National Vision of Hydrogen Energy Chains in France issued from the work of the Group HyFrance

The French stakeholders (Group HyFrance) have thought about an intuitive vision of hydrogen energy in the period 2010-2050. This collective vision, which takes into account the specificities of the French energy system, is consistent with the national energy policy orientations: guarantee of long term supply, energy supply at competitive costs, sustainable energy development.

1. Development of the French energy system

Today, 90% of the electricity produced in France is CO_2-free (80% for nuclear energy, 10% for renewable energy) and the energy conversion sector has thus a weak contribution to CO_2 emissions. Moreover, the road transport sector is the only major one depending exclusively on oil, without a large substitution movement of fossil fuels by alternative fuels, even if the share of bio-fuels increases significantly. This sector is also the only one that increases its CO_2 emissions (1 to 2 % per year, in heavy trend). Conversely, in the stationary sector (residential/tertiary, industry), the trend is to increase the energy efficiency and savings and to substitute fossil fuels by energy forms with CO_2-free (renewable energy) or -reduced (electricity) emissions.

As a result, the power sector in France has no major impact on climate change, whereas the road transport sector has the highest priority to substitute the fossil fuels by clean fuels. In the future, according to the baseline scenario in HyWays (Energy trends to 2030), the share of renewable energy in the French electricity mix would increase significantly to the detriment of nuclear energy, but while keeping the general trend of CO_2-free emissions.

In this perspective, France should take advantage of the electricity mix and renewable energy resources (wind and biomass as a priority) to produce hydrogen by water electrolysis or biomass gasification. In addition, the potential of CO_2 storage in sedimentary basins should be mobilized to store CO_2 produced by steam methane reforming (SMR) which remains today the most competitive process for hydrogen production at large scale.

2. French vision of hydrogen chains

The French vision of hydrogen chains has been elaborated using a geographical distribution of the national territory in six large areas (groups of regions), depending on the population density: Centre-North (C-N), South-East (S-E), North-West (N-W), East (E), South-West (S-W) and Centre (C).

The specificities of the French energy system described above will lead to favour three basis sustainable options to produce hydrogen:

- Centralized SMR with CO_2 Capture and Storage (CCS);
- Conventional water electrolysis, centralized or decentralized, using the French electricity mix;
- Dry biomass gasification, using cost-effective regional resources.

This strategy will be completed by an appropriate use of the renewable electricity generated, above all wind electricity, to produce hydrogen by water electrolysis in decentralized installations. In addition, the future centralized production of CO_2-free hydrogen will require new electrolysis systems, more efficient and economical, e.g. using high temperature heat issued from an innovative nuclear reactor.

2.1 Near term vision (up to 2020)

In the near term phase, hydrogen will be served to develop the early energy markets, including transport (captive fleets, specialist vehicles), stationary markets (UPS, back-up power…), portable micro-fuel cells and by-product hydrogen. The French manufacturers Axane (subsidiary of Air Liquide) and Helion (subsidiary of Areva Group) could play a major role in this perspective.

The supply of hydrogen would require small quantities produced by SMR or water electrolysis, either on-site or in centralized installations, using the existing hydrogen infrastructures (e.g. Air Liquide capacities for hydrogen production and distribution). In case of centralized production, hydrogen would be delivered by truck (cryogenic, tube trailer…) or pipelines. To refuel vehicles in refuelling stations, another option would be to replace empty cylinders of hydrogen with full cylinders of hydrogen under high pressure.

To transport hydrogen from a centralized installation, an alternative option would be to mix hydrogen with natural gas in existing natural gas pipelines and extract hydrogen from the mixture at the point of use, provided a central separator is used and an appropriate credit is assigned to the gas-off. This alternative option would be tested through large demonstration projects to check its technical feasibility and economic competitiveness with the reference one (pure hydrogen pipelines).

The Early User Centres (EUC) would be localized in the most favourable border areas (S-E, C-N, E), i.e. those already including demonstration projects, with the local availability of experts and political commitment of regions. If applicable, the regional competitiveness clusters, which focus on the key factors of industrial competitiveness such as R&D-led innovation, would be a suitable framework for the development of hydrogen technologies.

2.2 Medium term vision (2020-2030)

In the medium term or transition phase, the growth of hydrogen demand would enlarge the range of options for decentralized and centralized hydrogen production, taking into account the French specificities. The production of hydrogen using renewable energy would emerge in the most favourable regions, up to 7 TWh by wind electrolysis (location in S-E, N-W, C-N) and 13.3 by biomass gasification (location in E, S-E, S-W) in 2030. These values result from an evaluation of French renewable energy resources likely to meet hydrogen demand.

Large quantities of by-product hydrogen (up to 0.4 GNm^3/year) would be served to regional markets, according to the economic competitiveness of the operation (good potentials in S-E: Fos-sur-mer, Lavéra…), but this contribution would be insignificant after the transition phase.

The capture and storage of CO_2 issuing from centralized SMR installations would be envisaged in this phase at industrial scale, but this option would be privileged afterwards, assuming a dissuasive CO_2 taxation. The transport of hydrogen through the natural gas pipelines (see § 2.1 above) would be a significant option at the end of this phase (10%), profiting by improvements on the central separator, but its economic interest would disappear afterwards.

SMR would be suitable in areas with large population density (C-N, S-E), when hydrogen demand is high and CO_2 geological storage feasible at large industrial scale. In areas with a lower population density (N-W, E, S-W, C), hydrogen would be produced preferably by decentralized or centralized water electrolysis using the French electricity mix, whereas SMR would be used depending on the economic competitiveness of the process, including CO_2 transport and storage costs.

The transport of hydrogen by pipeline would be progressively the most attractive option for significant quantities of hydrogen delivered, whereas the transport by truck would be preferred for more limited quantities. The hydrogen would be delivered to the refuelling stations, for hydrogen vehicles, and to the distribution centres (via local hydrogen mini-grids), for the individual households, buildings and industry. The refuelling stations would be distributed near urban centres and along mains roads and the distribution centres near urban centres and industrial areas.

2.3 Long term vision (2030-2050)

In the long term or vision phase, the range of options for hydrogen production will reflect a sustainable vision of hydrogen economy.

The centralized SMR with CCS and delivery of hydrogen through dedicated pipelines would be used depending on the competitiveness of the process, penalized by the increasing costs of natural gas. The production of hydrogen using renewable energy would increase to 30.2 TWh by wind electrolysis (location in S-E, N-W, C-N) and 34.6 TWh by biomass gasification (location in E, S-E, S-W) in 2050, but these contributions depend on the scenarios adopted for the final use of energy resources. The production of hydrogen by conventional water electrolysis using the electricity mix would be promoted for environmental reasons. It would be decentralized or centralized depending on the regional population density and growth of the demand.

However, in case of high demand in densely populated regions, the emergence of innovative nuclear reactors would allow a massive production of CO_2-free hydrogen by high temperature (HT) electrolysis. This process would use the energy (heat, electricity) provided by the nuclear reactor (e.g. EPR), taking advantage of a lower electricity consumption. The consumption of both heat and electricity by the HT electrolyser could justify the construction of dedicated nuclear reactors producing electricity at prices below market prices. Conversely, conventional electrolysers would consume the French electricity mix but at the market price.

The contribution of this innovative HT process would be significant in the production mix (10% in 2030, 20% in 2050), thus reflecting the political will to promote hydrogen issued from water electrolysis in the most efficient way.