IMPROVING DECISION-MAKING FOR THE ENERGY TRANSITION

Guidance for using Strategic Environmental Assessment

CHAPTER 11

GREEN HYDROGEN AND AMMONIA

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CHAPTER 11

GREEN HYDROGEN AND AMMONIA

Put simply, ***green hydrogen*** is produced by splitting water into hydrogen and oxygen using renewable energy. ***Green ammonia*** is made from green hydrogen, with the process powered by renewable energy as well. The production of green hydrogen and ammonia has both positive and negative environmental and social impacts.

Green hydrogen (see Table 11.1) is seen as a major carrier of GHG-free energy in the global transition to sustainable energy and net zero emissions. Momentum is growing to rapidly expand green hydrogen production to meet IPCCC GHG reduction targets. It is emerging as an option for storing energy (see also Chapter 13 for other energy storage options) from renewables with hydrogen-based fuels potentially being transported over long distances, from regions with abundant energy resources to energy-hungry areas thousands of kilometers away.

Green ammonia, in liquid form, sourced from green hydrogen, is considered along with green hydrogen because of its current and potential role in transporting hydrogen over long distances, offering a number of advantages as a safer fuel transport medium. Ammonia is also a valued agricultural and industrial product.

Green hydrogen featured in a number of emissions reduction pledges at the UN Climate Conference, COP26, as a means to decarbonize heavy industry and its applicability as a fuel for long-haul freight, shipping, and aviation. Governments and industry have both acknowledged green hydrogen as an important pillar of a net zero economy.[1]

The “Green Hydrogen Catapult,” a United Nations initiative to bring down the cost of green hydrogen, announced that it is almost doubling its goal for green electrolyzers from 25 GW, set in 2020, to 45 GW by 2027. The European Commission has adopted a set of legislative proposals to decarbonize the EU gas market and to ensure energy security for all European citizens by facilitating the uptake of renewable and low-carbon gases, including hydrogen. The United Arab Emirates’ new hydrogen strategy aims to hold a quarter of the global low-carbon hydrogen market by 2030, and, recently, Japan announced that it will invest $3.4 billion from its green innovation fund to accelerate research and development and promotion of hydrogen use over the next 10 years.[2]

It is predicted that green or low-carbon hydrogen will become cost-competitive by 2040, given increased scale and lower costs of renewables, along with higher costs for producing brown, gray, and blue hydrogen.[3] White hydrogen is naturally occurring hydrogen found within the earth’s crust.[4]

The production of green ammonia is promoted as an additional option in the transition to net zero carbon dioxide emissions. Its uses in this regard include:

- ***Energy storage*** – ammonia is easily stored in bulk as a liquid at modest pressures (10-15 bar) or refrigerated to -33°C. This makes it an ideal chemical store for renewable energy. There is an existing distribution network in which ammonia is stored in large, refrigerated tanks and transported around the world by pipes, road tankers, and ships.

- ***Zero-carbon fuel*** – ammonia can be burned in an engine or used in a fuel cell to produce electricity. The maritime industry is examining the potential of ammonia to replace fuel oil in marine engines. However, combustion of ammonia can release harmful nitrogen and nitrous oxides, and these emissions must be eliminated before this can be adopted as a viable replacement fuel.

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[1] World Economic Forum (2024)
[2] Obayashi, Y. (2021)
[3] Wood Mackenzie (2020); IRENA (2020b)
[4] Hawkinson, K. (2023)

- ***Hydrogen carrier*** – there are applications where hydrogen gas is used (e.g., in PEM[5] fuel cells). However, hydrogen is difficult and expensive to store in bulk (needing cryogenic tanks or high-pressure cylinders). As a liquid, ammonia is easier and cheaper to store and transport, and it can be “cracked” and purified to give hydrogen gas when required. However, there are significant conversion losses in the transformation process.

11.1 EXISTING STRATEGIC ENVIRONMENTAL ASSESSMENT GUIDANCE/GUIDELINES FOR THE PRODUCTUION OF GREEN HYDROGEN AND AMMONIA

An international survey of existing strategic environmental assessment (SEA) guidelines conducted for the International Association for Impact Assessment was unable to identify any guidelines specifically focused on infrastructure associated with the production of green hydrogen or ammonia.

11.2 TECHNOLOGIES FOR THE PRODUCTION OF GREEN HYDROGEN AND AMMONIA

Power-to-X, also known as P2X or PtX, refers to a bundle of pathways for the conversion, storage, and reconversion of electric power, especially that generated by renewable energy. It is an “umbrella” term, where X can be heat or chemicals including hydrogen, syngas, synthetic fuels, and many more.[6]

Hydrogen can be produced using various technologies and various terms are in use reflecting the technology used, e.g., brown, gray, blue, and green (Table 11.1), and sometimes even pink, yellow, white, or turquoise.

Table 11.1: Main types of hydrogen

Hydrogen type	Manufacturing process
Brown hydrogen	• Created through coal gasification.
Gray hydrogen	• Produced from natural gas but generates carbon dioxide waste. Producing and piping natural gas is a major source of climate-warming methane leaks.
Blue hydrogen	• Captures and stores the carbon dioxide produced in the creation of brown or grey hydrogen.
Green hydrogen	• Involves the use of an electrolyzer — a device that uses electricity and water and has an anode and a cathode separated by an electrolyte (see Box 11.1). Heat is generated as by-product of the process. The process is energy intensive and, where possible, that energy is derived from renewables. There are no greenhouse gas emissions, unlike other methods that use natural gas and steam. Electrolysis can also help to balance the electricity grid by adjusting the demand for electricity. • A new generation of polymer electrolyte membrane (PEM) electrolyzers are being developed and used that are more efficient and less material-intensive compared to the more mature alkaline electrolyzers.

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[5] Polymer electrolyte membrane, or proton-exchange membrane, is a semipermeable membrane generally made from ionomers and designed to conduct protons while acting as an electronic insulator and reactant barrier, e.g., to oxygen and hydrogen gas

[6] Gong, J., English, N. J., Pant, D., Patzke, G. R., Protti, S. and Zhang, T. (2021)

11.2.1 Green hydrogen

Initiatives potentially included in the green hydrogen value chain are very diverse and may include, for example:

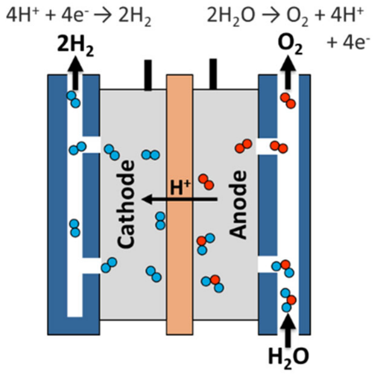
- Greenfield integrated developments, potentially including renewables farms, transmission lines, electrolyzers, conversion units to ammonia/methanol, and shipping facilities;
- Large- or medium-size brownfield developments in existing industrial areas, most often where green hydrogen (and eventually the by-product, oxygen) is utilized in existing units for power generation or steel or ammonia/fertilizer production;
- Medium-/small-size projects or distributed projects to produce hydrogen for mobility; and
- Projects that include hydrogen transmission pipelines or distribution systems.

The role of electrolysis[7] in green hydrogen production

Electrolysis is an especially appealing option for the production of hydrogen from renewable energy sources such as wind and solar. The process of splitting water into hydrogen and oxygen in an electrolyzer is shown in Figure 11.1.

Figure 11.1: The Electrolysis Process

Source: Energy.gov (n.d.-a)



Three types of electrolyzers are available:

- Alkaline electrolyzers where the electrolyte is a liquid alkaline solution of sodium or potassium;
- Polymer electrolyte membrane electrolyzers where the electrolyte is a solid specialty plastic material; and
- Solid oxide electrolyzers where the electrolyte is a solid ceramic material.

The differing levels of the electrolysis process are shown in Box 11.1 and Figure 11.2.

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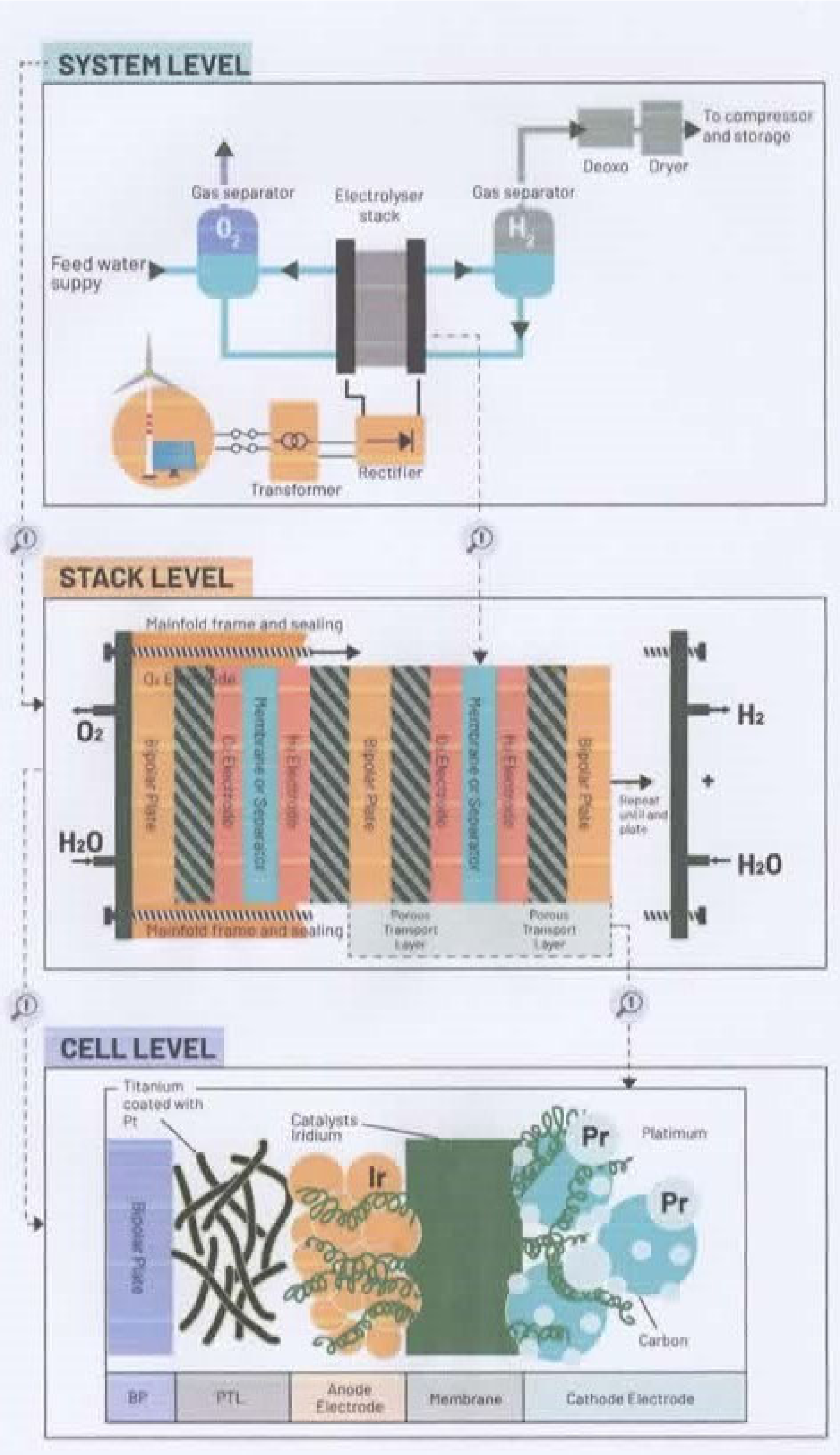
[7] Energy.gov (n.d.-b)

Box 11.1: Electrolyzer levels

An electrolyzer consists of three different levels (see Figure 11.2):

- ***The cell*** is the core of the electrolyzer where the electrochemical process occurs. At the electrode, water is split into oxygen and hydrogen, with ions (typically H+ or OH-) crossing through a liquid or solid membrane electrolyte. The membrane or diaphragm between both electrodes is also responsible for keeping the produced gases (i.e., hydrogen and oxygen) separate and avoiding their mixture.
- ***The stack*** includes multiple cells connected in series and related frames (providing mechanical support) and ancillary items.
- ***The system*** (or balance of plants) goes beyond the stack to include equipment for processing hydrogen, treating water supplied to the electrolyzer, and auxiliary activities.

Figure 11.2: The green hydrogen process
(Source: Signoria and Barlettani, 2023)



11.2.2 Ammonia

About 70% of ammonia is used for fertilizers, while the remainder is used for various industrial applications such as plastics, explosives, and synthetic fibers.[8]

The process of making most of the ammonia consumed in the world is currently not a "green" process. It is most commonly made from methane, water and air, using steam methane reforming (SMR) (to produce the hydrogen), and the Haber-Bosch process.[9] Approximately 90% of the carbon dioxide produced is from the SMR process. This process consumes a large amount of energy and produces around 1.8% of global carbon dioxide emissions.[10]

One way of making green ammonia is by using hydrogen from water electrolysis and nitrogen separated from the air. These are then fed into the Haber-Bosch process, all powered by sustainable electricity.

11.3 GLOBAL PRODUCTION OF HYDROGEN AND AMMONIA, AND STORAGE

11.3.1 Hydrogen

Global hydrogen use reached 95 Mt in 2022, a nearly 3% increase from 2021. Use has grown in all major consuming regions, with the exception of Europe.[11] Both greenfield and brownfield initiatives are under development, with different implications in terms of their potential environmental and social aspects. Huge greenfield developments may change the socioeconomic characteristics of a vast area, while other projects, such as those related to initiatives for distributed hydrogen production for mobility, have a completely different socioeconomic pattern.[11]

The Global Hydrogen Review (2023) is an ongoing annual publication by the International Energy Agency to track progress in hydrogen production and demand, as well as in other critical areas such as policy, regulation, investments, innovation, and infrastructure development. Key points of the review are set out in Box 11.2.

Box 11.2: Key points from the Global Hydrogen Review, 2023[12]

Low-emission hydrogen production can grow massively by 2030, but cost challenges are hampering deployment

- The number of announced projects for low-emission hydrogen production is rapidly expanding.
- After a slow start, China has taken the lead on electrolyser deployment.
- Equipment and financial costs are increasing, putting projects at risk and reducing the impact of government support for deployment.
- Governments have started to make funding available to support the first large-scale projects, but slow implementation of support schemes is delaying investment decisions.
- Electrolyser manufacturers have announced ambitious expansion plans.

Efforts to stimulate low-emission hydrogen demand are lagging behind what is needed to meet climate ambitions

- Hydrogen demand reached a historical high in 2022, but it remains concentrated in traditional applications.

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[8] IEA (n.d.)

[9] The process converts atmospheric nitrogen (N_2) to ammonia (NH_3) by a reaction with hydrogen (H_2) using a metal catalyst under high temperatures and pressures.

[10] Gong, J., English, N. J., Pant, D., Patzke, G. R., Protti, S. and Zhang, T. (2021)

[11] Signoria and Barlettani (2023)

[12] IEA (2023-b)

- Measures to stimulate low-emission hydrogen use have only recently started to attract policy attention and are still not sufficient to meet climate ambitions.
- The private sector has started moving to adopt low-emission hydrogen through off-take agreements, but efforts remain at very small scale.
- International cooperation initiatives can help to aggregate demand for low-emission hydrogen, but demand signals from these initiatives are unclear.
- Scaling up low-emission hydrogen use is also key to enabling the nascent hydrogen trade.

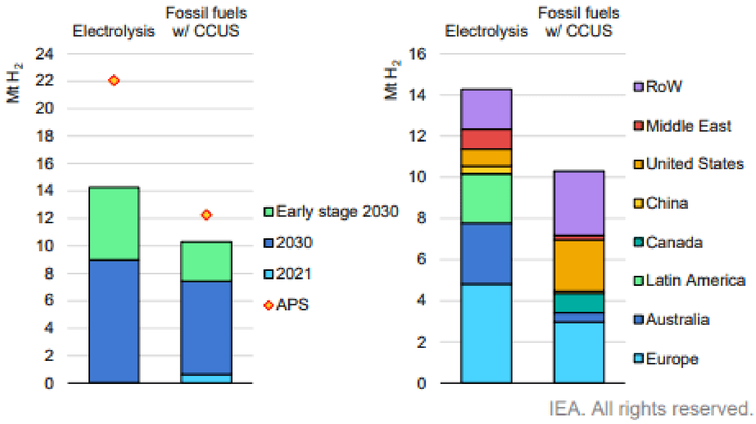
Transforming momentum around hydrogen into deployment remains a struggle

- Political momentum behind low-emission hydrogen remains strong, but deployment is not taking off.
- Regulation and certification remain key barriers to adoption, but strong international cooperation can be crucial to finding solutions.
- Governments need stronger policy action on multiple fronts to tap into the opportunity that low-emission hydrogen offers.

Figure 11.3 shows low-emission hydrogen production data for 2020 and a projection for 2030.

Figure 11.3: Low-emission hydrogen production, 2020 and 2030
Source: IEA (2022c)

Low-emission hydrogen production, 2020 and 2030



Notes: RoW = rest of world; APS = Announced Pledges Scenario. In the left figure, the blue columns for 2020 and 2030 refer to projects at advanced planning stages. The right figure includes both projects at advanced planning and early planning stages. Only projects with a disclosed start year for operation are included.
Source: IEA, Hydrogen Projects Database (2022).

11.3.1 Ammonia

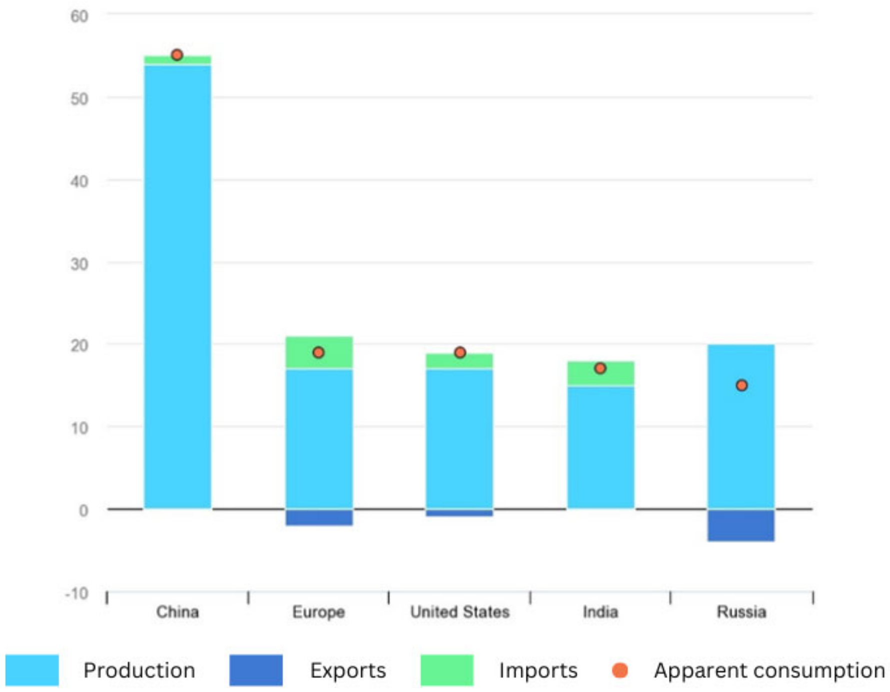
The biggest producer of ammonia in 2022 was China, followed by Russia and the USA (see Table 11.2). Almost all of this production is from natural gas sources.

Production, consumption, and trade statistics for ammonia for 2022 are shown in Figure 11.4.

Table 11.2: Ammonia production worldwide in 2022, by country
Source: Statista (2024)

Country	**Production** (1000 metric tonnes)		**Country**	**Production** (1000 metric tonnes)
China	42,000		Qatar	3,300
Russia	16,000		Algeria	2,600
USA	13,000		Poland	2,100
Other countries	13,000		Germany	2,000
India	12,000		Netherlands	2,000
Indonesia	6,000		Ukraine	2,000
Saudi Arabia	4,300		Oman	1,700
Trinidad & Tobago	4,200		Australia	1,700
Egypt	4,000		Malaysia	1,400
Iran	4,000		Viet Nam	1,200
Canada	3,800		Nigeria	1,100
Pakistan	3,400		Uzbekistan	1,100

Figure 11.4: Production, consumption and trade of ammonia in selected countries and regions, 2020
Source: IEA (2022d)



According to IEA, existing and announced projects totaling nearly 8 Mt of near-zero-emission ammonia production capacity are scheduled to come online by 2030, equivalent to 3% of total capacity in 2020.[13]

It is reported that, in 2026, South Africa will start operations at a large green ammonia plant at Mandela Bay in the Eastern Cape at a cost of USD $4.6 billion and creating at least 20,000 jobs.[14] It will be powered by a nearby solar farm extending over thousands of hectares and will get its water—

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[13] IEA (n.d.)

[14] Prisco, J. (2022)

of which vast amounts are needed to make ammonia—from a local table salt factory that desalinates seawater. The NEOM Green Hydrogen Company of Saudi Arabia is building the world's largest green hydrogen plant to produce green ammonia at scale in 2026. The project has a total value of USD $8.4 billion and will integrate 4 GW of solar and wind energy to produce 600 tons of green ammonia by the end of 2026. An exclusive 30-year off-take agreement of all the produced green ammonia has been secured.[15]

Many large hydrogen and ammonia projects are being delayed due to challenges in their commercial viability.

11.3.2 Storage of hydrogen

Hydrogen can be stored in steel or composite tanks or in underground geological formations. Tanks of various sizes and pressures are already used in the industry. Underground storage is possible in different types of reservoirs, but the most feasible are salt caverns, which are also used for natural gas storage. Underground storage is more suited to large volumes and long timeframes (weeks to seasons).

However, storing hydrogen is not easy, and leakage may occur. It is "corrosive," and, due to its small molecule size, it is more prone to leakage. Hydrogen affects the electrochemical kinetics of the metal, which subsequently lead to pitting and accelerate the rate of intergranular corrosion. The interaction of hydrogen and stress can significantly escalate the stress corrosion cracking susceptibility of steel, especially in the welded joints.[16]

Hydrogen leakage is thus an important consideration in the context of climate change. Though hydrogen molecules do not directly trap heat, they have an indirect global warming effect by extending the lifetime of other GHGs. Certain GHGs (e.g., methane and ozone) are gradually neutralized by reacting with hydroxide radicals (OH) in the atmosphere. When hydrogen gas is released to the atmosphere, it reacts with OH radicals, depleting atmospheric OH levels and delaying the neutralization of GHGs. This effectively increases the lifetime of these GHGs in the atmosphere. A recent study modeled continuous emissions of hydrogen and estimated that, over a 10-year period, hydrogen has an approximately 100 times stronger warming effect than carbon dioxide (CO_2).[17]

The relationships between green hydrogen production, conversion and end uses are shown in Figure 11.5.

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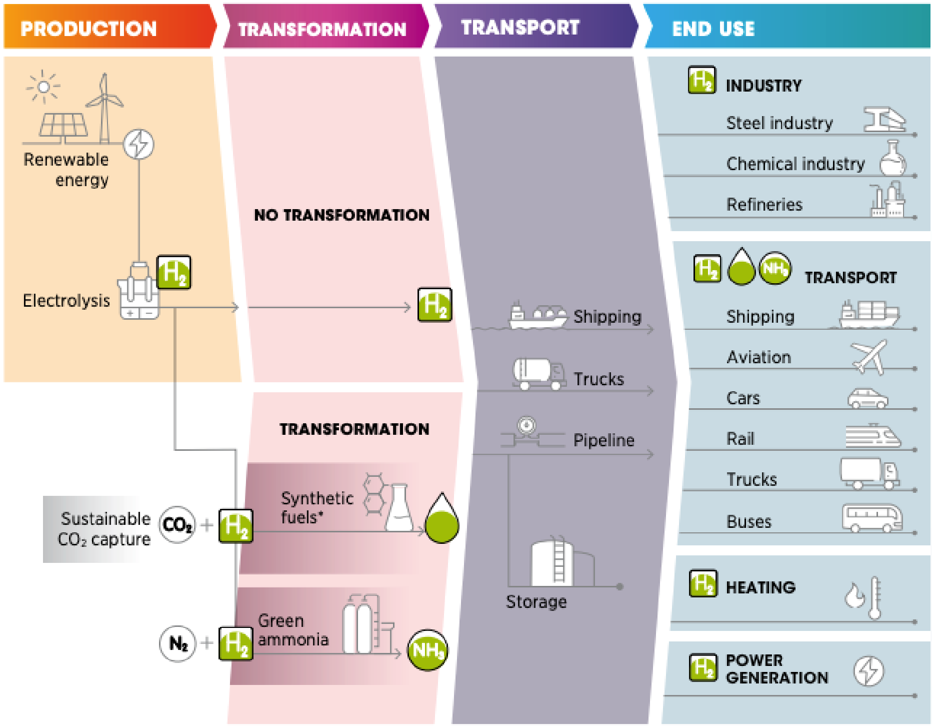
[15] NEOM (2023)

[16] Li, W. et al. (2021)

[17] Fan, Z. et al. (2022)

Figure 11.5: Green hydrogen production, conversion, and end uses across the energy system
Source: IRENA (2020)



Source: IRENA.
** The term synthetic fuels refers here to a range of hydrogen-based fuels produced through chemical processes with a carbon source (CO and CO_2 captured from emission streams, biogenic sources or directly from the air). They include methanol, jet fuels, methane and other hydrocarbons. The main advantage of these fuels is that they can be used to replace their fossil fuel-based counterparts and in many cases be used as direct replacements – that is, as drop-in fuels. Synthetic fuels produce carbon emissions when combusted, but if their production process consumes the same amount of CO_2, in principle it allows them to have net-zero carbon emissions.*

11.4 ENVIRONMENTAL AND SOCIOECONOMIC ISSUES ASSOCIATED WITH PRODUCING GREEN HYDROGEN AND AMMONIA

The production of green hydrogen and, in turn, green ammonia, is based on the use of large amounts of electricity derived from renewable sources. Most often it is assumed that this will come from wind and solar power. The environmental and socioeconomic impacts of wind and solar power are discussed elsewhere in Chapters 6 and 7, respectively. But the generation, storage, and transport of green hydrogen and ammonia will also result in direct and indirect environmental and socioeconomic impacts (Table 11.3). The environmental impacts of other forms of hydrogen are not discussed.

Table 11.3. Environmental and socioeconomic risks associated with green hydrogen and ammonia

Source: Hurwitz et al. (2023); Signoria and Barlettani (2023)

Issue	Green hydrogen	Green ammonia
Environmental		
Transport-related issues	• Transportation of hydrogen and ammonia by trucks or ships (including to homeowners) adds emissions of pollutants	
Water	• Large amounts of water are needed to produce hydrogen (approximately 9 L per 1 kg of hydrogen). This has the potential to make water (a critical requirement in production) scarce, especially to local communities and particularly where it is already limited, exacerbating **water shortages, causing conflicts with food production,** and threatening lives and livelihoods. • The use of deionized water produced by desalination plants may reduce freshwater demand, but it generates a need to **discharge brine** into water sources and soils (see Box 14.3). This increases the salinity and density of the receiving water, which may lead to higher water stratification and reduced oxygen exchange in the water column. Desalination also requires significant amounts of energy, which will have to be generated by renewable sources. • Offshore wind hydrogen production using electrolysers also affects ocean salinity with potential adverse impacts on pelagic and other marine species and ocean currents. Electrolysers and desalination systems also require significant amounts of energy, which will have to be generated by renewable sources. • **Eutrophication** due to phosphate enrichment if polyphosphates and organic cleaning solutions are added to the brine (if desalination occurs). • **Discoloration of receiving waters** due to high concentration of ferric substances, also with high-suspended solids and turbidity. • Increased salinity can **impact the composition and distribution of biota**. • **Biodiversity can be affected** by impacts to water resources (whether freshwater or seawater) receiving brine discharge from desalination plants, particularly if dilution (e.g., using a diffuser) is inadequate.	Ammonia and methanol generate waste, and production often involves the use of catalysts and other ***chemicals that can be toxic or harmful to the environment***, potentially contaminating water sources and soils during production and transportation if not handled properly. In cases of continuous discharge or leaks into water bodies, this may represent an immediate danger to aquatic life, with subsequent impacts on the livelihood of communities depending on it.
Land use/land cover change	• Large amounts of land are required for associated wind or solar energy generation. This could lead to the ***conversion of natural habitats or agricultural land***, which could have negative impacts on biodiversity, ecosystem services, and food security. • Such changes can lead to ***deforestation, land degradation and habitat fragmentation***, invasive alien species, overexploitation, hydrological changes, nutrient loading, and pollution. • This may involve the ***loss of natural buffer areas*** such as wetlands, mangroves, and upland forests that mitigate the effects of natural hazards such as flooding,	

Issue	Green hydrogen	Green ammonia
	landslides, and fire; these may result in increased vulnerability and community safety-related and health-related risks and impacts. • Production plants and associated infrastructure (e.g., transport pipelines, transmission lines, port facilities, access roads) will also involve land use change with similar impacts. This will also result in increased human access to less developed areas. • The presence of hydrogen-related infrastructure may also cause visual and aesthetic impacts.	
Waste	• ***General waste, sludge, and wastewater*** from (fresh) water purification for electrolysis requires careful management to avoid pollution of water courses and groundwater. The quantity of sludge will depend on the level of contaminants originally present in the raw water, and on the purity of water required by the specific electrolysis process adopted. • ***Electric and electronic waste and hazardous substances*** as a result of the decommissioning of electrolyzers and plants. • Risk of abandonment of the facilities at the end of their lives (probably 20-30 years).	
Pollution	• ***Emissions from trucks*** during construction phase.	
Socioeconomic		
Transport accidents	Risk of ***accidents*** on roads and at start/end sites.	
Occupational health and safety	• Hydrogen is ***highly flammable***. If not handled properly, it can pose a significant risk to workers' safety during production, transportation, and storage (explosions and fires). • The production process involves the operation of complex and potentially dangerous ***high-pressure equipment*** (containers and pipelines) and the handling of ***hazardous chemical***s, which can lead to accidents and injuries. • Workers may also be exposed to ***intense electromagnetic fields*** within the electrolyser building, to ***toxins*** (including methanol and ammonia) in conversion and storage units, and to ***cold surfaces*** in cryogenic storage units.	
Labor risks and working conditions	• Risk of ***poor/unacceptable working conditions*** (including lack of training or protective equipment) at production sites and associated infrastructure. • Catalyzers involves the use of rare earth elements such as iridium, which can present ***labor risks in the primary supply chain*** if not sourced responsibly, including the risk of ***forced and child labor***.	
Influx of workers	An influx of workers, both unskilled and skilled, is likely, particularly during the construction phase. Impacts include: • ***Induced pressure on land, natural resources, and availability and price of goods and services*** at the local level as the influx of newcomers in the area will likely increase demand for food, fuel, housing, and land. Such pressure may exert the greatest impact on the most vulnerable in the location, as well as on those communities whose livelihoods are highly or even exclusively resource-based, in particular those depending on subsistence agriculture. • An influx of labor from outside may stretch beyond capacity the local level's **social service infrastructure** due to increased demand in housing services, schools, and health care, as well as generating additional pressure on waste management, sanitation, water, power, and transportation services. • Labor influx may cause communities to experience **significant boosts to the local economy** associated with the start of projects, followed by **sharp declines** once construction works have concluded.	

Issue	Green hydrogen	Green ammonia
	• External worker influx may pose ***threats to the health and safety of local communities***, provoking higher rates of violence, injuries, alcohol and drug consumption, and communicable diseases (including sexually transmitted diseases) in the local population. • ***Conflicts*** between local community members and workers from outside the community may arise with respect to employment opportunities, wages, and demand and pressure on natural resources. • A large influx of external male workers may lead to an increase in ***gender-based violence.***	
Job opportunities	• Potential for significant ***new jobs,*** but this will need to be balanced by the requirements of training workers in new renewable energy technologies.	
Associated livelihood opportunities	• Potential for ***new livelihoods*** servicing production plants and associated infrastructure (e.g., shops, stalls). • Potential to return electricity and desalinated water to communities in areas where water and electricity access are problematic.	
Improved local services	• Potential for developers to invest in/provide ***new and improved local services*** (e.g., schools, clinics, bus services).	
Cultural heritage	• There is a risk that ***cultural, religious, and archaeological sites*** may be disturbed or destroyed as a result of developing hydrogen production sites or associated infrastructure, or access to such sites may be restricted or denied.	
Land rights	• There are risks that acquisition of land for plants and associated infrastructure will undermine, restrict, or limit ***local community rights to access*** particular areas of cultural or livelihood importance; this may lead to ownership conflicts, particularly as regards agricultural lands.	
Gender issues	• There is a potential that ***gender inequalities*** may arise during the construction and operation of plants and associated infrastructure. These can interact with other inequalities (e.g., socioeconomic, ethnic, racial, disability) and exacerbate barriers to accessing project benefits, limit the ability to deal with negative project impacts, and create other vulnerabilities. • ***Women may be discriminated*** against or subjected to sexual harassment or abuse in the workplace due to gender and/or sexual identity and orientation. • Land fragmentation and land take may ***affect women disproportionately***, also taking into consideration that land acquisition processes occur within a framework of inequalities rooted in all dimensions of land rights, i.e., ownership, management, transfer, and economic rights, in particular those associated with agricultural lands. • A large influx of external male workers may lead to an increase of ***gender-based violence*** against women and young girls, particularly in socioeconomic settings where there is an existing gender differentiation in terms of power and norms. • If green hydrogen/ammonia developments induce additional water stress, women (particularly in Indigenous communities) will likely bear a ***disproportionate impact of lack of access to safe water*** for drinking, sanitation, and other purposes. Without safe access at home and/or in work and study places, it is significantly harder for women and girls to lead safe, productive, and healthy lives. • Alongside other disadvantaged groups and minorities, women risk being ***left out of and/or underrepresented*** within consultation processes and activities of stakeholder engagement. Conversely, this may also provide opportunities for women-owned and operated renewable energy companies.[18]	
Indigenous communities	• *Indigenous Peoples may be particularly and disproportionately affected by many of the above socioeconomic issues. However, opportunities may arise for development of Indigenous-owned companies producing green hydrogen and ammonia.*	
Economic	• New green hydrogen and ammonia development will provide an economic boost to a country and to the local economy.	

Many of the socioeconomic impacts above are not exclusive to green hydrogen projects but typically arise in the construction phase of large infrastructure projects.

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[18] WRISE (2024) For more information, see: wrisenergy.org

Box 11.3: Options for managing brine from desalination for hydrogen production

Source: Signoria and Barlettani (2023)

- Deep well injection;
- Evaporation ponds;
- Discharge into surface water bodies;
- Disposal into municipal sewers;
- Concentration into solid salts (e.g., salt harvesting and on-site generation of sodium hypochlorite);
- Irrigation of plants tolerant to high salinity;
- Reusing the brine;
- Zero liquid discharge;
- Aquaculture;
- Application in soils.

Potential impact can be minimized and regulated by treatment and recycling technologies, by limiting concentration values of brine at the discharge point, as well as by imposing concentration values within a prescribed circular mixing zone in coastal waters via outfall design.

The increase in salinity or temperature, or the reduction in dissolved oxygen, in the water bodies receiving brine discharge from electrolyzers or cooling systems can be modeled with available software tools.[19] The selection of the most appropriate models will depend on various factors:

- Complexity of shoreline topography;
- Presence of streams within receiving bodies;
- Possibility of water recirculation (for example, within bays with strong tidal streams), with pollutant accumulation;
- Sensitivity of local ecosystems to average and/or peak pollutant concentrations;
- Discharge geometry (along the shoreline, under water level, single or multiple discharge, etc.);
- Distance to discharge point at which the respect of a limit is requested (point of compliance).

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[19] The US Environmental Protection Agency (EPA) maintains and updates a specific page (currently available at https://www.epa.gov/hydrowq/surface-water-models-assess-exposures) with a list of commercial software and freeware tools, with recommendations for their use in different situations.