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Under what conditions can hydrogen serve climate neutrality?

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Since summer 2020, hydrogen has been in the European Union’s spotlight: eight Member States and the European Commission have published a strategy for hydrogen deployment by 2030 and 2050 with the mobilization of major investment—including nearly €9 billion from France—partly within the framework of the post-Covid-19 European recovery plan. While the deployment of hydrogen can contribute to the decarbonization of key economic sectors, with the aim of achieving climate neutrality, particularly in industry and transport, its roll-out must adhere to strict criteria in terms of use, production and supply methods, and infrastructure. These criteria are currently under discussion at the European level in the context of “Fit for 55”, including as part of the review of renewable energy, and in the framework of the gas package, but also at the French level through the review process of the National Low-Carbon Strategy, which will be adopted by Parliament in summer 2023.

A key, but “niche”, decarbonization vector

Today, hydrogen is produced from natural gas (fossil methane) and used in industry, where it is used almost exclusively as a chemical reagent, mainly in refineries and in the chemical industry, especially for ammonia production. This is also the case in France, where hydrogen production accounts for 3% of national emissions. To what extent and under what conditions can hydrogen help to achieve climate neutrality in compliance with the Paris Agreement?

Hydrogen could have an important role as a chemical reagent or energy carrier in the decarbonization of so-called “hard-to-abate” sectors, namely industry and heavy or long-distance transport. The advantage of hydrogen over other vectors is that it is relatively easy to store for long periods, especially compared to electricity, and that it is “easily” transportable due to its fairly high energy density in terms of mass. Hydrogen can be used directly or combined with CO₂ to form synthetic fuels (ammonia, methane, kerosene), which offer the advantage of replacing their fossil fuel equivalents, avoiding the need for major adaptations to equipment. Nevertheless, for many purposes, hydrogen and its derivatives are relatively less energy efficient and more expensive energy carriers compared to alternatives (notably the direct use of electricity). It is therefore necessary to distinguish the applications of hydrogen that would be relevant to achieving climate neutrality.

- **Applications without alternatives to hydrogen or derivatives.** This refers to existing industrial uses of hydrogen that require decarbonization (refineries, chemical industry). While, from a climate-neutral perspective, many of these applications should be largely phased out, there would also be new industrial uses (particularly steel). Regarding long-distance transport (air and sea), hydrogen could play a role in the form of synthetic kerosene or ammonia for example.
- **Applications where alternatives exist, but where hydrogen could still play a role** because its technical and economic performance is similar to that of the alternatives: high temperature heat in industry, heavy duty transport and storage in the electrical system. The contribution of hydrogen to these sectors depends on long-term strategic choices, the evolution of industrial sectors and technological progress in hydrogen and its alternatives.

Conversely, many applications where hydrogen could theoretically be used are not relevant in a decarbonization context (or at best are only marginally applicable), as it would be much less efficient than alternatives, notably for short-distance transport, heating in buildings and for combining with methane.

Finally, hydrogen as a fuel for thermal power stations and as a storage solution for variable renewable electricity in times of surplus may provide valuable flexibility for the electricity system in the long term, especially where there is a high penetration of variable renewable electricity. The need to mobilize hydrogen for this purpose will depend on the evolution of electricity consumption and the development of other flexibility solutions in the system. The significant energy losses involved in converting electricity to hydrogen and back to electricity mean that this use should only be sparingly applied at moments where the supply-demand imbalance is greatest, such as winter consumption peaks.

Beneficial applications for hydrogen from a climate neutrality perspective according to IDDRI's classification (refining, ammonia and fertilizer, chemicals, steel, maritime transport and aviation) would represent between 19 TWh and 62 TWh in 2050 according to RTE's estimates in its two hydrogen pathways to 2050 for France (“reference” and “hydrogen+”¹), while the total electricity demand would be between 645 TWh and 754 TWh by this date². This highlights the hydrogen vector's modest role in a carbon-neutral energy system over the long term: vital for a small

number of “niche” sectors, but relatively limited in terms of volume.

In a carbon-neutral system, hydrogen is generally more expensive than fossil alternatives

In a carbon-neutral system, hydrogen production must be decarbonized, which is only possible through electrolysis from renewables or nuclear electricity. Natural gas reforming, with or without carbon capture and storage (CCS), can only be a temporary solution as CO₂ emissions generated cannot be fully captured and due to its reliance on fossil fuel, which raises key issues of the economic viability of investments.

The availability of sufficient renewable or nuclear electricity to meet industrial and transport needs for hydrogen is an important issue in an electrification context (e.g., heating in buildings), which calls for a limitation of hydrogen demand. In addition to the volumes of hydrogen produced by electrolysis, its cost is a major factor for the deployment of applications. Even in the long term it appears that most hydrogen production would be more expensive than alternative fossil fuel solutions, in the absence of specific regulations such as a carbon price. This underlines the importance of support policies to both direct hydrogen towards priority areas, and to ensure a competitive long-term supply. This support also aims to ensure that the countries of the European Union master electrolysis production technologies and uses that are currently underdeveloped in order to limit future dependence.

Imports: how to define “sustainable” hydrogen?

Although most of the announced spending on hydrogen in the EU is focused on domestic production, there is also talk of importing hydrogen or hydrogen products to take advantage of cheaper natural gas or renewable electricity sources elsewhere in the world, such as Morocco, Namibia and Chile.

Such exchanges could in theory represent a good economic opportunity because of the low cost of producing renewable electricity in some areas. Nevertheless, the practical conditions for implementation are complex and opportunities for trade must address unanswered questions: how should hydrogen infrastructure be financed in non-European countries? In what form should hydrogen be transported (gas, liquid, derived fuel)? How can producing countries reduce domestic emissions, guarantee the energy needs of their populations and produce “sustainable” hydrogen for export? This last question can be resolved as part of the necessary discussion on the environmental criteria for “sustainable” hydrogen in the domestic context.

Possible plans to import hydrogen and hydrogen derivatives into the EU require close cooperation between Member States to ensure a convergence of approaches to importation. Firstly, it is important to agree on the criteria for defining “sustainable” hydrogen in the domestic context and also in that of potential imports, and secondly to define the possible pathways in terms of hydrogen needs and potential trade between European countries. Finally, Member States could jointly build import partnerships with countries outside Europe by promoting an ambitious vision of hydrogen in environmental and social terms, compatible with Green Deal objectives.

¹ RTE (2021). Futurs Energétiques 2050. Le rôle de l'hydrogène et des couplages (Chapter 9).

² RTE (2021). Futurs Energétiques 2050. Principaux résultats.

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