The transition to low-carbon hydrogen

Opportunities and challenges for the electricity system by 2030-2035

JANUARY 2020

MAIN RESULTS

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EXECUTIVE SUMMARY

Low-carbon hydrogen: an asset for the energy transition

The development of low-carbon hydrogen is an important part of the energy transition.

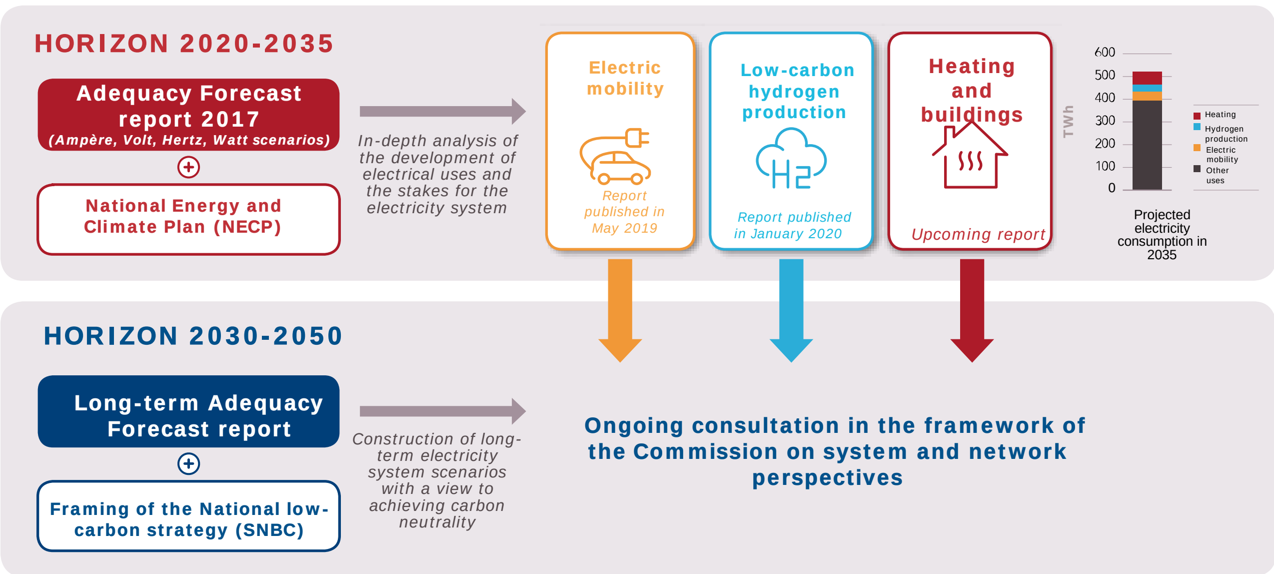
In the medium term, it offers a solution that can reduce emissions from the industrial sector by replacing hydrogen that is currently produced using fossil fuels, as provided for by law and as set out in the French National Energy and Climate Plan (NECP). It also creates opportunities to reduce emissions in the transport sector (heavy mobility, as a substitute for oil) and gas networks.

In the long term, developing the production and storage of low-carbon hydrogen can offer additional ways to make the electricity system more flexible, particularly interesting in the light of scenarios including a high share of renewable energies.

In any event, the first step is to develop significant volumes of low-carbon hydrogen production in France over the next ten years. This development will be largely based on electricity, which has the advantage of already being largely decarbonised (93%), via the electrolysis of water.

How this transition will take place needs to be specified. The large-scale development of electrolysis will be based on the growth in production of decarbonised electricity planned under the NECP, and will result in additional electricity consumption. Its consequences, and the opportunities it offers, will depend on how electrolysers work in practice. The technical conditions, the emission reduction performance, the cost of processing and the economic balance depend largely on this.

These are the issues to be addressed in the RTE report.



Through the examination of a large number of variables, this aims to answer the questions raised by a wide variety of stakeholders during the consultation (ability to accommodate new uses of electricity, effects on emissions, economic consequences).

As such, it is part of the work programme initiated in 2018 and developed over the past two years on new uses of electricity: electric mobility (summary of the main results published in May 2019), hydrogen production by electrolysis (the subject of this document) and heating in the building sector (in collaboration with ADEME).

It also contributes to implementation of the hydrogen deployment plan published by the government in June 2018, by responding to the energy minister's request regarding the services that electrolysers can provide to the electricity system.

Finally, it contributes to the work and consultation under way on the construction of the next long-term scenarios for the Adequacy Forecast report to 2050, and in particular the "100% renewables" scenarios.

Two distinct reasons for developing hydrogen are often confused in the debate

In projections on the evolution of the energy mix in the long term, hydrogen is often presented both as a source of flexibility and as a factor in reducing greenhouse gas emissions.

However, the theories behind these reasons are quite distinct, and must be distinguished in the analysis:

- On the one hand, it is a question of decarbonising existing uses, current industrial uses of hydrogen, for example, but potentially also for heavy mobility (as a complement to fully electric solutions) or, in the medium term, supplying the existing gas network as a substitute for fossil gas (within a certain limit).
- On the other hand, hydrogen could contribute, under certain conditions, to the balance of the electricity system by providing a storage and retrieval solution (the power-to-gas-to-power principle).

By 2030-2035, the challenge of developing low-carbon hydrogen will contribute to a decarbonisation process, and is thus part of the first reason. In this time frame, the use of hydrogen for storage is not needed to achieve a diversified electricity mix (reduction of the nuclear share to 50%) and to accommodate the volumes of renewable energy planned under the NECP.

In the longer term (to 2050), however, scenarios based exclusively or to a very large extent on renewable energies will necessarily have to rely on storage. **In such cases, the power-to-gas-to-power loop, using hydrogen, is an option to consider,** despite its low energy efficiency (currently between 25% and 35% depending on the technology).

1

Decarbonising gas uses (hydrogen, methane, etc.) or mobility

To meet national and international decarbonisation targets

→ Opportunities over the period 2020-2035

2

Contributing to the balance of the electricity system by providing a storage / retrieval solution

Seasonal storage via the power-to-gas-to-power loop

→ Of possible interest in the long term

In the medium term, a clear interest in decarbonising the hydrogen used in industry

At present, the hydrogen consumed in France corresponds almost exclusively to non-energy industrial uses, mainly in the oil refining and chemical sectors.

The hydrogen used in these processes is mainly derived from processes using fossil fuels (95% from gas, oil and coal), which emit CO_2. Part of this production is “unavoidable” and inherent to the industrial activities concerned. Another part (about 40%) is produced by dedicated steam methane reforming plants: this could be replaced by low-carbon hydrogen.

One of the priorities identified by the State for the development of hydrogen is to convert the conventional production of industrial hydrogen to a decarbonised production method. The law of 8 November 2019 on energy and the climate thus provides for the development of low-carbon and renewable hydrogen, with the prospect of reaching about 20 to 40% of total industrial hydrogen consumption by 2030.

Among the possible technologies for the production of low-carbon hydrogen, the priority is to develop electrolysis, in order to limit the use of carbon capture and storage technologies, which still present uncertainties regarding availability, reliability and acceptability.

The replacement of steam reforming by electrolysis, as provided for in the guidelines from the public authorities, will lead to a reduction in emissions in France of around 6 million tonnes of CO_2 per year by 2035, i.e. slightly more than 1% of national emissions.

Ultimately, the development potential of hydrogen could go far beyond these references. For example, a number of studies identify the potential for using hydrogen for other applications, such as in the steel industry, which would open up significant development prospects.

Hydrogen as an energy vector can also be a substitute for petroleum fuels (for heavy mobility) or fossil gas (via direct injection into the gas network or as a replacement for the gas used in some industrial processes). If these applications come to fruition, the potential for reducing greenhouse gas emissions will increase accordingly.

The electricity system planned under the NECP is capable of accommodating the development of electrolysis without any particular difficulty

From a technical point of view, the integration of a large number of electrolysers into the electricity sector will first of all result in significant electricity consumption, in the order of 30 TWh by 2035.

Accommodating such a volume does not present any particular technical difficulty in the framework of the energy road map set by the public authorities.

From an energy point of view, the NECP leads to decarbonised electricity production of approximately 615 TWh by 2035. This appears to be more than sufficient to cover the development of electrolysis envisaged by the public authorities.

Indeed, even assuming a strong growth in electrolysis over the next few years (making it possible to produce 630,000 tonnes of hydrogen a year, i.e. 60% of current hydrogen consumption), less than 5% of total decarbonised electricity production (nuclear and renewable) would be devoted to electrolysis by that time.

From the point of view of power demand and the security of supply, the accommodation of electrolysis is not a cause for concern either.

This is linked to the characteristics of the electricity system planned under the NECP, which should have significant margins by this time with the development of renewable energies, load management and interconnections. In addition, the electrolysers are flexible by nature and can be turned off during peak consumption periods.

Electrolysers should be "technically capable" of providing flexibility services to the electricity system, but the associated value remains of secondary importance in the medium-term hydrogen economy

The ability of electrolysers to vary their level of electricity consumption in a matter of seconds means that it is technically possible for them to provide services to the electricity system, for supply-demand balance and for grid operation. RTE will do its best to integrate these new devices into existing mechanisms.

Except in very special cases, the value associated with the provision of these services should, however, be limited in relation to the costs of the electrolysers.

In the detail, the provision of services to balance supply and demand (system frequency services, fast and complementary reserves, etc.) can be remunerative, but this is a small market in which competition with other flexibility solutions is fierce (active demand management, batteries). The participation of electrolysers in these services is also associated with real constraints in terms of availability and activation that can affect the volume of hydrogen produced.

With regard to the services that can be provided to the network, the analyses carried out as part of the network plan published in September 2019 show that the value associated with resolving congestion remains low compared with other solutions (network development, localised capping), including in areas of high development of renewable energies. A case of particular interest has been identified at this stage: the location of an electrolyser on the Normandy coast to help resolve network congestion on the Normandy-Manche-Paris axis in the event of strong development of electricity production in this area (offshore wind and nuclear).

The RTE report makes it possible to test different low-carbon hydrogen production methods, with very different technical and economic characteristics

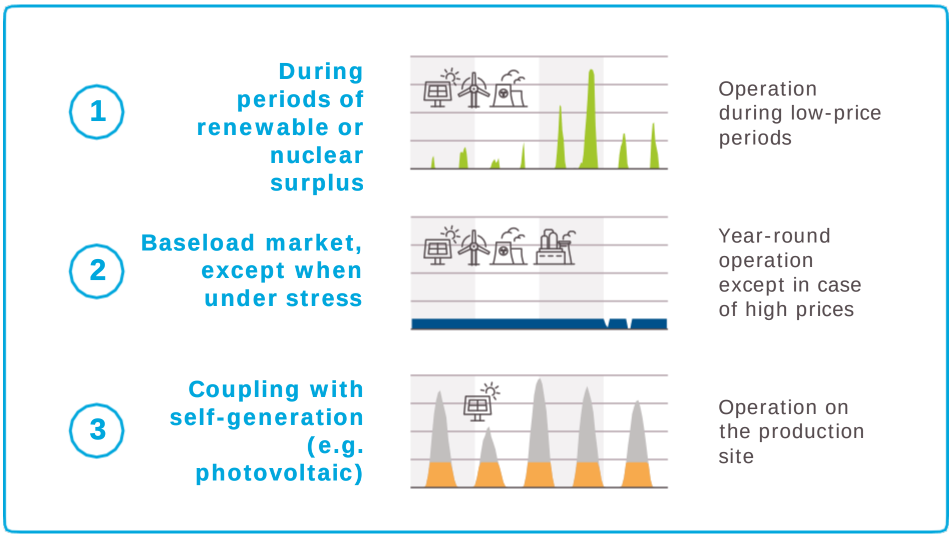
An analysis of the models currently being considered for the production of decarbonised hydrogen in France suggests several possible operating modes for electrolysers. The study explores three operating modes, which are deliberately very distinct:

1) supply on the electricity market during periods of surplus renewable or nuclear production;
2) supply on the "baseload" electricity market, excluding situations where it is under stress;
3) coupling with renewable production (e.g. photovoltaic) in the framework of "local" models.

Each of these models leads to very different electrolyser load factors and technical and economic challenges.

As an example, the study shows that even by 2030-2035, periods of excess decarbonised electricity production, characterised by low or even zero electricity prices, would be very unevenly distributed throughout the year and likely to be highly variable. A model in which low-carbon hydrogen is produced only during these periods would lead to irregular hydrogen production, raising important issues for the organisation of the downstream part of the chain (industrial integration and/or the need to develop dedicated hydrogen storage capacities to ensure continuity in the hydrogen supply).

These model situations are intended to be illustrative, and it is likely that different models will emerge in practice, as shown by the great diversity of projects currently being set up, particularly in the context of initiatives supported by certain regional and metropolitan authorities. To achieve economies of scale and meet French energy goals, significant load factors nevertheless seem necessary for at least some of the electrolysis facilities (between 3000 and 6000 hours a year).



Gains on emissions are clear from a national accounting perspective

The electricity produced in France is already very largely decarbonised (93%) and the announced closure of the last coal-fired power stations will lead to a further improvement in the carbon footprint over the next few years.

This situation is favourable to the development of new uses, such as the switch to electrolysis for conventional hydrogen production. Regardless of how the electrolysers are operated, the reductions in emissions from steam reforming are real (reduction in emissions of nearly 6 million tonnes of CO_2 per year in France), while the French electricity sector's impact on emissions remains low.

However, a rigorous analysis of the effect on emissions must necessarily take into account the interconnection of the French system with its neighbours, as well as the change in the mix that accompanies the development of new uses of electricity:

- with an unchanged mix, the analysis at the European level is more nuanced. All other things being equal, the increase in electricity consumption in France (to supply the electrolysers) leads to a reduction in exports of decarbonised electricity to other countries. Yet exporting decarbonised electricity to avoid production from coal or gas-fired power plants - the latter will still have a strong presence in the European mix in 2035 - saves more CO_2 than replacing gas with electricity to produce hydrogen;
- this effect is offset by the increase in decarbonised production planned under the NECP. By integrating this adaptation, the decarbonised capacity is increased as and when new uses of electricity such as electrolysis are developed.

Taking all these effects into account, the development of electrolysis associated with the adaptation of the decarbonised electricity production fleet in France leads to the avoidance of annual emissions of at least 5 million tonnes of CO_2 by 2035 in the scenario of the draft NECP.

These prospects can be increased by integrating possible gains in the transport sector (heavy mobility) or in the scope of gas consumption (injection into networks).

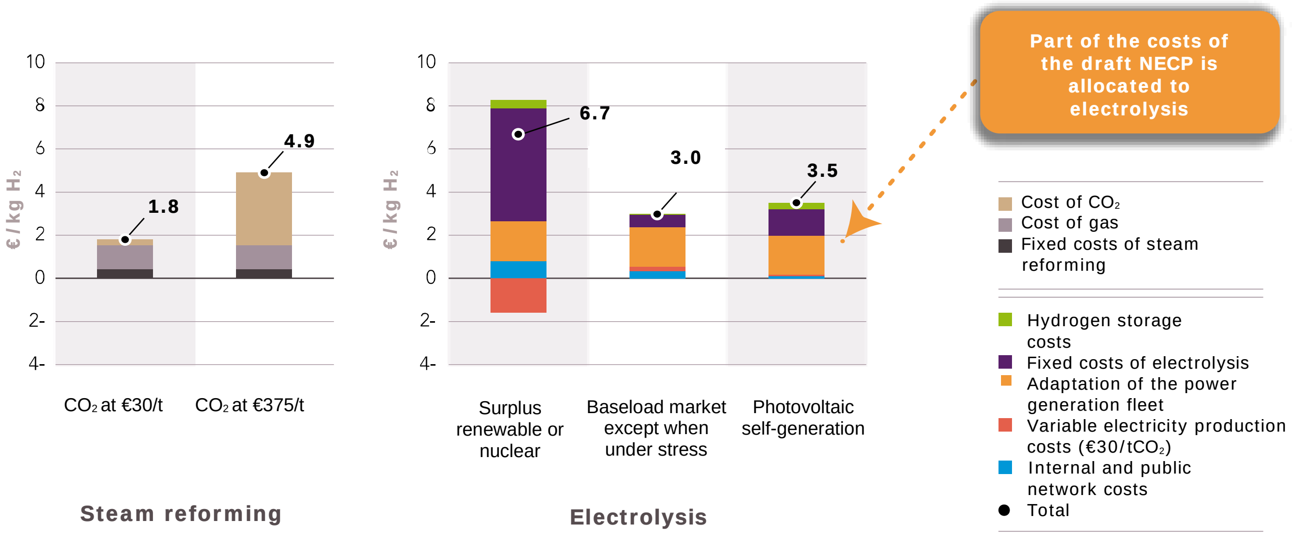
For the community, the production of low-carbon hydrogen is justified - from an economic point of view - in most of the cases studied by integrating a high value for carbon

Reasoning from the point of view of the community, the comparison of the full cost of electrolysis with that of steam reforming is highly dependent on the value put on the CO_2 externality.

Assuming a low value put on CO_2 (€30/t), the total cost of electrolysis appears to be much higher than that of steam reforming. This explains why the hydrogen used today is of fossil origin.

On the other hand, if a high value is put on the environmental externality - by taking the shadow price of carbon by 2035 (€375/t), for example - electrolysis appears to be generally less expensive. This shows the socio-economic relevance of substituting steam reforming with electrolysis over the next fifteen years.

Comparison of the collective costs of steam reforming and electrolysis



For stakeholders, the economic interest depends on public support and taxation regimes, and includes many other parameters than the cost of the electrolysers

In practice, the effective development of the sector will be determined by the comparative competitiveness of the different methods of hydrogen production (carbon and carbon-free) from the point of view of the economic actors, integrating all the economic signals they are confronted with.

With an unchanged regulatory and tariff framework, the price of decarbonised hydrogen produced by electrolysis appears, with all three methods, to be higher than that of steam reforming, even taking into account significant reductions in the cost of electrolysers. The development of the sector will therefore depend on changes in taxation and public support.

The three operating methods are, nevertheless, sensitive to different factors:

- For method 1 (supply on the electricity market during periods of surplus renewable or nuclear production), the price of electricity on the wholesale market has little effect on the economic equation because the operation is, by design, based on periods of low price. Nevertheless, this production method implies reduced operating times, leading to an increase in the sizing of the electrolysers for the same hydrogen production, and possibly to the development of a downstream hydrogen distribution chain including dedicated storage facilities to compensate for the variability of electrolyser operation.

- For method 2 (supply on the baseload electricity market), the cost of the electrolysers does not appear to be a key factor, which may put a different perspective on the current debate on the development of investment costs for electrolysis facilities. The issue identified by the study is more about access to low-price electricity. Paradoxically, the increase in the price of carbon on the European ETS market does not favour low-carbon hydrogen (compared with hydrogen from fossil fuels) with this method: the price of European electricity does not reflect the moderate cost and decarbonised nature of the French mix and remains highly dependent on the price of CO_2 on the ETS market. Thus, an increase in this price is ultimately to the detriment of production of low-carbon hydrogen by electrolysis.

- Finally, for method 3 (coupling with self-generation), the decisive factor in the economic model is the full cost of the renewable production facilities coupled to the electrolysers.

In the long term, the role of hydrogen as an energy vector and storage solution will vary according to the public choices made for the French electricity mix

Beyond 2035, the role of hydrogen as an energy vector, and possibly as a seasonal storage solution in electricity mixes with a significant share of renewable energy, depends on the choices made in development of the electricity system, and should therefore be the subject of in-depth studies.

RTE has undertaken studies of this type as part of the construction of the next long-term scenarios for the Adequacy Forecast Report, which will cover the period 2035-2050. This work was launched at the beginning of 2019 under the aegis of the Commission on system and network perspectives, and is currently the subject of extensive consultation structured around various thematic working groups. The work will continue throughout 2020, and will include a specific contribution on the “100% renewables” scenarios in cooperation with the International Energy Agency.

The priorities currently identified from the consultation concern the study of the development of a large number of possible uses for hydrogen, such as different ways of greening gas (direct injection into the gas network, transformation into synthetic methane), different industrial uses (the steel industry in particular), seasonal storage solutions, or the positioning of these analyses in relation to green gas import scenarios.

These analyses will lead to a clarification of the role of hydrogen in the scenarios for decarbonisation of the energy system, with a view to achieving the goal of carbon neutrality by 2050. They will make it possible to anticipate the growth of the hydrogen sector and its interactions with the electricity system, and to provide guidance on the most valuable uses and services to ensure that hydrogen is not lacking in the energy transition.