APPUNTI DI ENERGIA

Hydrogen yes, hydrogen no

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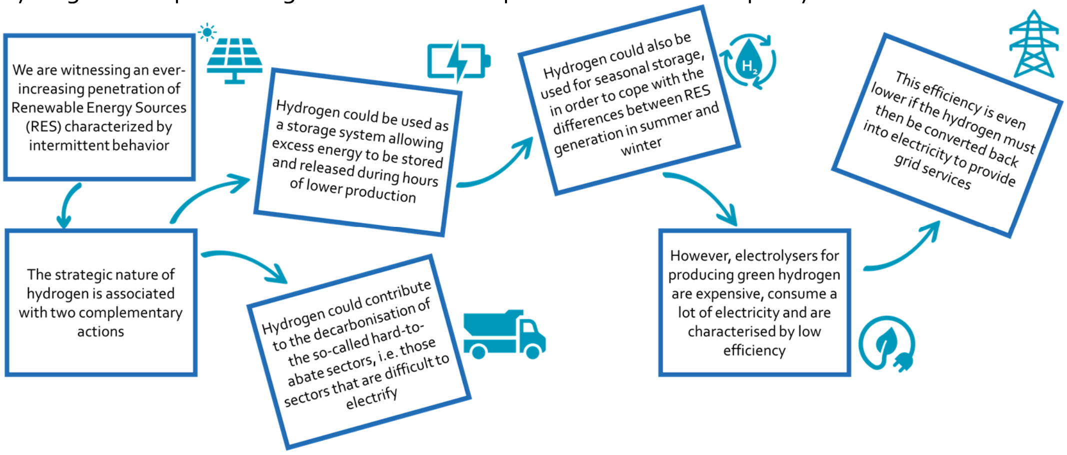
What it is about

Hydrogen is currently the subject of a major debate. The European Commission considers hydrogen an important ingredient of the European decarbonization policy.

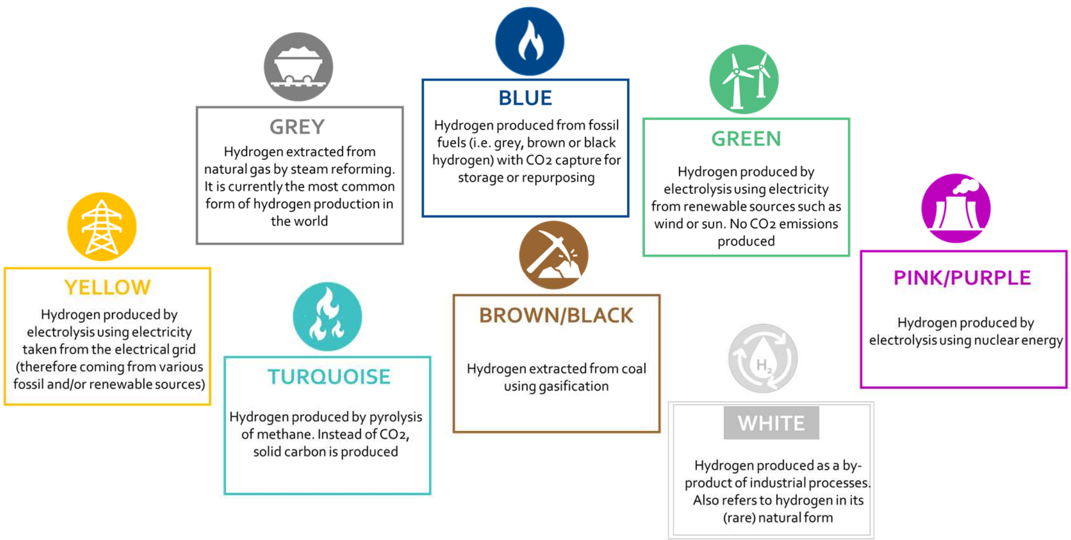


For an in-depth discussion of all the issues related to hydrogen, the reader is referred to the recent review paper by the same authors published in the journal ENERGIES

Review paper

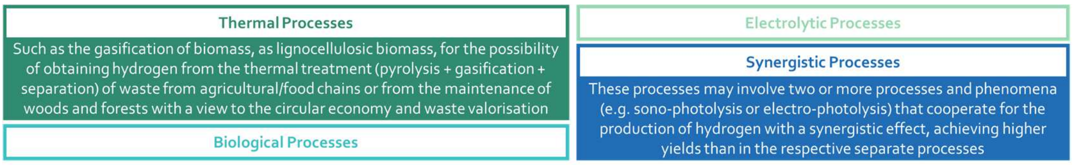
For these and other reasons, the pros and cons of using hydrogen as an energy carrier are currently still debated both at a technical and scientific level.
The following pages aim at defining on the one hand what advantages hydrogen could provide to the energy system in support of current decarbonization policies and on the other hand what problems still exist for its use on a large scale, which entails that some questions remain open and, at times, still the subject of scientific and technological research.
We will first consider hydrogen production technologies (the "supply" side), then the use of hydrogen by industry and transport, and finally the potential and problems related to interfacing with the electricity grid, including the future need to create a liquid market for the hydrogen commodity.

The colors of hydrogen

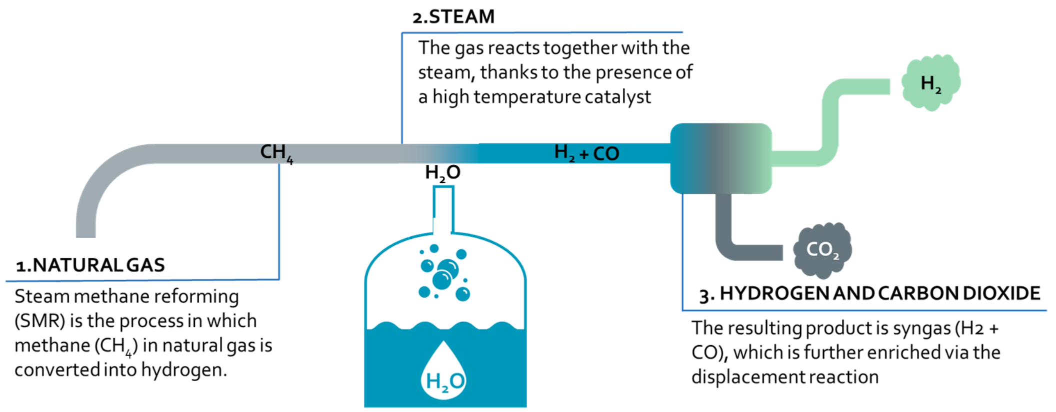


Hydrogen production

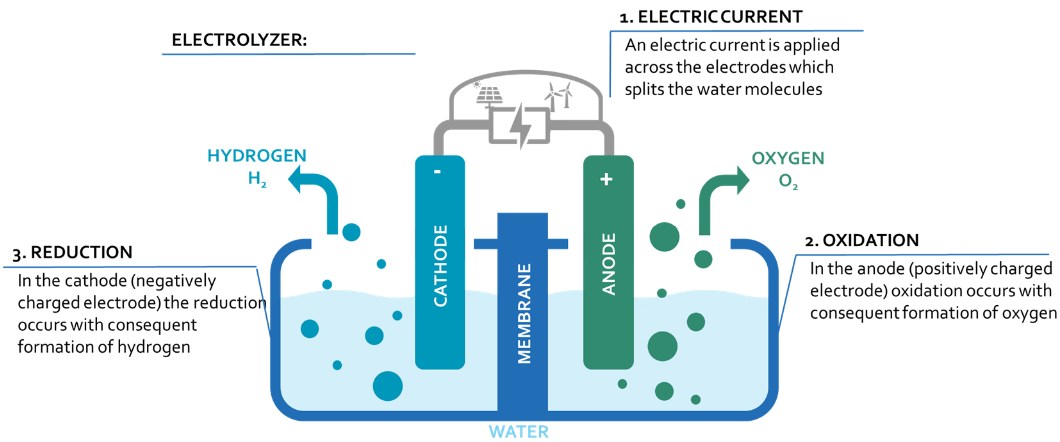
Hydrogen production is not an absolute novelty, there are already well-developed and highly commercialized processes. Thanks to the efforts in research and development in the sector, today we can count at least 30 hydrogen production technologies, of which 30% at a high level of maturity, and 20% less mature but with promising yields. There are four main families:



In the industrial sector today, hydrogen is mainly produced from methane (**steam reforming**), a process that allows hydrogen to be obtained by involving high-temperature steam, but which produces and releases carbon dioxide into the atmosphere.



Since this process is not consistent with the current decarbonization needs, another technology has become very popular: **the one that uses electrolysis through devices called electrolyzers**.



There are several variants of electrolyzers on the market and under development, even operating at high temperatures, with the aim of increasing the conversion efficiency, i.e. producing more hydrogen while consuming less electricity. In fact, a problem with the application of large-scale electrolysis for hydrogen production at the current stage is the strong dependence on the cost of electricity which affects the price per kg of hydrogen produced (currently very high in Italy).

In Italy, the costs of hydrogen from electrolysis, which is currently the most mature technology for producing green hydrogen, are currently around €6-7/kg, significantly higher than those (around €2/kg) for production from methane by steam reforming (which, however, generates CO2). This means that the large-scale use of green hydrogen for industrial applications is heavily dependent on subsidies that cover not only the capital costs for investing in new technologies but also the current gap in operating production costs. Generally, in the long term, the use of hydrogen is considered convenient only in those sectors where the electrification of the process is difficult to implement (so-called hard-to-abate sectors). These sectors include important energy-intensive industries, such as steel, cement and ceramics, and heavy transport.

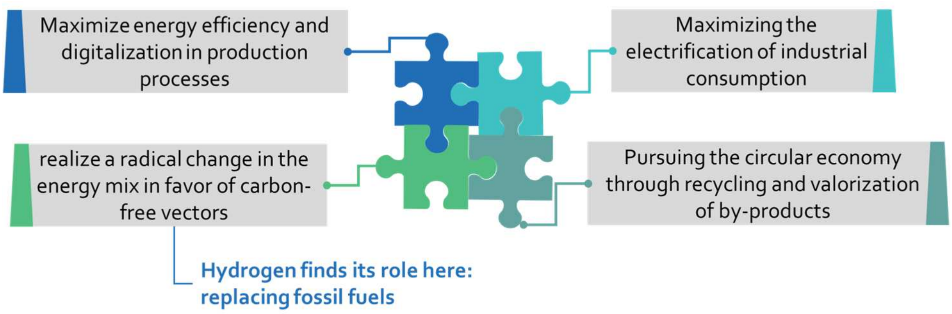
The technological development scenario therefore leads to two possibilities in the future, which could also occur simultaneously:

- hydrogen will have a greater chance of being competitive if produced with a more transversal technological approach, avoiding depending on a single technology, a single process and the related supply chain, with the risk of not being effective in the long term;
- by deepening the synergistic processes and allowing their integration into more mature technologies, it will be possible to explore the opportunity to increase their efficiency, reducing the energy demand for the same amount of hydrogen produced, with a consequent reduction of the related cost (e.g. higher efficiency electrolyzers, which consume less electricity to produce 1 kg of hydrogen).

Industrial uses

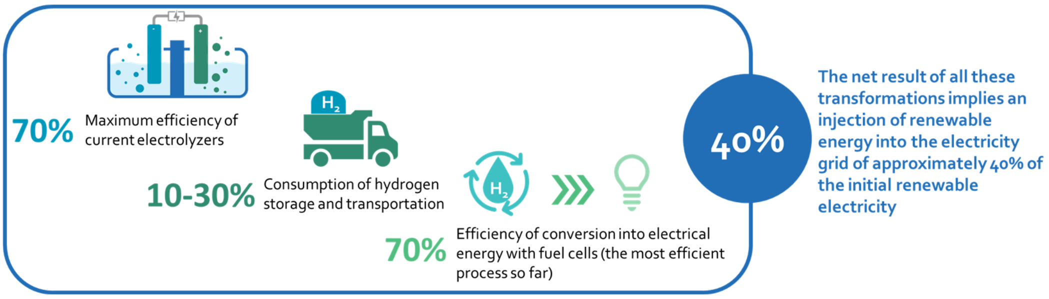
The industrial sector is responsible for approximately 45% of total greenhouse gas emissions. The most significant emissions come from

A correct and effective strategy for reducing emissions should include four fundamental actions:



In recent years, there has been a convergence in the scientific, political and industrial fields on the directions of use of hydrogen in industry, which cover various high-temperature processes and some chemical processes. In particular: as an energy vector in the iron and steel, glass and ceramic sectors and as a raw material in the petrochemical and chemical sectors. In other sectors such as foundries (cast iron and non-ferrous metals), cement and paper, a marginal use is expected, both due to the lower process temperatures and the smaller size of the equipment, which will allow a development of the processes towards electrification and the use of other low-carbon fuels.

A critical aspect that still needs to be overcome is the need for the industrial sector to have a constant and continuous supply of hydrogen for use in production processes. Renewable energy sources are notoriously non-programmable, so it is necessary to provide an infrastructure that guarantees significant production of hydrogen and the storage of large quantities. In fact, the uncertainty about covering electricity demand due to the intermittent behavior of non-programmable renewable sources implies the need to integrate with large energy storage facilities. Hydrogen, although suitable for this type of use, suffers from the low energy efficiency of the conversion processes (from electricity to hydrogen and vice versa): the replacement of fossil fuels (mainly natural gas) with green hydrogen represents, from an energy point of view, a great waste of energy:



Transport sector

The prospects for the future use of hydrogen in the main mobility sectors are as follows.

Light transport

The use of hydrogen in internal combustion engines **has no prospects due to its very low efficiency**. The alternative technology is constituted by fuel cells which, although more mature, are still not able to guarantee a sufficient level of efficiency to justify large-scale application in light vehicles, in favor of the electric (battery) solution.

Heavy road transport

In this sector, despite the uncertain technological prospects, hydrogen is still considered a **possible solution**, considering the greater autonomy connected to this type of power supply compared to electric, provided that there is a widespread diffusion of refueling stations, as planned for the next few years. It should be considered, however, that the autonomy of battery-powered heavy vehicles is expected to grow significantly and, therefore, it is awaited that the competitive advantage for fuel cell vehicles will be progressively eroded.

Public transport by road

This sector will see a progressive replacement of the existing fleet at a national level, and in the coming years it is possible to expect an **expansion of the use of hydrogen**, especially in the vicinity of local districts of production, distribution and use of hydrogen itself (hydrogen valleys). In fact, in these places large quantities of hydrogen will be available that can be used, predictably, at more competitive costs than the current ones, a factor that is not negligible now. However, the prevailing future solution, already widely used in local public transport especially in urban areas, is the battery one. Therefore, I a more significant use of the hydrogen carrier is awaited for extra-urban routes, in relation to the greater autonomy that vehicles powered in this way can guarantee.

Rail mobility

In addition to the spread of "native" hydrogen trains, **mobility currently limited mainly due to the very high costs** of these rolling stocks, we can mention some interesting experiences of retrofitting diesel locomotives, with costs 30-50% lower than the purchase of an equivalent one. Even in this case, however, we note an initial spread, for the moment for routes shorter than 80 – 100 km, of battery-powered trains, in competition with hydrogen powered ones.

Maritime transport

There are **problems related to the safety and energy density of the hydrogen carrier.** The energy density of hydrogen is lower than that of conventional fuels. Therefore, it is necessary to reserve a lot of space for hydrogen storage on-board the ships, unless expensive and complex solutions are used to reduce the volume, such as low-temperature liquefaction, high-pressure compression or the use of derivatives such as ammonia or methanol. Added to this there are safety issues related to the risk of detonation, in a legislative framework that is not yet fully responsive on the subject.

Aeronautical sector

The use of hydrogen currently appears to be **too uncertain and not sufficiently mature**, especially about the creation of an efficient supply chain, to draw precise and definitive considerations in this regard, so a clearer picture will only be possible in the coming years. Community constraints in terms of the use of SAF (Sustainable Aviation Fuels), including synthetic hydrogen-based fuels, in any case suggest a future use of hydrogen, if not significantly in pure form, at least in composition.

Hydrogen to support the electricity grid

In the future, the implementation of hydrogen storage infrastructures could prove to be an important opportunity, to the advantage of both industry and the electrical system.

1. The availability of a hydrogen storage could allow to increase the flexibility of the manufacturing processes and overcome any problems related to an insufficient or intermittent hydrogen supply.
2. Hydrogen storage could be used as a source of flexibility for the electricity system
3. Hydrogen (along with hydroelectricity and "flow batteries") is one of the few currently mature technologies that can implement seasonal storage, compensating for the difference between summer and winter in average renewable generation production.

As shown by a study by Frontier Economics and ENTSO-E, Europe has a significant potential for saline geological structures, concentrated mainly in Northern Europe (it is said that there is a storage potential of 85,000 TWh, well above the hydrogen production that could be required to compensate for the overproduction of renewable generation). However, there are relatively few sites available in Southern Europe, where most of the photovoltaic potential is located.

LOW DENSITY BASSA

Furthermore, hydrogen, although characterized by a higher lower calorific value than methane and oil (120 MJ/kg), has a very low density in atmospheric conditions (about 0.089 kg/m3), and therefore requires much higher volumes than traditional fuels. For this reason, hydrogen is usually compressed, liquefied or transformed into other energy carriers such as ammonia (however the conversion is low efficiency – 29% for ammonia).

REDUCED EFFICIENCY

Another issue that could potentially limit the use of hydrogen storage is the fact that electrolysers, as seen previously, are characterized by a relatively low efficiency (60-70%). However, the loss of 30% of renewable electrical energy in the process of conversion into hydrogen is partially compensated by the advantage of being able to accumulate energy in chemical form for very long periods, also allowing for seasonal storage.
Other technologies such as solid oxide electrolytic cells seem promising for the future and would be characterized by much higher efficiency (80-85%) but currently still have problems to overcome

to become suitable for industrial production. Even worse are the current yields of fuel cells used to produce electricity from hydrogen (45-60%).

DEDICATED TRANSPORT NETWORKS

Since electrolysers consume a lot of electricity, it is clear that a significant increase in the production of green hydrogen from electrolysis could lead to high costs for the reinforcement of the electricity grids to which the electrolysers will be connected. In general, a question arises as to whether it is better to produce hydrogen in industrial sites where it is required (brown fields), possibly strengthening the electricity grid where necessary, or to produce it where there are large infrastructures for electricity production from renewable sources and then transport it from there to the plants that use it via dedicated infrastructures. This would make it necessary to create large networks dedicated to the transport of hydrogen or to adapt part of the current gas pipelines to use with hydrogen ("repurposing"). This is certainly very convenient economically, but it comes with some technical problems, as highlighted by the Agency for the Cooperation of European Energy Regulators (ACER) in the report "Transporting Pure Hydrogen by Repurposing Existing Gas Infrastructure: Overview of existing studies and reflections on the conditions for repurposing". Among the major technical problems for gas-hydrogen conversion, we can mention the greater degradation of the steel of the pipes caused by hydrogen, in addition to the need to increase the power of the compressor stations by about three times, compared to the power required by natural gas.

ACER report

ITALY AS AN IMPORT HUB

Italy's geographical position in the Mediterranean could suggest a role for it as a "hub" for importing hydrogen from third countries, for example from North Africa, where there is strong potential for photovoltaic production. In this sense, SNAM has recently signed an agreement with the Transmission System Operators of the respective Austrian and German gas networks for the construction of a South Corridor for the import of hydrogen from the North African coasts.

SNAM agreement

HYDROGEN AS A COMMODITY

It must also be considered that a future large-scale production of hydrogen will make it a commodity itself, with the need to create a dedicated market. Given the strong interaction between electricity system and hydrogen, the architecture of a future market for the latter will have to be designed by taking into account the current electricity market architectures, so as not to create "gaming" opportunities for producers with potential market power and perhaps active on both commodities.

Notes by:


Piergiovanni Domenighini, Gianluigi Migliavacca, Claudio Zagano, Claudio Carlini

Piergiovanni after the Degree in Civil Engineering obtained the Doctorate in Energy and Sustainable Development.
Gianluigi has been coordinator of three European projects on smart grids and currently coordinates the activities on "multi-energy" of the Energy Systems Development department of RSE.
Claudio Zagano has a degree in physics and in RSE he is the project leader of the Hydrogen Research funded by the PNRR.
Claudio Carlini graduated in Electrical Engineering from the University of Pavia in 2009. Join RSE in 2010.

appuntidienergia@rse-web.it