Innovative Energy Climate Action

Part 2: HYDROGEN MATTERS FOR GREEN TRANSITION

Jan 2022

Discussion paper

Authors: Andrea Raccichini, Marco Contardi, Marco Saverio Ristuccia

FGV EUROPE

PART 2:
HYDROGEN MATTERS FOR GREEN TRANSITION

Hydrogen is a chemical element, discovered in 1766 by Henry Cavendish, **that is now enjoying a positive momentum in the energy market**. Hydrogen has had several waves of interest in the past, mostly due to oil prices spikes, worries about the oil peak and research on alternative fuels. Nowadays, we are living a new interest wave.

As a matter of fact, as an energy carrier, hydrogen has several positive features that are increasing stakeholders' interest around the world. In fact, hydrogen can be:

- Produced by different energy sources and technologies;
- Used in several sectors and applications;
- Stored and transported in a stable way;
- Combined with other elements;
- Used as a feedstock in industry.

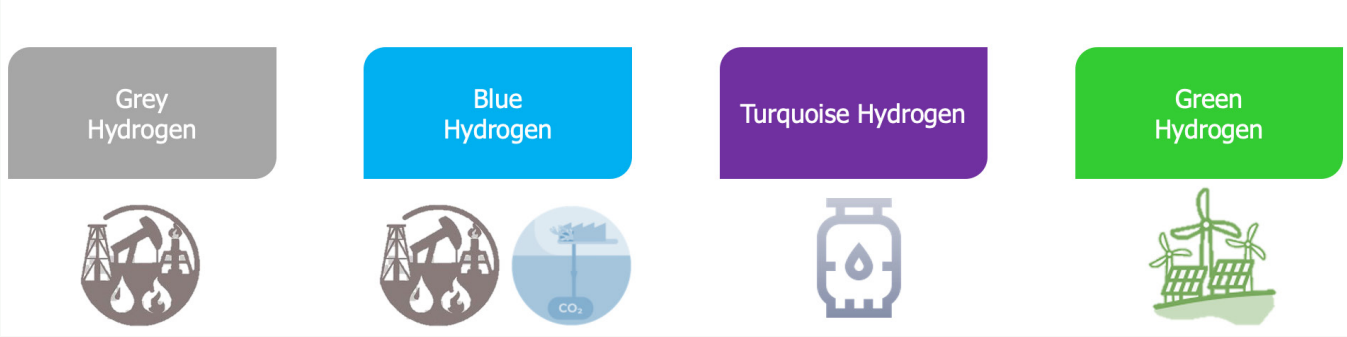
Moreover, it is considered a low-carbon energy carrier that can strongly contribute to fight climate change. Nevertheless, it depends on the way it is produced. For instance, upstream production with renewable energies and an electrolysis process of generation, will provide a "green hydrogen"; while "grey hydrogen" is produced, if the energy input is a fossil fuel without carbon capture.

In that regard, even though there is no unique standard on hydrogen classification, a common color code nomenclature is becoming used in the market to refer to different sources of production. Thus, according to the International Renewable Energy Agency - IRENA (2020) there are:

- Grey Hydrogen: produced from fossil fuels (methane or coal) with SMR (steam methane reforming) or gasification production process;
- Blue Hydrogen: produced from fossil fuels (methane or coal) with SMR or gasification with carbon capture;
- Turquoise Hydrogen: combines the use of natural gas as feedstock with no CO2 production, using pyrolysis process;
- Green Hydrogen: hydrogen produced from renewable energy through the established technology option of water electrolysis[7].

7 There are other technological paths that can be used to get the green hydrogen, such as physicochemical or biochemical processes. Please find more information in the following document "Bases para a Consolidação da Estratégia Brasileira do Hidrogênio, 2021, EPE, MME.

Figure 1 – Hydrogen Shades



Source: FGV Europe, adapted IRENA (2020)

As reported by IRENA (2020), current hydrogen production is mostly based on natural gas and coal (95% of production) and 5% is derived by electrolysis as a by-product from chlorine production. Furthermore, today's hydrogen output is mainly used for crude oil refining, ammonia and methanol synthesis (75% of the combined pure and mixed hydrogen demand). Thus, there is a major grey and blue production and a low insertion of green hydrogen in strategic sectors to contribute to fight climate change.

However, within such scenario, **global interest – governments and market players – is now focusing on "green hydrogen" due to its sustainable features (net-zero route) and cost-technical enhancement (lowering costs and technological improvement). Such energy carrier is crucial for the green transition of current economies, contributing to decarbonise industries that nowadays are using massively fossil fuels**.

Indeed, economies are facing the green transition where the energy sector has a pivotal role. Green hydrogen, with its potentialities and challenges, is a strong ally to reduce green gas emissions and foster innovation. Hence, IRENA (2020) affirms:

> Converting to green hydrogen can significantly reduce carbon emissions from the industrial sector, which is currently responsible for about one-quarter of all energy-related CO2 emissions (or 8.4 GtCO2/yr). Four industries in particular – iron and steel, chemicals and petrochemicals, cement and lime, and aluminium – account for around threequarters of total industrial emissions (IRENA,2020b).

Thus, green hydrogen development can contribute to fight climate change while assuring energy security and resilience, due to energy carrier characteristics. Governments and markets have to works together to scale-up such innovative solution in the energy market, and the next ten years are absolutely critical (IEA 2019).

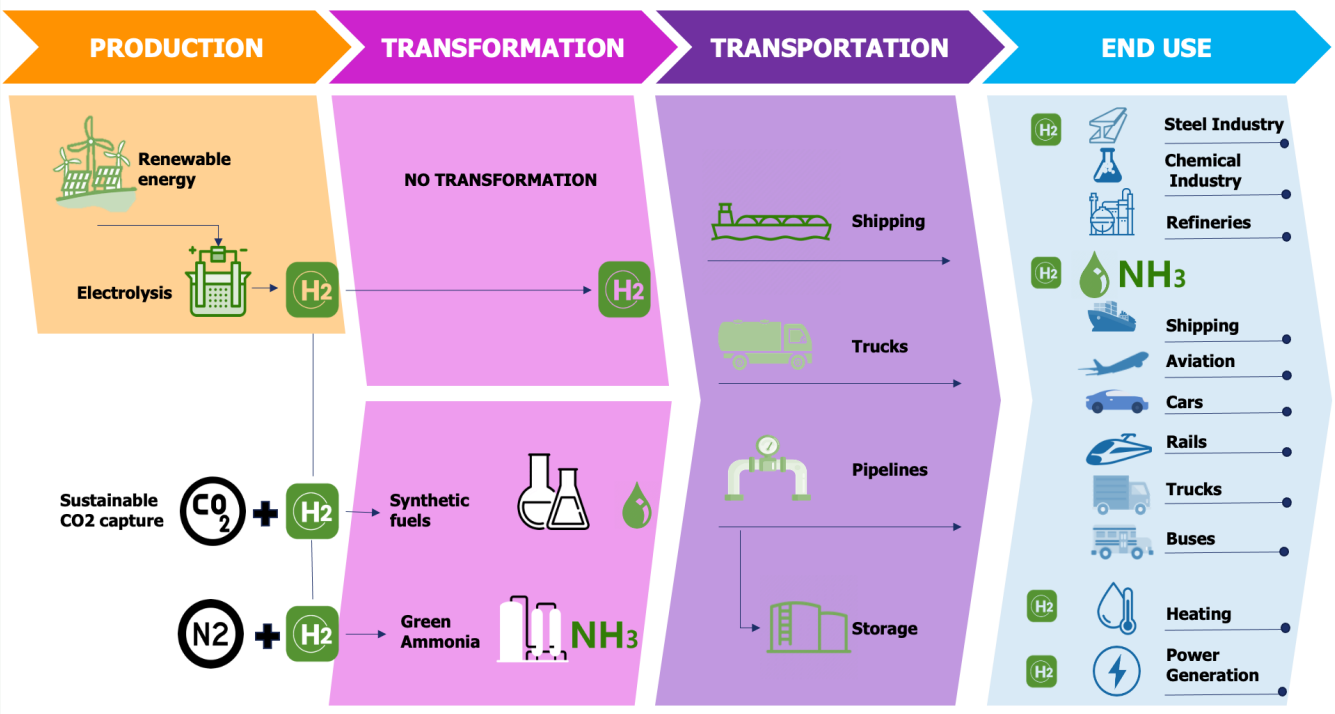
Green hydrogen novel market is currently gaining momentum and according to IRENA (2020) there are six main drivers:

1. Low variable renewable energy (VRE) electricity costs: renewable electricity costs are constantly decreasing, turning this option more and more attractive;
2. Technologies ready to scale up: hydrolysis production costs are falling since 2010, giving a new scenario to market growth;
3. Benefits for the power system: hydrogen is a flexible energy carrier due to its storage characteristic, which can stabilize renewable energy volatility;
4. Government objectives for net-zero energy systems: green hydrogen is crucial to reach Paris Agreement and Sustainable Development Goals (SDG), and in line with the results of COP 26. In fact, states are running to cope with such environmental threat, conceiving ambitious emission reduction goals, and green hydrogen could be a strong ally. Green hydrogen can play a key role in decarbonizing hard-to-abate sectors[8] such as steel, cement, chemicals, heat for buildings, long-haul road transport, maritime shipping and aviation;
5. Interest of multiple stakeholders: all these points have risen market players and government bodies interest for green hydrogen.

In terms of green hydrogen value chain, it is clear how the energy carrier is a key element for the energy transition due to its flexibility and versatility. Green hydrogen is produced by renewable energies and it can be transported by different carriers and also be stored. After that, it can be used in several key industries. Moreover, green hydrogen can be combined with CO2 to generate synthetic fuels or with nitrogen to create green ammonia (Figure 5).

8 A key element to highlight, is the option to use green hydrogen in hard-to-abate industries, that are currently fueled by fossil fuels and not electricity. As matter of fact, IEA (2019) pinpoints that "four-fifths of total final energy demand by end users today is for carbon-containing fuels, not electricity. In addition, much of the raw material for chemicals and other products contains carbon today and generate CO2 emissions during their processing". Hard-to-abate sectors such as steel, cement, chemicals, heat for buildings, long-haul road transport, maritime shipping and aviation, might be transformed in more sustainable industries through the multiples uses of green hydrogen.

Figure 2 – Green Hydrogen Value Chain



Source: IRENA (2020), adapted FGV

IRENA (2020) pinpoints that is crucial to decide which application should be prioritized, as a policy decision: “Policy makers should identify the highest-value applications for a given amount of green hydrogen, in order to focus their policy efforts where they could provide the most immediate advantages and enable economies of scale”. For example, continues the institution, “one potential role for green hydrogen policy is to support and then accelerate a shift to green hydrogen in industrial applications where hydrogen is already used, such as refining and the production of ammonia and methanol (IRENA, 2020)”.

Nevertheless, green hydrogen needs to overcome some challenging barriers in order to scale up in the market. IRENA (2020) lists the following barriers:

1. High production costs: in 2019 the cost of producing green hydrogen using renewable energies is on average two or three times more expensive than grey hydrogen. Also, if taking into account end use technologies, adopting green hydrogen utilization can be expensive. For instance, fuel cells and hydrogen tanks costs are at least 1.5 to 2 times than fossil fuel technology (The National Renewable Energy Laboratory - NREL, 2020). In the aviation industry, too, synthetic fuels are up to eight times more costly than fossil fuel jets (IRENA, 2019a);

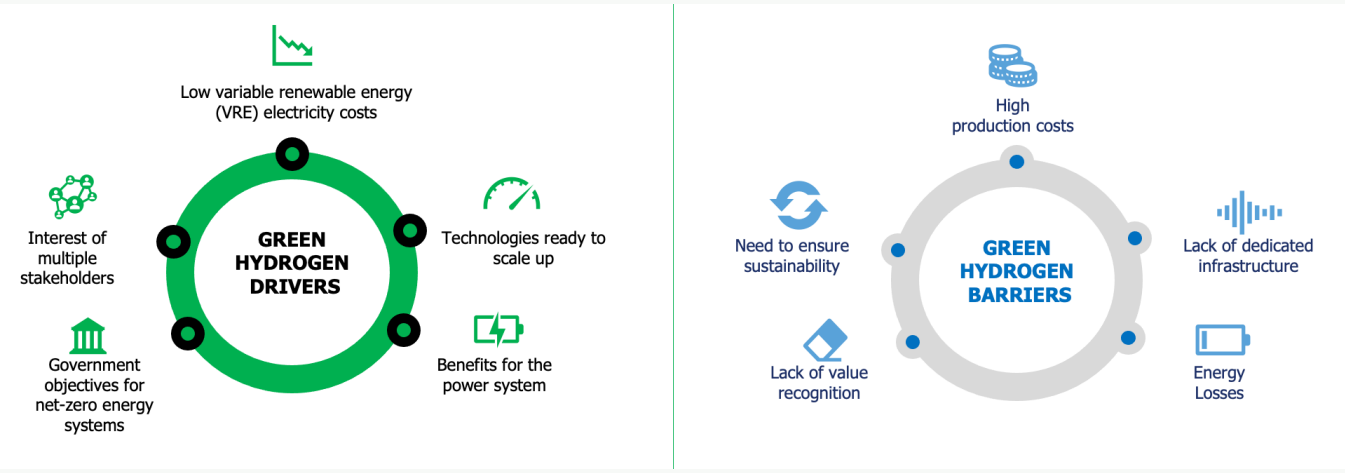
2. Lack of dedicated infrastructure: even though hydrogen can use existing infrastructure, there are some challenges to be considered. Hydrogen production used to be made in a decentralized manner. So, current transmission pipelines (5.000 km) are low in comparison with existing natural gas infrastructure (3 million km), globally speaking (Hydrogen Analysis Resource Center, 2016). The same is true for refueling stations around the world. Hydrogen has 470, and gasoline and diesel are 200.000 in the United States and Europe (Advanced Fuel Cells Technology Collaboration Programme - AFC TCP, 2020). Moreover, reusing existing natural gas infrastructure, is a real option, though it needs further investment to expand and adapt (retrofitting);

3. Energy Losses: throughout the green hydrogen value chain, significant energy losses occur. For instance, 30-35% of the energy used to produce hydrogen through electrolysis is lost (IRENA, 2020). Furthermore, the conversion of green hydrogen into other energy carriers, like ammonia, can result in 13-25% energy loss; even the transportation of hydrogen demands additional energy inputs, on average 10-12% of the energy of the hydrogen itself (BNEF, 2020; Staffell et al., 2018; Ikäheimo et al., 2017). Fuel cells use can also lead to an additional 40–50% energy loss. The key point, according to IRENA, is the higher the energy loss, the higher the need to produce green hydrogen. Thus, it has to be considered if the solar and wind production development pace is enough to meet the needs for both electrification of end uses, global green supply chain development and the cost of additional capacity;

4. Lack of value recognition: the market for green hydrogen and its final uses are still in an incipient phase. In fact, IRENA (2020) affirms that there is “no green hydrogen market, no green steel, no green shipping fuel and basically no valuation of the lower GHG emissions that green hydrogen can deliver”. Furthermore, the agency asserts that “hydrogen is not even counted in official energy statistics of total final energy consumption, and there are no internationally recognized ways of differentiating green from grey hydrogen”;

5. Need to ensure sustainability: green hydrogen is produced by renewable energies, and such feature gives it a sustainability characteristic. However, if electrolysis is realized from the use of electric grid or the mix with renewable energies, it is possible that the energy produced stems from fossil fuels too. Therefore, it needs to consider origin lifecycle emissions to evaluate sustainability aspects of green hydrogen.

Figure 3 – Green Hydrogen Drivers and Barriers



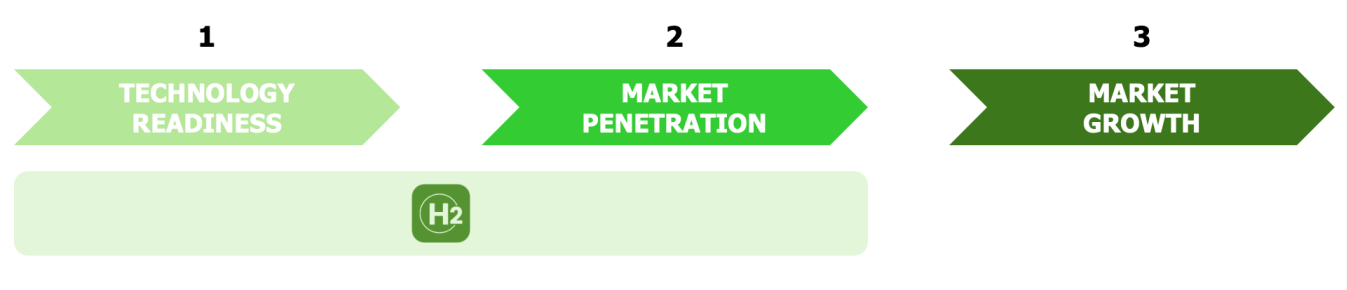
Source: IRENA 2020, figure made by FGV

Given the above information, it is now possible to give a strategic positioning of the green hydrogen market, in general terms. Using policy stage approach[9] (IRENA, 2020) – Stage 1 Technology readiness, Stage 2 Market penetration and Stage 3 Market growth – green hydrogen positioning is at the first stage and, in some countries or industries, is performing in the second stage.

Hence, the technology is ready to be used, though is facing technological, market and institutional barriers that have to be overcome through research and development investments, regulation enhancement, economic incentives and market fostering. Some regions though, like Europe, are experiencing industrial cases that are going beyond demonstrational cases but are conceiving investment-ready projects, that have the potential to scale up (i.e. hydrogen valleys).

9 *According to IRENA (2020) there are three policy stages, as follow: 1. Technology Readiness: At this stage, green hydrogen is a niche technology with little use except in demonstration projects; it is mostly produced on-site with limited infrastructure development. The largest barrier to greater use is cost. The main role of policy makers is to encourage and accelerate further deployment of electrolysers.2. Market Penetration: At this stage, some applications are operational and able to prove what green hydrogen can do and at what cost. Scaling up these technologies and developing experience through learning-by-doing reduces costs and helps close the profitability gap. This stage also begins to see benefits from synergies between applications, increasing hydrogen demand and realising economies of scale for production and infrastructure. These synergies can take place in industrial clusters, hydrogen valleys (e.g. cities) or hubs (e.g. ports).3. Market Growth: At this stage, green hydrogen becomes a well-known and widely used energy carrier and is close to reaching its full potential. It has become competitive both on the supply side and in its end uses. Direct incentives are no longer needed for most applications and private capital has replaced public support in driving hydrogen growth. There is full flexibility in converting hydrogen to other energy carriers, making it possible to use the most convenient alternative depending on the specific conditions in each region. The power system has been decarbonised and only green hydrogen is being deployed. Most natural gas infrastructure has been repurposed to transport pure hydrogen. For further information, please read IRENA (2020).*

Figure 4 – Policy Stages and Green Hydrogen Market positioning



Source: FGV

In order to foster green hydrogen market penetration, it is worth to highlight the role of international cooperation. Such partnerships could mutually benefit countries by identifying and deploying projects that consider technological transfer and absorption, best practices exchanges, sustainable finance, capacity building and international trade (import/export). Such activities and initiatives have the potential to contribute to trigger off green hydrogen market in a cooperation perspective.

The focus is on the potential cooperation between Brazil and European Countries on the hydrogen market and hydrogen valley related model. Indeed, WEF (2021) pinpoints that, given the actual geopolitical context, middle powers can exercise leadership to reinforce global resilience. Hence, partnerships with great powers countries can be very beneficial for green hydrogen market development.

Thus, Brazil has a key role to play in the novel green hydrogen market in partnership with European countries, where such industries can give relevant insights. Conversely Europe could benefit with Brazil partnership in innovation and commercial terms.

The next article will expand on the European experiences in green hydrogen market, specifically the hydrogen valleys model. The following article will describe Brazil green hydrogen market. Lastly, the final article will explain Brazil-European relations on such market.

BIBLIOGRAPHIC REFERENCE
PART 2

AFC TCP (Advanced Fuel Cells Technology Collaboration Programme) (2020), Energy Technology Perspectives 2020, International Energy Agency, Paris, www.iea.org/reports/energytechnology-perspectives-2020.

BNEF (Bloomberg New Energy Finance) (2020), Hydrogen Economy Outlook, Bloomberg New Energy Finance.

BNEF (2019), Renewable Energy Auctions Database, Bloomberg New Energy Finance. (Needs subscription).

COP26, COP26 the Negotiations Explained, UN Climate Change Conference UK 2021 in partnership with Italy, UK Government, 2021

EC, European Commission, A Clean Planet for all A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, Brussels, 28.11.2018 COM (2018) 773 final

IEA, The Future of Hydrogen, Seizing today's opportunities, Report prepared by IEA for the G20, Japan, 2019

IRENA (2020), Green Hydrogen: A guide to policy making, International Renewable Energy Agency, Abu Dhabi

IRENA (2020b), Reaching Zero With Renewables: Eliminating CO2 Emissions From Industry and Transport in Line With the 1.5°C Climate Goal, International Renewable Energy Agency, Abu Dhabi.

IRENA (2020c), Reaching zero with renewables: Eliminating CO2 emissions from industry and transport in line with the 1.5oC climate goal, International Renewable Energy Agency, Abu Dhabi. ISBN 978 - 92 - 9260 - 269 – 7 Available for download: www.irena.org/publications

IRENA (2019a), Hydrogen: A Renewable Energy Perspective, International Renewable Energy Agency, Abu Dhabi.

IKÄHEIMO, J. et al. (2018), “Power-to-ammonia in future North European 100% renewable power and heat system”, International Journal of Hydrogen Energy, Vol. 43, pp. 17295-17308, www.sciencedirect.com/science/article/abs/pii/S0360319918319931?via%3Dihub

MME, Programa Nacional do Hidrogênio, Proposta para Diretrizes, Julho 2021

STAFFELL, L. et al. (2018), The role of Hydrogen and Fuel Cells in the Global Energy System, The Royal Society of Chemistry, www. pubs.rsc.org/en/content/articlepdf/2019/ee/c8ee01157e

UN, Glasgow Climate Pact, Conference of the Parties serving as the meeting of the Parties to the Paris Agreement Third session Glasgow, 31 October to 12 November 2021, Organization of work, including for the sessions of the subsidiary bodies Proposal by the President Draft decision -/CMA.3 Glasgow Climate Pact, 2021

WEF, The Global Risks Report 2021, 16th Edition, is published by the World Economic Forum. ISBN: 978-2-940631-24-7

We are an institution of a technical, scientific, educational and philanthropic nature, founded on December 20,1944,as a legal entity subject to private law.Our purpose is to act in the field of the social sciences, particularly economics and administration, as well as to contribute to environmental protection and sustainable development.

Headquarters
Praia de Botafogo, 190, Rio de Janeiro – RJ CEP 22257-900, Tel: (21) 3799-4747, www.fgv.br

Director of FGV Europe
Dr. Cesar Cunha Campos

Advisor of Finance and Compliance
Francisco Eduardo Torres de Sá

EDITORIAL CREDITS

Strategic Coordination
Dr. Cesar Cunha Campos

Authors
Andrea Raccichini
Marco Contardi
Marco Saverio Ristuccia

Editorial Coordination
Andrea Raccichini
Sara Amaro Pais
Paul Thomas Woodhouse

Graphic Design
Paul Thomas Woodhouse

Proofreading
Sara Amaro Pais

Notice