Chapter 14

KEY ISSUES FOR SEA IN THE PRODUCTION OF GREEN HYDROGEN AND AMMONIA

Put simply, ***green hydrogen*** is produced by splitting water into hydrogen and oxygen using renewable energy. When burned, only water is emitted, but creating hydrogen can be costly. ***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 14.1) is seen as a critical enabler of the global transition to sustainable energy and net zero emissions economies. Momentum is growing to develop green hydrogen as a clean energy solution. It is emerging as a leading 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 kilometres away. As a liquid fuel, green ammonia, sourced from green hydrogen, offers a number of advantages as a transport medium.

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 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 electrolysers 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 by facilitating the uptake of renewable and low carbon gases, including hydrogen, and to ensure energy security for all European citizens. 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 green? 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, grey and blue hydrogen[3]. Pink hydrogen, derived from nuclear power, is another option for future hydrogen production[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 burnt in an engine or used in a fuel cell to produce electricity. When used, ammonia's only by-products are water and nitrogen. The maritime industry is likely to be an early adopter, replacing the use of fuel oil in marine engines. However, its use as a clean energy fuel currently remains nascent.
- ***Hydrogen carrier*** – there are applications where hydrogen gas is used (e.g. in PEM 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, to transport

1 What is green hydrogen? An expert explains its benefits | World Economic Forum (weforum.org)
2 Japan Sets Aside $3.4B for Hydrogen R&D (oedigital.com)
3 Hydrogen production costs to 2040: Is a tipping point on the horizon? | Wood Mackenzie
4 Explained: Pink Hydrogen, The Future of Clean Energy (iamrenew.com)

and it can be readily “cracked” and purified to give hydrogen gas when required. However, there are conversion losses in the transformation process.

14.1. EXISTING SEA GUIDANCE/GUIDELINES FOR THE PRODUCTUION OF GREEN HYDROGEN AND AMMONIA

An international survey of existing SEA guidelines conducted for the IAIA was unable to identify any guidelines specifically focused on infrastructure specifically associated with the production of green hydrogen or ammonia.

14.2 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[5].

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, electrolysers, conversion unit to ammonia/methanol, and shipping facilities
- Large- or medium-size brownfield developments in existing industrial areas, most often where GH (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
- Projects that include hydrogen transmission pipelines or distribution systems.

Hydrogen can be produced using various technologies and various terms are in use reflecting the technology used, e.g. ‘brown’ grey’, ‘blue’, and ‘green’ (Table 14.1), and sometimes even ‘pink’, ‘yellow’ or ‘turquoise’ .

Table 14.1: Main types of hydrogen

Hydrogen type	Manufacturing process
Brown hydrogen	• Created through coal gasification
Grey 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 grey hydrogen
Green hydrogen	• Involves the use of an electrolyser - a device that uses electricity and water and has an anode and a cathode separated by an electrolyte (see Box 14.1). 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) electrolysers are being developed and used that are more efficient and less material-intensive compared to the more mature alkaline electrolysers.

[55] Power-to-X: Lighting the Path to a Net-Zero-Emission Future | ACS Sustainable Chemistry & Engineering

Box 14.1: Electrolyser levels

An electrolyser consists of three different levels (see Figure 14.1):

- The cell. The cell is the core of the electrolyser, and it is 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. The stack level includes multiple cells connected in series and related frames (providing mechanical support) and ancillary items.
- The system (or balance of plant). It goes beyond the stack to include equipment for processing hydrogen, treating water supplied to the electrolyser, and auxiliary activities.

Ammonia

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 (or Haber-Bosch) process[6]. 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[7].

The process for obtaining hydrogen is denoted by a colour (see Table 14.1). Even though ammonia is always a clear, colourless but pungent gas[8], it is also denoted by a colour prefix dependent on the hydrogen source. In the USA, 92% of ammonia produced is from natural gas, or “Grey”, generating millions of tons of carbon emissions each year.

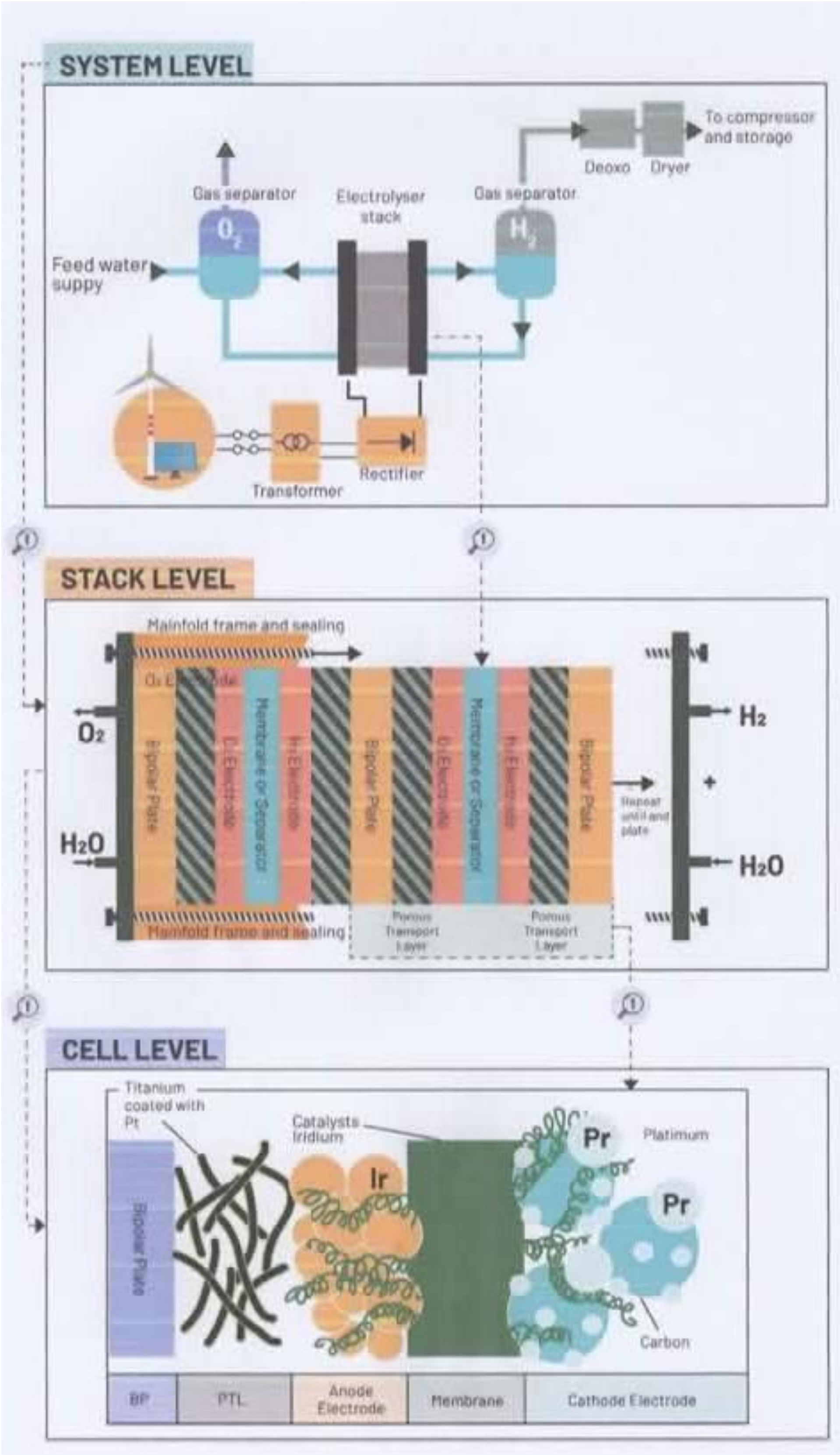
One way of making green ammonia is by using hydrogen from water electrolysis and nitrogen separated from the air. These are then fed into the Haber-Bosch process, all powered by sustainable electricity. Blue ammonia uses blue hydrogen and is used as a way to reduce carbon dioxide emissions through carbon sequestration.

[6] 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.

[7] Power-to-X: Lighting the Path to a Net-Zero-Emission Future | ACS Sustainable Chemistry & Engineering

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

Figure 14.1: The green hydrogen process
(Source: Signoria and Barlettani, 2023



14.2 GLOBAL PRODUCTION OF HYDROGEN AND AMMONIA, AND STORAGE

Hydrogen

Green hydrogen projects span from distributed and small-size production facilities to huge projects. Both greenfield and brownfield initiatives are under development, with different implications in terms of 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[9].

The Global Hydrogen Review (2022) is the second edition of a new 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 14.2.

Box 14.2: Key points from the Global Hydrogen Review, 2022[10]

Hydrogen demand reached 94 million tonnes (Mt) in 2021, recovering to above pre-pandemic levels (91 Mt in 2019), and containing energy equal to about 2.5% of global final energy consumption.

The first fleet of hydrogen fuel cell trains started operating in Germany. There are also more than 100 pilot and demonstration projects for using hydrogen and its derivatives in shipping, and major companies are already signing strategic partnerships to secure the supply of these fuels. In the power sector, the use of hydrogen and ammonia is attracting more attention; announced projects account for almost 3.5 GW of potential capacity by 2030.

The review estimates that hydrogen demand could reach 115 Mt by 2030, although less than 2 Mt would come from new uses. This compares with the 130 Mt (25% from new uses) that would be needed to meet existing climate pledges put forward by governments around the world so far, and with nearly 200 Mt needed by 2030 to be on track for net zero emissions by 2050.

If all projects currently in the pipeline were realised, by 2030 the production of low-emission hydrogen could reach 16-24 Mt per year, with 9-14 Mt based on electrolysis and 7-10 Mt on fossil fuels with CCUS (carbon capture, utilisation and storage). In the case of electrolysis, the realisation of all the projects in the pipeline could lead to an installed electrolyser capacity of 134- 240 GW by 2030, with the lower end of the range similar to total installed renewable capacity in Germany and at the upper end in all of Latin America. Meeting governments' climate pledges would require 34 Mt of low-emission hydrogen production per year by 2030 and a path compatible with reaching net zero emissions by 2050 globally would require around 100 Mt of production by 2030.

Electrolyser manufacturing capacity sits at nearly 8 GW/yr. Based on industry announcements, it could exceed 60 GW/yr by 2030.

With today's fossil energy prices, renewable hydrogen could already compete with hydrogen from fossil fuels in many regions, especially those with good renewable resources and that must import fossil fuels to meet demand for hydrogen production.

The world's first shipment of liquefied hydrogen from Australia to Japan took place in February 2022, a key milestone in the development of an international hydrogen market. Based on the export-oriented projects under development, an estimated 12 Mt of hydrogen could be exported annually by 2030, with 2.6 Mt/yr planned to come online by 2026. However, off-take and importing arrangements lag behind the scale of planned exports: only 2 Mt H_2/yr has secured a customer or potential customer. Project developers and investors are facing high uncertainty in a nascent market for hydrogen and many governments have yet to implement specific hydrogen trade policies, which are necessary for the successful development of projects.

[9] Signoria and Barlettani, 2023

[10] Global Hydrogen Review 2022 (windows.net)

There are projects under development to repurpose thousands of kilometres of natural gas pipelines to 100% hydrogen. Governments, particularly in Europe, are considering repurposing liquified natural gas (LNG) terminals, though the opportunities depend on whether they will ultimately receive hydrogen or ammonia.

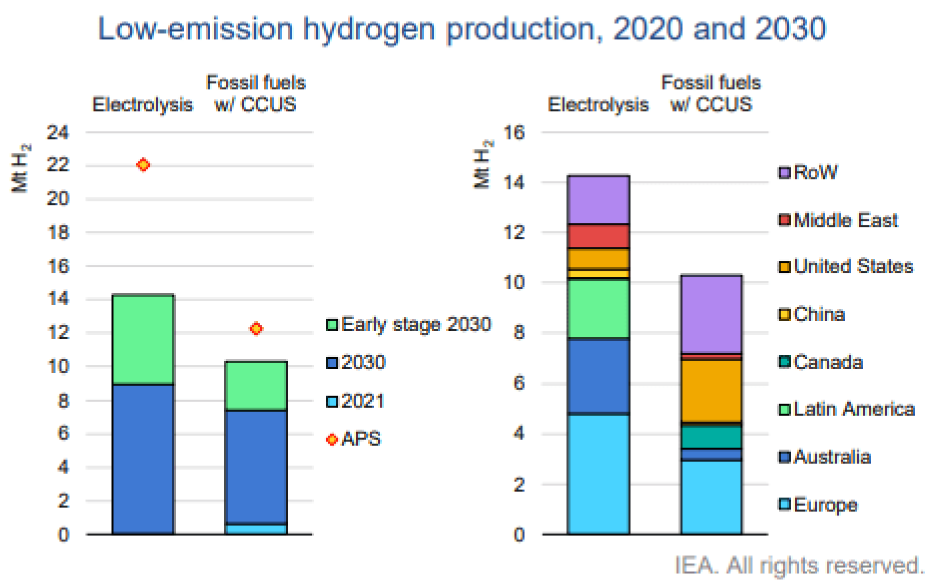
Governments continue to consider hydrogen a pillar of their future energy sector strategies: nine new national strategies have been adopted since September 2021, bringing the total number to 26. Some countries are moving to the next step by implementing concrete policies, with a particular focus to support commercial scale projects for low-emission hydrogen production and infrastructure (e.g., the EU Important Projects of Common European Interest, the US Inflation Reduction Act and the German H2Global Initiative). However, there is still not enough policy activity for creating hydrogen demand, which is critical to secure off-take agreements.

There are only eleven plants to produce low-emission hydrogen: seven are facilities retrofitted with CO_2 capture and four use electrolysers. They produced around 260 kt of low-emission hydrogen in 2021 (around 0.7% of hydrogen demand in refining), a slight increase from the 230 kt used in refineries in 2020.

Figure 14.2 shows low-emission hydrogen production data for 2020 and a projection for 2030.

Figure 14.2: Low-emission hydrogen production, 2020 and 2030

Source: IEA (2022c)



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).

Ammonia

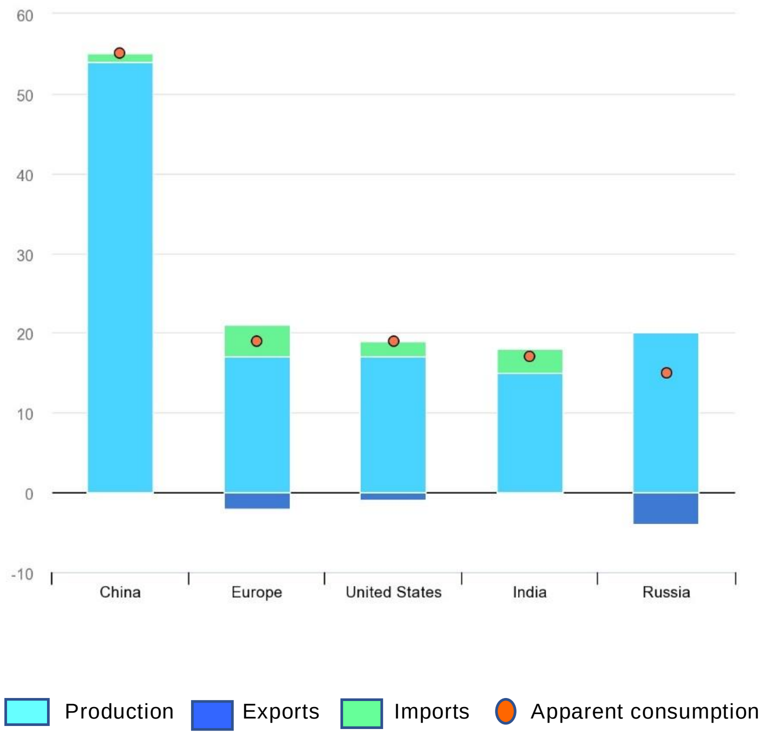
The biggest producer of ammonia in 2022 was China, followed by Russia and the USA (see Table 14.2). Almost all of this production is from natural gas sources.

Table 14.2: Ammonia production worldwide in 2022, by country
(Source: Global ammonia production by country 2022 | Statista)

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		Vietnam	1,200
Canada	3,800		Nigeria	1,100
Pakistan	3,400		Uzbekistan	1,100

Production, consumption and trade statistics for ammonia for 2022 are shown in Figure 14.3.

Figure 14.3: Production, consumption and trade of ammonia in selected countries and regions, 2020
(Source: IEA: Production, consumption and trade of ammonia in selected countries and regions, 2020 – Charts – Data & Statistics - IEA)



According to IEA, existing and announced projects totalling 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[11].

[11] Executive Summary – Ammonia Technology Roadmap – Analysis - IEA

It is reported that, in 2026, South Africa will start operations of the World's largest green ammonia plant at Mandela Bay in the Eastern Cape at a cost of US$4.6 billion and creating at least 20,000 jobs[12]. It will be powered by a nearby solar farm extending over thousands of hectares and will get its water — of which vast amounts are needed to make ammonia — from a local table salt factory that desalinates seawater.

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 more "corrosive" and, due to its small molecule size, it is more prone to leakage. 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 react 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 p study modelled 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)[13]

The relationships between green hydrogen production, conversion and end uses are shown in Figure 14.4.

12

13 https://www.energypolicy.columbia.edu/wp-content/uploads/2022/07/HydrogenLeakageRegulations_CGEP_Commentary_063022.pdf

Figure 14.4: Green hydrogen production, conversion, and end uses across the energy system
(Source: IRENA 2020)

Figure redacted pending securing copyright permission to use. If you have an image showing this spatial distribution that you can provide (with permission to use – please indicate the credit to cite) we would be delighted if you can send it.

13.5 ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACTS IMPACTS OF PRODUCING HYDROGEN AND AMMONIA

The production of green hydrogen, and green ammonia in turn, 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 socio-economic 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 socio-economic impacts (Table 14.3.)

Table 14.3. Environmental and socio-economic risks and opportunities associated with green hydrogen and ammonia
(Sources: 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 9L 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 can increase 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. • ***Eutrophication*** due to phosphate enrichment if polyphosphates and organic cleaning solutions are added to the brine. • ***Discoloration of receiving waters***, due to high concentration of ferric substances, also with high-suspended solids and turbidity. • Increased salinity can ***impact on 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 case 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 required for associated wind or solar production, 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, over-exploitation, hydrological changes, nutrient loading, and pollution, • Such loss may involve ***loss of natural buffer areas*** such as wetlands, mangroves, and upland forests that mitigate the effects of natural hazards such as flooding, 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.	

Issue	Green hydrogen	Green ammonia
	• 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 electrolysers and plants. • Risk of ***abandonment*** of the facilities at the end of their lives (probably 20-30 years).	
Pollution	From ***spills and leakage of fuels and chemicals*** stored and used on plant sites – which can enter water courses and groundwater.	
Socio-economic		
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). • 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.	
Labour 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 ***labour risks in the primary supply chain*** if not sourced responsibly – including the risk of ***forced and child labour***.	
Influx of workers	Significant influx of workers, both unskilled and skilled, is likely. 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 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. • A great influx of labour 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. • Influx of labour may cause communities to experience ***significant boosts to the local econom***y associated with the start of projects, followed by ***sharp declines*** once construction works have concluded. • External worker influx may pose ***threats to the health and safety of local communities***, provoking higher rates of violence, injuries, alcohol and drug	

Issue	Green hydrogen	Green ammonia
	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 of ***gender-based violence.***	
Job opportunities	Potential for significant ***new jobs*** but this will need to be balanced by the requirements of training of workers in new renewable energy technologies.	
Associated livelihood opportunities	Potential for ***new livelihoods*** servicing production plants and associated infrastructure (eg shops, stalls).	
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; lead to ownership conflicts – particularly as regards agricultural lands.	
Gender issues	• The is always the 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 subject 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 socio-economic 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[14].	
Indigenous communities	Indigenous peoples may be particularly and disproportionately affected by many of the above socio-economic 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.	

[14] Women of Renewable Industries and Sustainable Energy WRISE - WRISE (wrisenergy.org)

Box 14.3: Options for managing brine from desalination for hydrogen production

- 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 electrolysers or cooling systems can be modelled with available software tools[15]. The selection of the most appropriate models will depends 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).

Source: Signoria and Barlettan (2023)

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