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The Green Collection

Aligning Green Hydrogen Proposals to the Green Deal

The Green Collection: A series of short notes providing information to help align selected infrastructure projects to the European Green Deal.

This collection provides basic information on the environmental, climate, biodiversity and disaster risk reduction aspects of selected types of infrastructure projects. It aims at equipping colleagues dealing with such projects in Headquarters and European Union Delegations to better address their alignment to the Green Deal.

Policy Background

The *REPowerEU Plan* aims to replace Russian gas imports by 2030 by an additional 15 million tonnes of renewable hydrogen, on top of 5.6 mt planned under the *Fit for 55* initiative. This includes 10 mt of imported hydrogen for which the Commission will create hydrogen partnerships with partner countries.

EU Hydrogen Strategy for a climate-neutral Europe recognizes Eastern Neighbourhood, in particular Ukraine, and the Southern Neighbourhood countries as priority partners for cooperation on clean hydrogen. Therefore, one of the key actions is to *"promote cooperation with Southern and Eastern Neighbourhood partners and Energy Community countries, notably Ukraine, on renewable electricity and hydrogen"*. The Commission is working on a Mediterranean Green Hydrogen Partnership, the EU-Egypt Hydrogen Partnership, EU-Morocco Green Partnership, and a strategic partnership with Ukraine.

Hydrogen fundamentals

Hydrogen is under normal conditions a gas with the symbol H_2; it is the lightest and most common chemical element in the universe. It is colourless, odourless, tasteless, non-toxic, and highly combustible (read: explosive). In reaction with oxygen it produces water while releasing energy ($2H_2 + O_2 = 2\,H_2O$ + energy). The energy is produced **without CO_2 emissions**.

Hydrogen has many applications in (petro) chemical industry, is feedstock for the production of ammonia (and thus fertilizers), is used for cooling, and can **act as a carrier of energy**, the focus of this paper.

Being an energy carrier, **production of hydrogen** is energy intensive (the energy is trapped into the molecule). Hydrogen can be produced through a variety of processes, commonly divided into:

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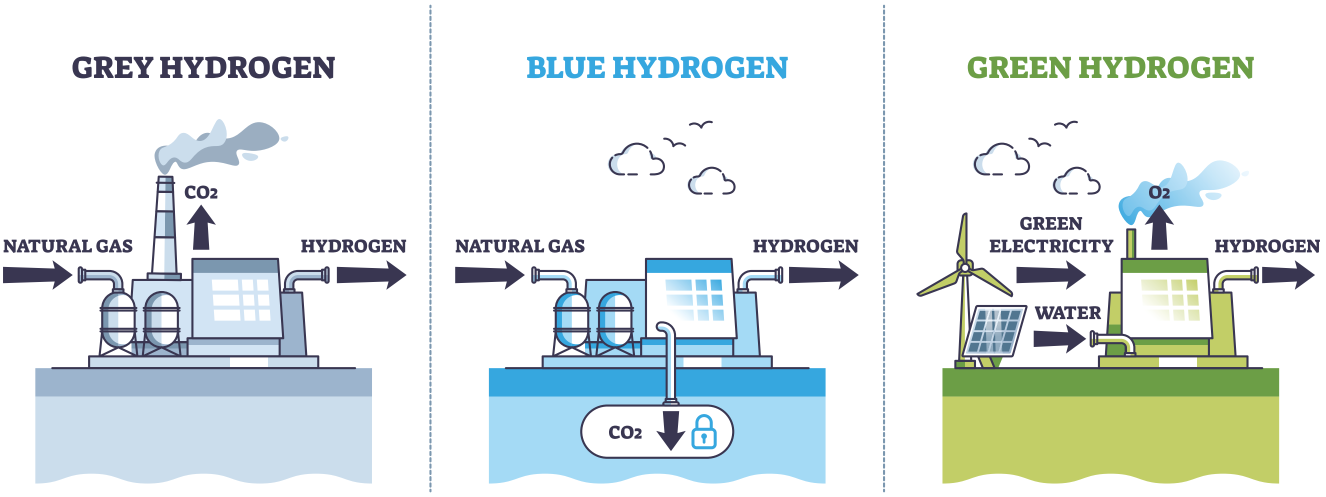
- **GREY Hydrogen** is produced by using fossil fuels, mainly the reforming of natural gas or the gasification of coal. This represents the bulk of hydrogen produced today. CO_2 originates from two processes: (i) the chemical process of splitting hydrogen from carbon-based molecules (for example: natural gas with steam: $CH_4 + H_2O \rightarrow CO + 3\ H_2$ followed by $CO + H_2O \rightarrow CO_2 + H_2$) and (ii) from the burning of fuels for heating. It thus emits serious amounts of carbon.
- **BLUE Hydrogen**, similar to grey hydrogen but greenhouse gases are captured and stored, also referred to as low-carbon hydrogen. Effectiveness of greenhouse gas capture is variable and their true potential is debated. Recent research suggests that both methane leakage and the power demands of carbon capture and storage makes blue hydrogen even worse than coal.
- **GREEN Hydrogen** is produced through the electrolysis of water, with electricity provided from renewable sources (mainly wind, solar PV). It is the reverse of the combustion process: $2\ H_2O + \text{energy} = 2\ H_2 + O_2$. If the electricity comes from carbon based power facilities, of course the hydrogen is NOT green.

Several other technologies exist to produce hydrogen in grey, blue or green manner[1] :

- *Pyrolysis* is a technology at high temperatures (> 500 ^{0}C) to convert methane, in the absence of oxygen, into hydrogen and carbon powder[2], without carbon emissions. The heating determines carbon emissions: a solar furnace is emission free - carbon fuels obviously not.
- Hydrogen may also be produced through the reforming of biogas or biochemical conversion of biomass. Biomass is renewable; CO_2 emissions resulting from the breakdown of biomass will be recycled. Yet, also this process needs high energy input; the energy source determines the grey, blue or green character.



Benefits of green hydrogen

This note focuses on green hydrogen and does not further address blue or grey hydrogen. The main benefit of green hydrogen is obviously its role in **achieving the climate change mitigation targets** by replacing fossil fuels and therefore lowering greenhouse gas emissions.

It offers a solution to decarbonise **sectors with high energy consumption** where carbon emission reduction is difficult. These include energy intensive industrial processes (chemicals, refining, steel, etc.) and heavy duty transport (freight trucks, bus fleets, shipping, aviation). Fuel cell electric vehicles (FCEVs) provide a low-carbon mobility option comparable to conventional vehicles.

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[1] Other colours sometimes referred to: Black (coal-based) and brown (lignite-based) hydrogen; pink hydrogen based on electrolysis with the use of nuclear energy; turquoise hydrogen based on methane pyrolysis; yellow hydrogen produced with solar energy.

[2] Carbon has many industrial uses, for example in the steel industry, as filtration material, in paints and batteries, etc.

Green hydrogen allows for **storage and transportation of energy**. The uneven worldwide distribution of renewable energy requires international transportation of hydrogen. Hydrogen (gas) pipelines and trucks (liquid) are the best solutions for transport over smaller distances. For larger distances, other techniques are available: to transport and store hydrogen:

- Ammonia as an energy carrier is produced through a reaction of hydrogen with nitrogen. This liquid is easy to store and transport at relatively mild temperature (- 33 ^{0}C). At destination, it is broken down ("cracked") into its components, releasing hydrogen and nitrogen. Storage and transport of ammonia is a disputed option because of its high toxicity and energy loss.
- A Liquid Organic Hydrogen Carrier (LOHC) is a liquid capable of absorbing and releasing hydrogen through a chemical reaction. The LOHC can simply be stored or transported in atmospheric conditions. (Dibenzyl toluene can absorb 56 kg of hydrogen in 1 m3 of LOHC). The process is inexpensive and safe. It is a diesel-like substance, which can be transported with regular trucks. This method requires much heat (=energy). The production of LOHC causes extra CO_2 emissions.
- Liquid hydrogen can be transported and stored at a temperature of -252.9 °C. A significant advantage of liquid hydrogen over ammonia or a LOHC is that the hydrogen retains its optimal quality. Extreme cooling takes a lot of energy, and superior quality insulation is required to maintain the extremely low temperature. In addition, a small amount of boil-off gas (evaporation) cannot be prevented.
- Hydrogen has only one quarter of the energy per unit volume of natural gas, whether liquefied or as a gas, meaning it takes up significantly more space.

Environmental concerns related to green hydrogen facilities

- **Impact on water sources:** hydrogen production by electrolysis of water consumes between 10 to 20 litres of water for each kg of H_2 produced. There are few studies on the water footprint of green hydrogen production. The magnitude of impact depends on the amount and quality of locally available freshwater. Areas with high potential for PV electricity and green hydrogen production (dry climate) may already suffer from limited availability of surface and groundwater. Impact on water resources is a major environmental concern in such regions. The water needs of **ecosystems** (maintaining biodiversity and ecosystem services) and **local populations** (agriculture, industry, domestic uses) have to be taken into account. Very *recent research* reports on emerging technologies to produce hydrogen directly from seawater.
- Hydrogen production with renewable energy can be **a competitor to other local or regional energy users**. Renewable electricity generation needs to feed first and foremost green electrification of domestic energy systems[3]. Hydrogen should be made from excess renewable electricity, as a way to stabilise the grid and/or store excess electricity production. Furthermore, to avoid too many losses (leakage and energy losses) hydrogen should preferably be used close to the production location. Exportation to faraway places is therefore seemingly incompatible with local and regional objectives for green and climate neutral development.
- **Contribution to global warming** is often underestimated. Because hydrogen is such a small molecule it easily leaks into the atmosphere throughout the value chain. Oxidation of hydrogen in the atmosphere leads to increasing concentrations of greenhouse gases. Recent research found that hydrogen leakage impacts are greater than previously thought. The farther it travels between production and end-use the greater the potential for leakages.
- **Climate change** may further diminish the amount of rainfall in dry areas. Climate vulnerability assessment is a must in dry areas.
- In coastal areas **desalination** is seen as a possibility to provide the required amounts of water. The common desalination process of reversed osmosis is a serious **energy consumer**; it results in freshwater and a potentially polluting high-concentration solution of salt, the **brine** (*see Green Collection note on Desalination*).
- **Common environmental impacts** that may occur are land occupation, visual impacts, and air/ water/ soil pollution as a result of production processes. In addition, since hydrogen is an odourless, colourless and flammable gas, **safety concerns** need to be taken into account. If the leak is not detected and gas collects in a confined area, it can ultimately ignite and causes **explosions**.
- Considering the size of RE deployment serious indirect impacts can be expected related to the hydrogen value chain, including the **extraction of the critical raw materials** needed for electrolyser technologies and fuel cells (cobalt, platinum, lithium, etc.), as well as for materials for renewable power generation technologies. Moreover, competition

[3] Battery powered electric cars are extremely efficient and simple compared to fuel cells and other equipment designed to use hydrogen. The latter have moving parts requiring maintenance; hydrogen can embrittle metal; it escapes through the tiniest leaks.

for a number of metals may occur with EV battery production. An assessment of the effectiveness of batteries compared to the use of hydrogen would be needed, including the value chain of waste and the recycling of valuable minerals.

- **Construction and operation of renewable energy facilities** can have social and environmental consequences, particularly on **biodiversity** (see *energy sector note on working with nature*).

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How to look at green hydrogen proposals

Invest in **knowledge development:**

- To determine the magnitude of hydrogen emissions/leakages and its **warming effect in the atmosphere**, in order to better define the effectiveness of hydrogen as a decarbonization strategy.
- To better estimate **freshwater needs** and define social and environmental boundaries for water extraction, including the energy and environmental consequences of a combination with desalination.
- Develop capacity for **assessments**. The green hydrogen value chain is associated with relatively new technologies for which little experience exists in environmental impact assessment. This includes assessment of full life-cycle greenhouse gas emissions and sustainability in terms of water supply and supply of critical raw materials. Serious efforts are needed in developing high quality environmental impact assessments at project level, strategic environmental assessments for renewable energy policies and plans, climate vulnerability and risk assessments and life-cycle assessment.

Ask for the following documents when dealing with a request for funding of green hydrogen:

- **National energy policy** explaining the role of hydrogen in the national energy mix; preferably supported by strategic environmental assessment (required by European directives) to assess the consequences of alternative energy scenarios, including their CC mitigation potential. Alternatives should be considered for different ways of powering the process (wind-powered, solar-powered, grid-based, etc.).
- **Nationally Determined Contributions** (NDC) to climate change mitigation, how these are reflected in the energy policy and how the proposed hydrogen project fits in.
- **River basin and water management plans** and the water needs for green hydrogen in this plan; preferably supported by a strategic environmental assessment, looking at cumulative impacts of all planned and existing interventions in the basin (including alternatives), taking into account climate vulnerabilities and expected consequences of climate change on water availability. Look into opportunities for nature-based solutions to enhance water storage and supply (for example wetlands for groundwater infiltration).
- **National Biodiversity Strategy and Action Plan (***NBSAP***)** to verify the plans with the national biodiversity policy, the location of protected areas, occurrence of protected and/or threatened species. Relevant not only for production facility but also for wind and solar power facilities providing the energy. Opportunities for biodiversity enhancement should be identified.

Make use of the available (sometimes legally required) tools to integrate environmental and climate concerns into green hydrogen development planning:

- **Strategic environmental assessment** (SEA) to inform government planning and decision-making on environmental and social opportunities and constraints for green hydrogen development within the broader context of a national energy policy, a regional development plan, or integrated water resources management plan.
- **Environmental and Social Impact Assessment** (ESIA) for green hydrogen projects, to enhance positive and avoid negative consequences and compensate those suffering from it. It is advised to ask for the ToR of such assessment to verify if all relevant issues will be studied. ESIA is designed to inform decision making, so make sure it does provide the needed information[4].
- **Climate Risk Assessment** shall be conducted especially from the future availability of water perspective. Can be a part of the ESIA process.

[4] For quality control a model of ToR can be found at *https://capacity4dev.europa.eu/groups/public-environment-climate/info/models-terms-reference-ceprep-sea-eia-cra*

- **Life Cycle Assessment:** The European Hydrogen Strategy states the need for a full life-cycle analysis (LCA) for green hydrogen production, including greenhouse gas emissions, water consumption, raw material demands, and emissions to water, soil and air. LCA should cover upstream steps up to hydrogen production site, including the power supply, and the subsequent steps (transport, including conversion, reconversion and shipping fuels, losses in pipeline systems). LCA can also be part of ESIA.

Further information and support

A hydrogen strategy for a climate-neutral Europe COM(2020) 301 final

Information note on hydrogen and its relevance for NEAR regions Ref. Ares(2023) 183367 – 11/01/2023

IPHE *Methodology for Determining the Greenhouse Gas Emissions Associated With the Production of Hydrogen*

Critical Review of the IPHE Working Paper “Methodology for Determining the Greenhouse Gas Emissions Associated With the Production of Hydrogen”

Ocko, I.B. and Hamburg, S.P.: *Climate consequences of hydrogen emissions*, Research article, Atmos. Chem. Phys., 22, 9349–9368, 2022

Osman, A.I. et al: *Hydrogen production, storage, utilisation and environmental impacts: a review* Environmental Chemistry Letters (2022) 20:153–188

Ullman, A.N and Kittner, N.: *Environmental impacts associated with hydrogen production in La Guajira, Colombia*, Environ. Res. Commun. 4 055003, 2022

Michael Liebreich (2021). *The clean hydrogen ladder.*

Contact

INTPA and NEAR Environment & Climate Change Mainstreaming Facility:
INTPA-GREENING-FACILITY@ec.europa.eu | *NEAR-GREENING-FACILITY@ec.europa.eu*