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Strategic priority

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ENERGETIC TRANSITION : A POINT ON HYDROGEN

The succession of scorching meteorological episodes, almost everywhere around the world and in particular in mainland France, leaves little room for doubt as to its origin. Thus, the need to fight against greenhouse gases (GHG), first of all carbon dioxide (CO2), firmly invites you to accelerate the exploration of new decarbonized energy models, with a view to annoying the climate change to which we are confronted. In this perspective, the hydrogen molecule arouses a largely shared hope while at the same time some votes rise to underline its ineffectiveness and exorbitant cost; However, research and various technological progress relating to the use of hydrogen is far from completed[1]. Auditor of the 22nd promotion of the IHEE[2] whose theme is devoted to the energy transition, I could see the extreme competition to which states and businesses are engaged, by visiting, among other things, *Air Liquid* facilities in Germany and those of *Hydroquébec* in Canada, or even by measuring the hope of a green finance in Frankfurt and trying me on electric mobility in the *Transdev* buses in Montreal. In order to clarify the question of hydrogen, I propose in this note a synthetic point on the technical principles currently mastered concerning this molecule. On the other hand, if this technology has many consequences in the field of energy geopolitics or in economics, these points will not be developed in the rest of this document which is intended to be primarily oriented towards processing of the process; However, they should not be lost in sight because they are part of the general equation to be resolved.

The hydrogen molecule H (more exactly, dihydrogen, H2, when it takes the shape of a gas) is to date the only possible alternative identified with fossil fuels, if and only if it is generated from an origin and according to a decarbonized process. It should be noted, however, that this molecule is not an energy source as such, but a vector of energy: hydrogen, far from producing *ex nihilo* of electricity, only promotes the restitution of an energy that it captured beforehand. Indeed, hydrogen, once isolated, allows storage, transport, then the reuse of electrical energy initially generated by another source. The present note will distinguish these two aspects, first that of the objective assigned to hydrogen, that is to say the restitution of a final energy (1) then will be interested in its generation from an energy primary (2); Finally, the French ambition in this area will be the subject of a presentation, because the technological issues are completely fundamental for the country (3).

I) The restitution of a final energy

The hydrogen molecule is the most widespread molecule in the universe; Its discovery is not recent because it dates back to the 16th century. It is currently used mainly in the chemical (production of ammonia for fertilizer and methanol) and petrochemical (reactive in the refining processes of petroleum, fuels and biofuels). However,

1 Read, for example, « *Les matériaux face au plasma en fusion* », Les défis du CEA, n° 249, p.13, mai-juin 2022.
2 IHEE : Institut des Hautes Etudes de l'Entreprise / Company High Studies Institute.

as part of the reduction of GHG emissions, the customs of use appear promising in the transport sector (responsible for 25% of GHGs), that of industry and construction (responsible for 18% of GHGs), or in the residential sector (responsible for 6% of GHGs). In particular, the production of non -decarbon primary energy alone weighs today for 41% of GHG emissions worldwide. Ultimately, 90% of GHG emissions are potentially affected by development prospects around hydrogen.

Benefits

The storage capacity offered by hydrogen constitutes in a way the "missing link" in the process of renewable energies: indeed, the absence of storage capacity of electric flows makes renewable energies difficult to channel so that production coincides With the need for consumption at the moment "T". The storage of electricity produced in batteries is technically controlled, but meets limits, today without solution, linked to energy density (the number of kWh stored by weight or liter) and the shelf life. Other sources of energy such as that from nuclear power are also faced with storage issues, even if it is possible to calibrate the production power upstream.

Hydrogen thus makes it possible to absorb a certain power produced at the time of its production and to restore it by transformation at the time of need. This molecule can take several forms to ensure the chemical storage of electricity: sparkling, liquid, and even solid. When electricity is generated from hydrogen, it does not produce CO2 but rejects water. For example, in terms of mobility, the hydrogen engine can take two forms: either it is a conventional combustion engine connected to a tank whose fuel is hydrogen, or the engine is electric and it is supplied by a fuel cell. In both cases, dihydrogen, H2 consumed is transformed into water (H2 + 0 = H2O) by combustion in contact with oxygen.

The fuel cell works on the principle of an anode which emits electrons from a fuel, hydrogen, and a cathode whose fuel is oxygen and which collects electrons. An electrolyte will force the passage of the electrons emitted by the anode via an external circuit which will generate continuous electrical energy, then these electrons are then captured by the cathode; In contact with oxygen, heat and water will be produced.

Direct combustion in a heat engine adapted to gas hydrogen allows in view of the latest findings, to obtain performance close to petrol engines, but with lower reconfiguration costs than in the case of a full replacement of motorization. However, even today, hydrogen must be mixed with more conventional fuels, which does not allow you to be zero GHG emissions. In addition, in this case, two distinct fuel tanks are necessary.

The transformation of the molecule creates heat which can be used in heat networks, so it is possible to inject a percentage of dihydrogen into gas networks in addition to other energy sources. Finally, at the residential level, it is allowed to imagine now hot water production balloons with a fuel cell and supplied by dihydrogen.

The inconvenients

The yield

The energy restitution rate is not very favorable, because it is much less than 25%: for a unit of electricity produced upstream by an energy source, the final energy returned by hydrogen will not be better than 0.25. Consequently, it appears that to maintain the same level of restitution of 1 in final energy, which corresponds to the need for consumption, it will be necessary to multiply by more than 4 the primary sources of electricity upstream. Challenges recalls that the EU targets the circulation of 10,000 hydrogen trucks by 2030, which corresponds to a new need for electricity production which is equivalent to 15 nuclear reactors.

A risk of explosion

Before the H2 molecule becomes again of water, its contact with oxygen makes it very flammable and explosive; In addition, the dihydrogen being the smallest of the molecules, it requires more powerful compressors and specific means of transport so as to avoid leaks. He is also odorless, colorless, non -toxic and non -corrosive, which complicates his mastery.

II) The absorption of primary energy[3]

60% of molecules combining hydrogen, it appears to be necessary to develop dissociation processes to isolate the H molecule.

3 Primary energy, according to the definition of the International Energy Agency.

In France, 1 million tonnes of hydrogen is produced each year (out of a global total of 70 million). However, to date and according to a parliamentary research note[4], 99% of hydrogen produced is not decarbonated and 50% of this production consists of fatal[5] or co -produced hydrogen: 48% is produced from gas[6] (we speaks of gray hydrogen, which becomes blue hydrogen if CO2 is captured[7]), 28% from petroleum derivatives (classification identical to that of gas) and 23% from carbon (brown hydrogen if it is lignite , or black if it is coal).

Hydrogen can be obtained from different processes: thermochemical or photochemical decomposition, vaporeformation (for gas), biomass pyrolysis or water electrolysis. However, so that hydrogen can be fully qualified as green, only water electrolysis can be retained as a production method, because CO2 emissions are then nonexistent provided they are supplied by renewable energies (Wind energies, biofuels, biogas, Houlomotor energies, biosourced geothermal energy and chemistry). In a very schematic way, this is the reverse process to that of the fuel cell, describes above, which is implemented to dissociate part H2. If at the end of electrolysis, hydrogen is isolated from nuclear energy, the molecule obtained will be qualified as yellow (also sometimes qualified as pink). Finally, there is also white hydrogen, which is obtained is the result of several natural processes and which does not emit any carbon dioxide. France has several important sources of white hydrogen but the operating conditions are not yet stabilized at the technical level.
Note that the ordinance of February 17, 2021 relating to hydrogen came to simplify the categorizations of the molecule at the French level:

- *Renewable hydrogen* for obtaining water electrolysis from renewable electricity (corresponds to green hydrogen);
- *Low carbon hydrogen*, if and only if the molecules obtained are identified yellow or blue;
- *Carbon hydrogen* if the molecule is obtained from fossil fuels.

The target to be reached is at least that of low carbon hydrogen.

The inconvenients
A decarbon source
As seen previously, the generation of hydrogen only makes sense if it is green, that is to say, resulting from an initial decarbonized energy as in the case of production from wind turbines, photovoltaic panels, hydrology or geothermal energy.
But the costs of obtaining green hydrogen are today about 5 times higher than those of gray hydrogen and 2 times higher for yellow hydrogen.

III) The french ambition

The Ministry of Energy Transition is responsible for piloting a large support plan for the development of decarbon hydrogen. This plan, with 7 billion euros, aims to reduce GHG emissions by 55% by 2030, which represents a volume of jobs estimated at 150,000.
Three priority axes were defined by the ministry:

1. Industry decarbonation
2. The development of heavy mobility to hydrogen
3. Support for a search for excellence and the development of training offers

Some French companies have already taken the plunge: thus in Béziers (34) Gendia installs an electrolyser allowing to mass produce green hydrogen[8]. The Helion company, a subsidiary of Alsthom[9] communicates on

4 Scientific note n° 25, *Les méthodes de production de l’hydrogène*, french parliamentary office for the evaluation of scientific and technological choices, April 2021.
5 Fatal means that it is obtained at the end of an industrial process without initial link with the production of H.
6 If the gas in question is methane treated by pyrolysis, the color code associated by the EU is turquoise.
7 Hydrogen capturing then requires long -term storage.
8 Technologies de demain, pourquoi la France peut encore gagner, *Capital*, n° 368, mai 2022, p. 44.
9 Hydrogène : de l’utopie à la réalité, *Challenges*, numéro spécial 3, mai-juillet 2022, p. 17.

its positioning as a pioneer of fuel cells for heavy mobility, in place of electric batteries whose embarkation weight is prohibitive for Guarantee a future for electric mobility.
For its part, France aims at 20% of electricity consumption based on green hydrogen in 2050 in the energy mix, which should lead to a doubling of decarbonated primary electrical production.

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It emerges from the above that hydrogen offers promising perspectives, in particular if the molecule is isolated by water electrolysis, itself fueled by renewable energies or in the absence of nuclear origin. However, the innovation cycle is far from completed. Electric mobility as we currently know it, i.e. by connection by cables at charging stations, therefore appears as a model of transitional movement at the technical plane. Indeed, mass production prospects are less than 20 years and hydrogen charging stations only begin to develop around the world.
On the other hand, the switch to low carbon hydrogen for industry or mobility now requires a massive investment in order to multiply primary electrical production. A 100% renewable energy mix does not appear immediately accessible, which gives nuclear energy a decisive role in filling with yellow hydrogen the needs of final consumption, at worst by capturing CO2 for blue hydrogen . Finally, it should be noted that economic issues are considerable for our country, both in terms of energy sovereignty and created jobs. When will the first gendarmerie hydrogen stations and the first propulsion intervention vehicles based on this molecule? Tomorrow, not after tomorrow, suddenly on.

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