HYDROGEN STRATEGY:
RESEARCH CHALLENGES AND OPPORTUNITIES AHEAD

Setting the scene

In recent years, hydrogen has gained growing attention, both at the EU and International level. Pure hydrogen can be used in fuel cells where an oxidation reduction reaction occurs, producing electricity without any CO2 emission. It can also be used as a fuel in industrial processes, in the transport sector with electrical vehicles (EVs), as well as an energy carrier and storage in the power sector, supporting global electrification where it is not possible to install it directly. Hydrogen has, therefore, the potential to positively impact on some of the most greenhouse gas (GHG) emitting sectors, making its deployment of crucial importance in order to achieve the EU's goal of a carbon-neutral society by 2050.

Nevertheless, hydrogen represents less than 2% of the EU energy mix, and it is still mostly produced from fossil fuels, using a so-called steam reforming process which, by releasing between 70 and 100 million tonnes of CO2 every year, strongly contributes to GHG emissions. Pure hydrogen produced by electrolysis represents only 4% of the total hydrogen production.

In recent months, the urgency of the environmental challenge, coupled with the latest technology developments, led hydrogen to gain an increasing momentum in the energy field. The EU objective, as set out in its strategic vision for a climate-neutral society published in November 2018, is to grow the share of hydrogen in the energy mix to at least 13-14% by 2050. In order to set out the strategic roadmap to make this possible, on the 8th of July 2020, the EU Commission has released its Hydrogen Strategy, specifically targeting hydrogen technologies for a clean energy transition. The latter is complementary to and supportive of the Energy System Integration Strategy, as well as of the EU Industrial Strategy. The objective of the Hydrogen Strategy is to make clean hydrogen, produced using renewable electricity, cost-competitive against fossil-based hydrogen. Within this framework, the priority should be to develop renewable hydrogen produced using primarily wind and solar energy, and to be able to deploy it at an industrial scale in approximately a decade.

The project is colossal, and a full value chain approach is needed for its implementation. Multiple aspects and issues need to be considered in parallel, from the different stages of the production of clean hydrogen, to the development of proper infrastructures to the end-consumer, including the creation of market demand.

Hydrogen strategy: The R&I challenges

In its Communication on a Hydrogen Strategy for Europe, the EU Commission presented a roadmap for the development of renewable hydrogen, leading to its widespread industrial deployment by the year 2050. The roadmap is divided in three important phases, these are:

- 2020-2024: Hydrogen production and carbon-intensive sectors decarbonization.

- Installation of 6 GW of renewable hydrogen electrolysers and 1 million tonnes production of renewable hydrogen.
- In this phase, the so-called **European Green Hydrogen Alliance** will be set up with the objective of facilitating and implementing the actions of the Strategy by supporting investments to scale-up hydrogen production and demand. The Alliance will serve as a first step in building an EU global leadership in the hydrogen sector.

- 2025-2030: Full integration of hydrogen into the energy system.
  - Installation of 40 GW of renewable hydrogen electrolysers and 10 million tonnes production of renewable hydrogen.
- 2030-2050: Renewable hydrogen technologies maturity and large-scale deployment in hard-to-decarbonize sectors.
  - One quarter of renewable electricity to be used for renewable hydrogen production.

The table below provides an overview of the areas of development identified in the EU Commission's strategic document. They are reported as R&I challenges, as our analysis focuses solely on the areas for future action holding the highest potential for further improvements through research and innovation actions. The measures involving actions outside of the scope of R&D activities (e.g., related to market regulation or deployment of already existing technologies) are not included in this analysis.

Pillar of the strategy	Identified R&I challenges
Pure hydrogen generation	1) Identify and improve other forms of hydrogen, such as **low-carbon and hydrogen-derived synthetic fuels** based on carbon neutral CO_2 using **carbon capture and storage** to create negative emissions (e.g., **sustainable biogas**) 2) Upscale hydrogen generation to **larger size**, **more efficient and cost-effective electrolysers in the range of gigawatts** connected to clean electricity production (for instance in industrial areas) a. **Mature the electrolyser-linked technologies** to decrease the cost of hydrogen production. b. Enlarge electrolysers **up to 100 MW.** c. Solutions at **lower technology readiness level** also need to be incentivised and developed. 3) Study the **raw materials** required by electrolysers and fuel cells production. a. Analyse with a **full life-cycle approach** to minimise the negative climate and environmental impacts of the production chain. b. Ensure **security** of the raw materials supply.
Infrastructure development	1) Install **electrolysers infrastructures** next to **demand sites** (e.g., larger refineries, steel plants and chemical complexes coupled with local renewable sources). a. Develop **Hydrogen Valleys concept** (e.g., local hydrogen clusters as remote areas/regional ecosystems with a hydrogen production based on decentralised renewable energy generation, responding not only to local demand as industrial and transport applications, but also with heat provision for residential and commercial buildings).

	2) Develop a **network of hydrogen refuelling stations** with **local electrolysers** for the transport sector. a. Analyse the fleet demand and the requirement for light- and heavy-duty vehicles. 3) Decarbonise **the already existing hydrogen production plant by retrofitting** them using carbon capture and storage technologies. 4) Develop **larger scale storage facilities.** 5) Elaborate **freight technologies** and a **backbone transmission infrastructure** to transport pure hydrogen (under liquid or gaseous form). a. Set up a **network of pipelines coupled with non-network-based options**. b. Repurpose the **existing natural gas infrastructures** for long distances. c. Develop and improve efficient **hydrogen transport technologies** as pressurized or cryogenic hydrogen transport, hauling of hydrogen bound in heavier molecules (e.g., ammonia or liquid organic hydrogen careers).
Large scale end-use applications	1) Develop **large-scale end-use applications in the industry and in the transport** sector. a. Industry sector: **reduce or replace fossil fuels** in hard-to-decarbonise sectors (e.g., steelmaking) and the **use of carbon-intensive hydrogen** in refineries. b. Transport sector: decarbonise the transport sector by **improving already existing technologies and searching for new solutions** (e.g., local city buses, commercial fleets, long-haul road freight, hydrogen fuel cell trains as well as in **aviation and maritime sectors**). c. Building sector: develop the **provision for residential and commercial buildings**. d. Storage sector: **research and innovate storage facilities**.
Policy making	1) Write dedicated **demand side policies** to integrate renewable hydrogen into the energy system. a. Lower the cost of renewable hydrogen production and use at different levels (e.g., cost of renewable energy/electricity, electrolysers and production infrastructure, storage, and bunkering facilities) b. Study the impact of supply chain risks and cope with market uncertainty on raw materials through well-placed investments and various options for EU-level incentives. 2) Enable improved and harmonised (safety) standards and monitoring and assess social and labour market impacts. a. Settle a common low-carbon threshold/standard for the promotion of hydrogen production installations based on their full life cycle GHG performance and sustainability

EERA Analysis

Hydrogen is gaining an increasing momentum as an important low-carbon replacement for gas and fossil fuels in the energy system. In its Hydrogen Strategy, the EU Commission sets out an ambitious vision for the production and deployment of hydrogen, aiming at its large-scale use by the year 2050. However, despite its ambitious long-term objectives, the Strategy fails to address some of the crucial issues linked to renewable hydrogen production and use.

First of all, while the long-term aim is to deploy hydrogen at a large industrial scale by the year 2050, the Commission also acknowledges the role of low carbon hydrogen in the short and medium term. Taking into consideration the latter, the Commission does not properly address the low efficiency of hydrogen technologies, as well as the complexity of the retrofitting and carbon capture processes. Indeed, according to recent studies, no steam methane reforming coupled with carbon capture and storage can sequester 90% of the CO_2 emissions, the percentage which would enable the produced hydrogen to be considered as low carbon. Moreover, hydrogen transport also presents some difficulties in terms of efficiency.

Furthermore, while the investments provided for boosting of the hydrogen sector will prioritize hard-to-decarbonize sectors, the strategy also foresees consistent investments for the production of fossil-based hydrogen, which is already available at a large industrial scale. The risk is that of strengthening the production of the latter and, consequently, making clean green hydrogen uncompetitive in the EU market.

Finally, the Hydrogen Strategy does not consider the environmental impact of hydrogen integration that would follow the construction of new infrastructure and the removal of already existing fuel networks. Besides an in-depth study on raw materials, the full-cycle approach on renewable hydrogen needs to take into account the already existing infrastructure and alternatives to avoid production of waste, such as recycling and repurposing.

The EU Hydrogen Strategy relies on new technologies that, until now, did not prove their efficiency and feasibility. Nevertheless, the urgency of the climate emergency does not permit to count on future technologies that still have not reached maturity. What is needed today is stricter regulations, such as carbon quotas or carbon taxes, as well as a concrete follow up of carbon-intensive sectors.

Conclusion

The Hydrogen Strategy presented by the EU Commission sets out ambitious long-term goals for the production and deployment of hydrogen. Nevertheless, as above described, it fails to address important issues and key challenges that need to be overcome in order to fully exploit the potential of hydrogen in the decarbonization of the environment.

Alongside the R&I challenges listed in the above table, a non-exhaustive list of additional key issues that should be addressed are:

- Clear explanation of the strict conditions to be met at each level of the renewable life cycle and concrete follow-up.
- Full cycle approach and study on recycling and repurposing of already existing gas grids and infrastructure.
- Detailed strategy to deploy renewable electricity production within Member States.
- Optimal and efficient hydrogen infrastructure development in coordination with the power system – existing and planned.

While the EU Hydrogen Strategy represents an important step towards the large-scale production and use of hydrogen, much work still needs to be done, both at the EU and national level, in order to be able to efficiently develop a proper hydrogen infrastructure, demand and supply.