Hydrogen – Energy carrier of the future?

Holistic SWOT analysis – Executive Summary

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Context

Over the past few years, **deep decarbonisation objectives** have been considered or announced in an increasing number of countries:

- European Union: -55% at the 2030 horizon (w.r.t. 1990 levels) and net zero in 2050
- United States: -50 to 52% by 2030 (with regards to 2005 levels) and net zero by 2050
- China: net zero by 2060
- Germany: net zero by 2045
- France: net zero by 2050

Indeed, the status of hydrogen has rapidly evolved over the past few years and this gas is now at the core of many deep decarbonisation strategies. Whilst it is generally recognised that energy efficiency efforts and the development of renewables can do most of the heavy lifting, a number of end-uses cannot be decarbonised via a direct electrification route. Hydrogen is one of the options to decarbonise these hard-to-abate sectors. However, different stakeholders have different views on the scope of the role of hydrogen, based on:

- Economic assessment of the trade-off between direct and indirect electrification routes
- Origin of hydrogen (electrolysis, pyrolysis, SMR + CCS, etc.)
- Role of alternatives (biomethane, CCS, etc.)
- Role of the gas infrastructure

In Europe, the **European Green Deal**[1], announced in late 2019, sets challenging objectives for the decarbonisation of the economy of the EU, and foresees an important role for hydrogen, especially in hard-to-abate sectors, but not only.

Multiple **policy initiatives** are being taken in order to ensure the hydrogen value chains scale up and can play their role in the decarbonisation of the economy. The European "**Hydrogen Strategy**"[2] proposes targets for the development of renewable hydrogen:

- 6 GW_e electrolysers by 2024 (1 MtH2 of renewable H2)
- 40 GW_e electrolysers by 2030 (10 MtH2 of renewable H2)

Numerous European **countries** have announced their own objectives for the development of electrolysis (far beyond what is announced in their NECPs):

- 6.5 GW in France by 2030
- 10 GW in Germany, 3 to 4 GW in the Netherlands, 2 to 2.5 GW in Portugal, 4 GW in Spain

Several **regions** in France and in other countries are developing hydrogen visions.

[1] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en
[2] https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

On the other hand, the deployment of electrolysers is subject to **rules and regulations** to mitigate the adverse impacts of uncoordinated developments

- The revision of RED II and the potential extension of the RFNBO requirement (additionality) to all sectors (not only transport)[3]
- The **delegated act** related to the **additionality** principle is expected to set rules to have joint investments in electrolysers and renewable capacities.[4]
- The EU **taxonomy**, requiring that emissions from electrolysis shall not exceed 3 kgCO2/kgH2 (i.e. circa 60 gCO2 per kWh_e).
- The **revision of the TEN-E Regulation** and the upcoming Guidelines on Cost-Benefit Analysis of hydrogen and electrolyser projects (and the eligibility criteria for categories (3) and (4) related to sustainability for inclusion into PCI or PMI Union lists).

The development of hydrogen is foreseen to have potentially deep **impacts on many sectors**.
The **hydrogen ecosystem** includes a large number of components and end-uses, some being in competition with direct electrification, others with the use of gases from other origins (e.g. biomethane, natural gas + CCS):

- Industry (ammonia, steel and iron…).
- Residential and tertiary sector (fuel cell CHP).
- Power sector (power to gas / gas to power, storage).
- Hydrogen production (electrolysis competing with SMR, ATR, pyrolysis, etc.).
- Gas infrastructure (blending, repurposing and refurbishment of pipes and storages, new investments…).
- Mobility (H2-vehicules, fuels for maritime and aviation).

Today we see **pilot projects emerge in all components of the ecosystem**, tackling complex issues such as:

- Regulation (taxes, sustainability assessment of electrolysis…).
- Finance (capital available for pilot projects, what about the massive investments needed to decarbonise the entire economy?).
- Public acceptance, attractiveness of options.
- Economic aspects (learning rates, subsidies…).

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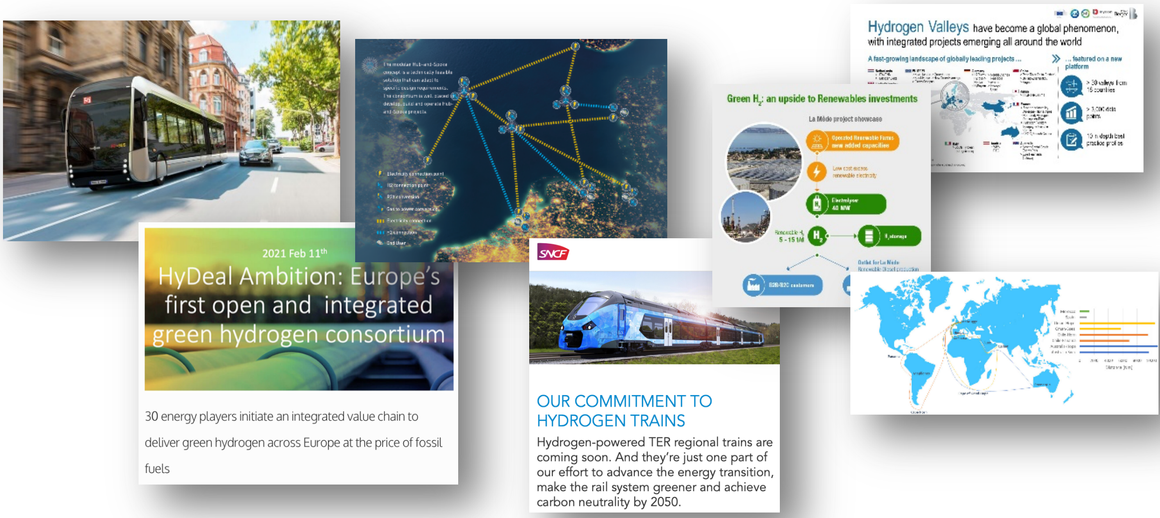
[3] https://ec.europa.eu/info/news/commission-presents-renewable-energy-directive-revision-2021-jul-14_en

[4] https://www.euractiv.com/section/energy/opinion/additionality-the-key-to-turn-the-hydrogen-buzz-into-a-renewable-boom/

Many projects are emerging but in a very fragmented way, and with very little common long-term vision.



Methodology

The methodology used relies on two work streams:

- A **literature review** of circa 25 recent publications that deal with one or several aspects mentioned in the introductory slides
- **Interviews of around 10+ key experts**. While they have participated in shaping some of the arguments presented today, the views expressed herein are those of the authors only.

The experts we interviewed gave insights and opinions on various aspects of the report. Those interviews helped inform the report but this shall not be considered as a shared vision amongst the different experts. On the contrary, we tried to highlight as much as possible the variety of visions, even if these visions are partially in contradiction. The listed experts should not be considered accountable for parts or the totality of the report.

Name	Company / Institution
Maxime Sagot	Afhypac
David Le Noc	ATEE
Pierre-Laurent Lucille	ENGIE
Guillaume Fournel	CRE
Carole Le Henaff	GIE/Storengy
Cédric Philibert	IFRI
Sylvain le Net	France Chimie
Paul Lucchese	IEA / CEA
Gniewomir Flis	Agora Energiewende
Stijn Carton	European Climate Foundation
Ines Bouacida	IDDRI
Jean-Pierre Goux	Independent expert (ex-Powernext CEO)
Florence Delprat-Jannaud	IFPEN
Daniel Marenne	ENGIE

A 3-perspective study

In order to structure our assessment, we have decided to look at the relevant aspects under **three different perspectives**, each of them having their own SWOT dimensions:

- **SYSTEM-LEVEL** (including economics, sustainability, externalities, value chain, etc.)
- **PROJECT DEVELOPERS** (from infrastructure to manufacturers of appliances via electrolysis)

- **CONSUMERS** (from industry to domestic sector via mobility)

Each theme of our literature review and expert's interview was examined sequentially under those 3 points of view. By doing so, we were able to identify some mismatches of interest and some potential measures to overcome this.

Key findings

In the context of deep decarbonisation of our economies, the consensus tends to make hydrogen emerge as a necessary brick of the energy strategy. Behind the current enthusiasm around hydrogen, the reality could be in fact much more complex and nuanced. If some people see H2 as "the oil of the zero-carbon economy", others predict much more restricted perspectives for this gas.

On a **systemic point of view**, hydrogen is an interesting solution that could help solve some of the most complex challenges of a carbon-free energy system.

Among the values for the system that could bring hydrogen, we identified the following three as the most important ones:

- H2 can be the key to decarbonise hard-to-abate emissions
- H2 can provide the missing technology for energy storage
- H2 can be a cost-effective way to transport large amounts of energy

On the other hand, we identified some hurdles that are clearly mitigating the prospects for hydrogen:

- The depth of the future H2 market is heavily debated with very different visions. For some experts, H2 is likely to remain a niche market compared to electrification
- The value chain efficiency of hydrogen is very low
- The transition costs are expected to be high
- H2 growth relies on technological bets
- H2 is a hazardous gas that is complicated to handle, especially besides industrial applications.

In addition, H2 development raises complex questions that need to be answered when considering its systemic value.

No consensus exists on the level of required infrastructure for H2. Hence what will the H2 infrastructure look like? Will the H2 system be made of local distributed systems around clusters or of a large European infrastructure?

In order to associate a positive systemic impact of H2 usage to reach net zero target, the true CO2 carbon impact of H2 production must be carefully examined. Yet, even electrolytic H2 consuming renewable electricity (the so called green H2) can in fact have an adverse impact on GHG emissions depending on the configuration. Indeed, the whole energy system must be taken into account and especially the potential lack of renewable electricity consumption for power usages resulting from the consumption for H2 production purposes.

Finally, the risks to have "game changer elements" emerging and changing the entire energy landscape must not be underestimated (long distance H2 shipping, deflation of the H2 bubble, large development of Small Modular Reactors, etc.)

The development of a « hydrogen economy » can represent very interesting opportunities for **project developers**. However, the risks remain high and the gain expectations unclear. Moreover, few of these opportunities are real "game changers" triggered by the new usage of hydrogen, as they do not really enable new goods and services to appear or reduce the cost of existing goods and services. Most of those opportunities seem relevant only in a context of deep decarbonisation.

For **consumers**, hydrogen usage has limited advantages compared to alternative solutions, besides the opportunity to decarbonise the final usage. On the contrary, the drawbacks of using hydrogen, and above all the cost premium can be important.

This lack of alignment of interest between the 3 studied perspectives suggest that the development of H2 is very unlikely to emerge by itself, even if its value for the system is clear. Some kind of support will be required to rape the hydrogen fruits in the future.

We refer the reader to the complete report for a detailed discussion of the SWOT analysis from the three perspectives and the detailed analysis of the sometimes conflicting signals that emerge between these visions.