1.75
Natural gas SMR with CCUS (blue)	0.4-2	1.4-2.9	1.3-2.8
Electrolysis (yellow)	≥0	0.9-2.2	-
Electrolysis (green)	≥0	2.5-4.5	0.7-1.6

*Estimated cost from Congressional Research Service

Sources: S&P Global, Mathis & Rathi, 2020[30]; Campbell, 2020.[30,31]

What Will Green, Blue, and Grey Hydrogen Cost?

Production costs for both blue and green hydrogen are highly geographically dependent. Regions with accessible natural gas reserves have been able to produce grey hydrogen cheaply, and with carbon capture technology will enjoy the same cost advantage for blue hydrogen. The cost of green hydrogen is largely a function of the cost of energy inputs, and—though less geographically determined than natural gas reserves—renewable energy is also more cheaply

[26] Bloomberg NEF, 2020, p. 2; Collins, L. (2020, March 19). A wake-up call on green hydrogen: the amount of wind and solar needed is immense. *Recharge*. https://www.rechargenews.com/transition/a-wake-up-call-on-green-hydrogen-the-amount-of-wind-and-solar-needed-is-immense/2-1-776481

[27] Hydrogen Council. (2020). *Path to hydrogen competitiveness: A cost perspective*, p. 20. https://hydrogencouncil.com/wp-content/uploads/2020/01/Path-to-Hydrogen-Competitiveness_Full-Study-1.pdf

[28] Amelang, S. (2020, July 24). Europe vies with China for clean hydrogen superpower status. *Clean Energy Wire*. https://www.cleanenergywire.org/news/europe-vies-china-clean-hydrogen-superpower-status

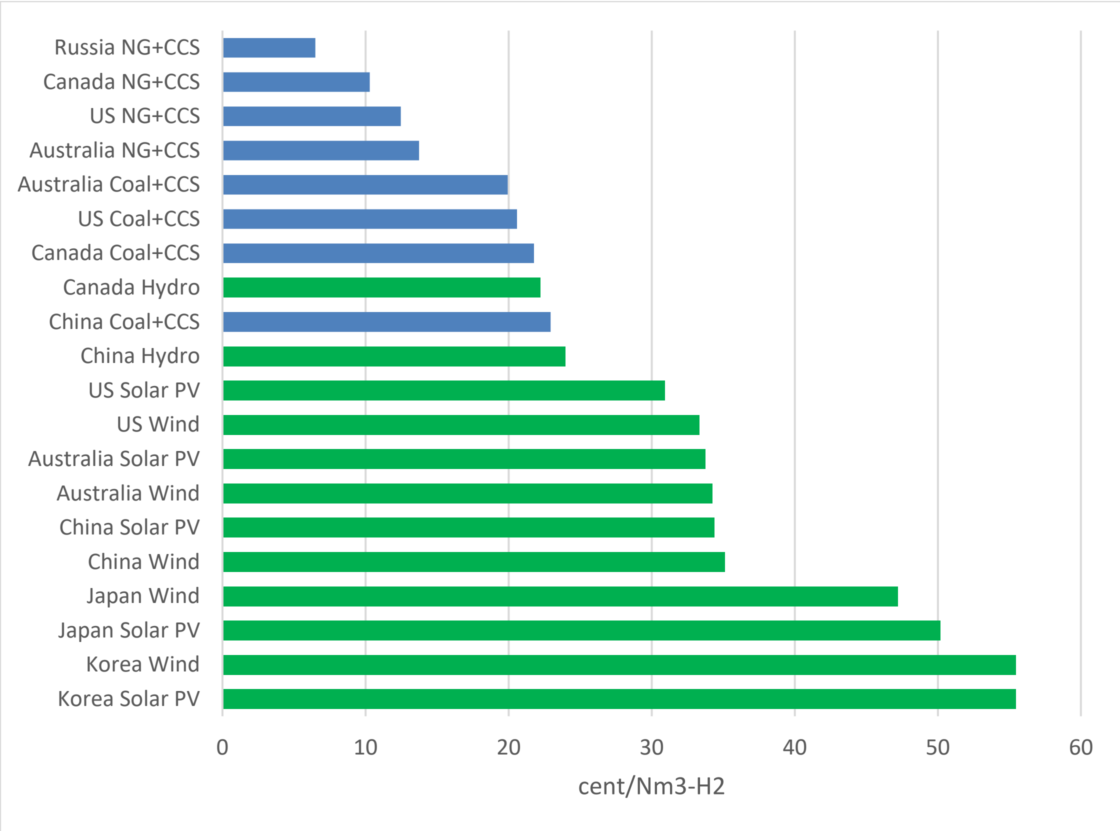
[29] Clean Energy Canada. (2020, July 2). *Media brief: Hydrogen as part of Canada's energy transition*. https://cleanenergycanada.org/hydrogen-as-part-of-canadas-energy-transition/

[30] Mohanty, S., Lewis, S., & Wang, F. (2020, May 13). *China ponders subsidies, cheaper technology for its hydrogen roadmap*. S&P Global. https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/051320-china-ponders-subsidies-cheaper-technology-for-its-hydrogen-roadmap

[31] Bloomberg NEF, 2020, p. 3; Mathis, W., & Rathi, A. (2020, January 14). *Green hydrogen could price gas out of power markets by 2050*. Bloomberg Green. https://www.bloomberg.com/news/articles/2020-01-14/green-hydrogen-could-price-gas-out-of-power-markets-by-2050; Campbell, R. (2020). *Hydrogen in electricity's future*. Congressional Research Service, p. 12; https://crsreports.congress.gov/product/pdf/R/R46436. Energy Options Network. (2020, July). *Zero-carbon hydrogen: An essential climate mitigation option. Nuclear energy's potential role,* p. 36. https://d1qmdf3vop2l07.cloudfront.net/fresh-locust.cloudvent.net/hash-store/45b2875b85350c341a53d50425c4e3a9.pdf

produced in certain environments. The Asia Pacific Energy Research Centre has published an estimate of 2018 hydrogen production costs based on energy input type and geographical location (Figure 2).

Figure 2. Cost of hydrogen production, selected pathways (2018)



Source: Asia Pacific Energy Research Centre, 2018.[32]

Importantly, because renewable energy technologies (especially solar photovoltaic) and electrolyzer manufacturing are less mature industries than natural gas SMR, they are on a much steeper downward price trend. IHS Markit notes the cost of producing green hydrogen has fallen 50% since 2015 and projects it will fall by another 30% by 2025.[33] Similarly, McKinsey forecasts a cost reduction of 60% by 2030 for hydrogen produced using offshore wind.[34] By 2030, green hydrogen could be produced for under USD USD 2/kg, and as low as USD 1.40/kg in places with especially abundant solar and wind power.[35] Because of these

[32] Asia Pacific Energy Research Centre. (2018, June). *Perspectives on hydrogen in the APEC region*. https://aperc.or.jp/file/2018/9/12/Perspectives+on+Hydrogen+in+the+APEC+Region.pdf

[33] IHS Markit. (2020, July 14). *Production of carbon-free "green" hydrogen could be cost competitive by 2030*. https://news.ihsmarkit.com/prviewer/release_only/slug/bizwire-2020-7-15-ihs-markit-production-of-carbon-free-green-hydrogen-could-be-cost-competitive-by-2030; Edwardes-Evans, H. (2020, September 9). *UK should focus on green hydrogen opportunity to integrate offshore wind: Report*. S&P Global. https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/090920-uk-should-focus-on-green-hydrogen-opportunity-to-integrate-offshore-wind-report?utm_campaign=corporatepro&utm_medium=dailyupdate&utm_source=sept10

[34] Hydrogen Council, 2020, p. 23.

[35] Hydrogen Council, 2020, p. 23; Bloomberg NEF, 2020, p. 4.

trends, many analysts predict that green hydrogen will overtake blue hydrogen as the cheapest form of clean hydrogen by the early 2030s.[36] The underlying assumptions of these projections, however, would be invalidated by changing levels of government support.

Should Countries Invest in CCS to Produce Blue Hydrogen?

Despite some forecasts anticipating falling costs for green hydrogen, countries with large natural gas reserves are betting on increasing demand for blue hydrogen. Blue hydrogen could help avoid stranded assets in the oil and gas industry and placate political opposition to the phase-out of fossil fuels. Canada's main oil-producing province, Alberta, is reported to be developing a blue hydrogen strategy to be unveiled in October 2020.[37]

Proponents of blue hydrogen see a way to gain buy-in from the oil sector for net-zero commitments, while some environmental groups have questioned whether it is wise to effectively subsidize the continued expansion of the sector. Fuelling further debate, the production of blue hydrogen can be scaled up more quickly than green, as most of the required infrastructure is already in place.[38] A fast scale-up of blue hydrogen could be useful to develop clean hydrogen supply chains and accelerate demand. This is the concept driving the development of a hydrogen node in Alberta's Industrial Heartland. The project, which aims to create a viable zero-emission energy system that can then be grown and replicated across Canada, is being led by a task force headed by the Transition Accelerator and consists of the mayors of five participating municipalities, and other government, business, energy, academic, and sustainability leaders.[39]

TRANSPORT, STORAGE, AND TRADE IN HYDROGEN

Most of the hydrogen is currently produced and consumed on-site as an industrial feedstock. Consequently, there is little infrastructure or regulation to support an international trade in hydrogen. Technical and political barriers must first be overcome before such a trade can be established.

Is International Hydrogen Trade Economical?

Hydrogen's low density presents technical challenges to its trade and storage. For economic transportation, hydrogen must by compressed, but at typical storage compression (700 bar), hydrogen's energy density is still 8 times lower than conventional fossil fuels.[40] To further reduce storage volume, hydrogen may be liquefied; however, doing so lowers energy efficiency

---

[36] IRENA, 2019, p. 29.
[37] Nickel, R., & Scherer, S. (2020, September 4). *Canada has big plans to use hydrogen to cut emissions - and produce more oil*. Reuters. https://www.reuters.com/article/us-canada-hydrogen/canada-has-big-plans-to-use-hydrogen-to-cut-emissions-and-produce-more-oil-idUSKBN25V1KL
[38] IRENA, 2019, p. 15.
[39] The Transition Accelerator. (2020, May 14). *New task force to create framework to advance hydrogen economy in Alberta's industrial heartland*. https://transitionaccelerator.ca/1197/
[40] IEA, 2019, p. 124.

by 25% to 35%.[41] Liquefied hydrogen therefore only becomes more economical than compressed hydrogen over very long distances, namely in intercontinental shipping.[42] According to Bloomberg NEF, distribution of hydrogen around Europe via pipelines should cost between EUR 0.07 and EUR 0.50 per kg (USD 0.083 to USD 0.59). Transport by trucks or ships is estimated to cost upwards of EUR 0.60 per kg (USD 0.71). Under unfavourable assumptions, the costs of transport can be prohibitive.[43]

Other methods of reducing hydrogen's volume for transport are being explored, including bonding H_2 with nitrogen to transport as ammonia, and creating other denser compounds, known as liquid organic hydrogen carriers. Aside from technical considerations, regulations around the world place limits on the allowable pressure, height, width, and weight of compression tanks, often well below what is technically possible to transport.[44]

Can Hydrogen Be Used to Match the Supply of Variable Renewable Energy to Demand?

Though during transportation hydrogen can be stored in tanks at 700 bar, gaseous hydrogen in large quantity is typically not stored at pressures exceeding 100 bar aboveground and 200 bar underground.[45] The storage volumes required for large-scale applications are therefore immense. One proposed use for hydrogen is to store excess energy produced by variable renewable energy sources and release it into the grid during periods of higher demand. The development of storage of longer than a few hours is still in its infancy. To power 50,000 households for one month would require roughly 1 ktH_2. Storage of such magnitude exists in salt caves and depleted oil and gas reservoirs. For example, a 3.5 ktH_2 storage demonstration project is planned for 2023 in a salt cavern in Germany.[46]

Like natural gas, hydrogen can be transported in pipelines. To prevent hydrogen embrittlement, a process that can cause cracks in metal, existing pipelines would need to be retrofitted by applying an interior coating—materials for which are currently being researched. Pipelines would also need new monitoring systems installed, as hydrogen leaks 4–5 times faster than methane.[47]

---

[41] IEA, 2019, p. 74.
[42] Bloomberg NEF, 2020, p. 4.
[43] Liebreich, M. (2020, October 8). Separating hype from hydrogen – Part one: The supply side. *Bloomberg New Energy Finance*. https://about.bnef.com/blog/liebreich-separating-hype-from-hydrogen-part-one-the-supply-side/
[44] IEA, 2019, p. 79.
[45] Andersson, J., & Grönkvist, S. (2019). Large-scale storage of hydrogen. *International Journal of Hydrogen Energy, 44*(23), pp. 11901–11919, https://doi.org/10.1016/j.ijhydene.2019.03.063
[46] IEA, 2019, p. 69.
[47] Melaina, M.W., Antonia, O., & Penev, M. (2010). *Blending hydrogen into natural gas pipeline networks: A review of key issues*. National Renewable Energy Laboratory, p. 21. https://www.nrel.gov/docs/fy13osti/51995.pdf

CONCLUSION

There is much to be optimistic about regarding the potential role of hydrogen in the energy system, but many questions remain. Debate continues around the sectors beyond ammonia production and oil refining that will reach industrial scale. Hydrogen has a number of key technical advantages in sectors including heating and transport, but in each sector, there are competing technologies and barriers to transition. Questions remain regarding the sustainability credentials of hydrogen from fossil feedstocks, and solving the practical challenges of transport, trade, and storage of hydrogen will require governmental support and international cooperation.

Published by the International Institute for Sustainable Development.

The International Institute for Sustainable Development (IISD) is one of the world's leading centres of research and innovation. The Institute provides practical solutions to the growing challenges and opportunities of integrating environmental and social priorities with economic development. We report on international negotiations and share knowledge gained through collaborative projects, resulting in more rigorous research, stronger global networks, and better engagement among researchers, citizens, businesses and policy-makers.

IISD is registered as a charitable organization in Canada and has 501(c)(3) status in the United States. IISD receives core operating support from the Government of Canada, provided through the International Development Research Centre (IDRC) and from the Province of Manitoba. The Institute receives project funding from numerous governments inside and outside Canada, United Nations agencies, foundations, the private sector, and individuals.

Head Office
111 Lombard Avenue, Suite 325, Winnipeg, Manitoba, Canada R3B 0T4
Tel: +1 (204) 958-7700 | Fax: +1 (204) 958-7710 | Website: www.iisd.org

IISD
International Institute for Sustainable Development