THEMATIC RESEARCH

15 March 2021

Green & Sustainable

Financing green hydrogen's development: clearing the hurdles

- Now perceived as a central solution for the decarbonisation of entire swathes of industry and mobility, the hydrogen sector, more particularly the green hydrogen sector, is still at the take-off phase.
- By 2030, **some $300bn is to be invested in the entire sector**, not just to deploy what remains an embryonic value chain, but also to achieve economies of scale to bring down costs right across this chain, from hydrogen's production to its end-uses in the industrial, mobility and energy sectors. Only part of the $300bn will be financed by the public sector, with $70bn announced to date, which underscores the extent of the challenge facing the sector.... and private finance.
- Far from being a homogeneous whole, **the hydrogen sector, more particularly green hydrogen, amounts to a vast value chain at the crossroads of three sectors** (industry, mobility and energy), bringing together three large business lines (manufacturing of upstream and downstream equipment, hydrogen production and infrastructures for hydrogen end-uses), each with its own challenges and a specific risk profile. These characteristics present **a twofold challenge for the financial sector to participate in green hydrogen's take-off**, being to: (i) **develop instruments with features adapted to the challenges and risk levels** of the assets/entities financed across the value chain; and (ii) **replicate wherever possible across this chain the most cost-effective financing mechanisms** already massively deployed in other sectors of activity, taking advantage of both nascent business models and public support mechanisms.
- In this respect, the **recent example provided by the deployment of renewable energies** offers a good illustration of the role as a trigger played by private finance (through asset-based lending) in shaping an industry that was technologically immature at the onset, but in receipt of public support aid in various forms. **For green hydrogen, it is largely the public authorities that will provide the levers for private finance's increasing involvement in the sector's coming of age**: development at the initiative of local authorities of territorial hubs concentrating hydrogen end-uses in mobility and industry, start made introducing feed-in-premia to electrolysers, direct and indirect support mechanisms to stimulate demand for green hydrogen in the industrial and mobility sectors, and so on.
- **Still nascent, these mechanisms could**, in time and under certain conditions, **support the deployment within the hydrogen sector of financing based on the credit quality of the very assets being financed**: **secured senior debt instruments** for green electrolysis and hydrogen-centric ecosystems, spurred by public initiatives (territorial hubs and national, even international infrastructures, including airports), **lease/pay-per-use financing for hydrogen-powered equipment** provided by the suppliers, ultimately by commercial banks. In time, the maturing of financing mechanisms accompanying the sector's attainment of commercial viability would enable **the involvement of a wide array of financial sector players: commercial banks, institutional investors (infrastructure fund, insurers)**.

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1. Huge investments expected in a sector that is still in the making[1]

In a general context marked by heightened awareness of climate challenges[2], the hydrogen sector has seen a sharp acceleration in its development. This is perceptible through the multiplication of hydrogen-centric projects at the crossroads of the energy, industrial and mobility sectors, also in the ramp-up of government support to the sector.

In **Europe**, which is in the midst of an unprecedented health and economic crisis, the last six months have been marked, at both the level of the European Union and the Member States, by **the announcement of huge economic stimulus plans featuring ambitious measures to promote hydrogen**, focused on:

(i) **The development of hydrogen production capacities**, chiefly "green" hydrogen (i.e. produced using water electrolysis powered by electricity from renewable or nuclear energy sources, a nascent process in the same way as "blue" hydrogen, being developed in response to the climate externalities associated with the production of "gray" hydrogen[3]);

(ii) **The development of hydrogen end-uses across the industrial and mobility sectors**.

In these two sectors, whose decarbonisation is considered challenging on account of their reliance on fossil fuels (coal, natural gas, oil) as a feedstock and/or primary energy source, **recourse to low-carbon hydrogen (green or blue) is now seen as a powerful lever in advancing decarbonisation alongside technologies/processes based on low-carbon electricity** (so-called "electrify everything" movement).

In the **industrial sector**, low-carbon hydrogen is seen as a way of decarbonising:

(i) **Activities** (ammonia and glass production, refining, etc.) **currently using hydrogen as a feedstock in its "gray" form**; and also

(ii) **Activities currently relying on fossil fuels** (the case in **steel production**, with the substitution of hydrogen for coal in the direct reduction process used to obtain iron).

Concurrently, in the **mobility sector**, **hydrogen fuel cell technology can address certain of the constraints besetting electric battery technology** (low autonomy, lengthy charging time, battery mass, etc.), **ushering in a decarbonisation of**:

(i) **Personal transport** (passenger vehicles); and also

(ii) **Collective transport** (buses and, in time, aircraft and ships); and

(iii) **Commercial vehicles** (heavy-goods vehicles, waste collection trucks, etc).

Finally, in the **energy sector**, **the use of hydrogen is seen as a lever in preserving the economic value of assets currently reliant on the use of gas for the generation of electricity and heat, as part of a successful transition of contemporary economies towards climate neutrality**. At the cost of a partial transformation (retrofit) so as to burn hydrogen in the case of gas-fired power plants or transport hydrogen in the case of gas transmission and distribution systems, these assets would retain their role in a low-carbon economy.

1.1. Huge investments expected out to 2030 across the entire value chain

A report published recently by the Hydrogen Council[4] confirms there has been an **unprecedented intensification of efforts on the part of both the public and private sectors to develop the production of hydrogen and its end-use**, with to date:

(i) **The release of hydrogen roadmaps by more than thirty countries**; and

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[1] The general purpose of this research paper is to analyse financing conditions specific to the green hydrogen value chain, from its production (using electrolysis powered by electricity obtained from low-carbon energy sources) to end uses. Note, however, the end-uses are the same whatever the method of production of the hydrogen and its colour.

[2] Three recent political developments illustrate the growing awareness of the challenges presented by climate change at the level of OPEC+ countries: the decision of the United States to rejoin the Paris Agreement following Joe Biden's election (January 2021); the announcement by China that it aims to achieve carbon neutrality by 2060 (September 2020); the European Union's decision to revise upwards its intermediate target, which is now to reduce greenhouse gas emissions not by 40% but by 55% below their 1990 level by 2030 (December 2020).

[3] Produced through water electrolysis powered by low-carbon sources of electricity (renewable and nuclear energies), green hydrogen is obtained using a climate-neutral production process. This is in stark contrast to so-called gray hydrogen obtained using steam methane reforming (SMR), a process that remains dominant in the world (accounting for 95% of hydrogen production). While this process is carbon intensive (global median intensity of 9kg CO_2 per 1kg of H_2), its carbon footprint can be neutralised by fitting the steam cracker unit with a carbon capture and sequestration system. This produces what is referred to as blue hydrogen. See general study published in December 2020 by Natixis on the hydrogen sector, which contains a presentation of gray, blue and green hydrogen production, "**Low-carbon hydrogen: sensing the path to large-scale deployment**". Note that, at the level of the European Union, the inclusion of electrolysis powered by electricity obtained from nuclear energy in green hydrogen production processes is controversial. The hydrogen obtained in this way is often referred to as purple hydrogen to distinguish it from other forms obtains obtained from renewable energy sources. In regulations governing hydrogen production (see below), the French State draws a distinction between this low-carbon electrolysis and processes powered by electricity obtained from renewable energy sources. For simplicity's sake, in this research paper, the term green hydrogen encompasses all low-carbon electrolysis processes.

[4] **https://hydrogencouncil.com/en/hydrogen-insights-2021"/**, February 2021.

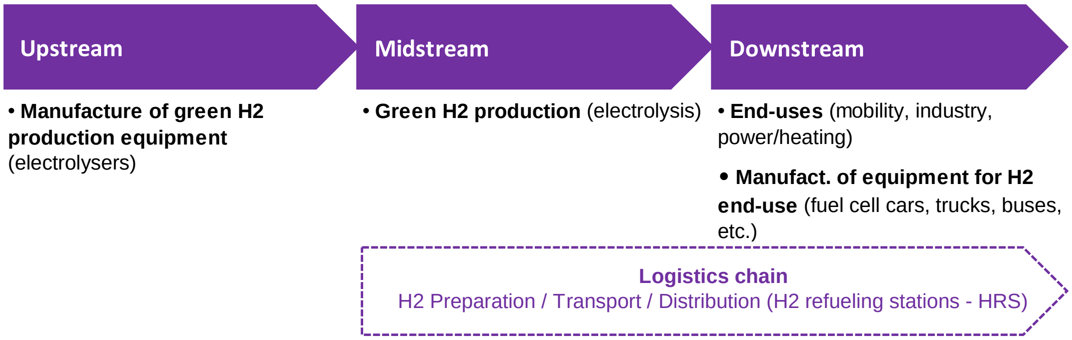
(ii) **The announcement of 228 large-scale hydrogen projects across the value chain**, of which 85% in Europe, Asia and Australia.

Still according to this report, **if all announced projects come to fruition, total investments will exceed $300bn through 2030**[5], with governments worldwide having committed more than $70bn in public funding.

The scale of the investments in the sector can be explained by the combination of three factors:

(i) **The need to set up a value chain** (production/distribution and storage/end-uses in the industrial, energy and mobility sectors - see below) building on near non-existent infrastructures.

Synthetic view of green hydrogen value chain



Upstream

- **Manufacture of green H2 production equipment** (electrolysers)

Midstream

- **Green H2 production** (electrolysis)

Downstream

- **End-uses** (mobility, industry, power/heating)
- **Manufact. of equipment for H2 end-use** (fuel cell cars, trucks, buses, etc.)

Logistics chain
H2 Preparation / Transport / Distribution (H2 refueling stations - HRS)

Source: Natixis

In the midstream segment of the value chain, the scale of the investments needed stems from both the quasi-embryonic installed electrolysis capacities (this process still accounting for less than 5% of total hydrogen production worldwide) **and the necessity to develop low-carbon electricity generation capacities to power electrolysers**. In this respect, France constitutes an exception: as fossil fuels account for a very slight share of total electricity production (less than 5%), it can be envisaged to produce hydrogen at low-carbon electrolysers powered directly from electricity supplied by the national grid. By contrast, **in most developed economies, electricity generation still relies substantially** (at least or more than 30% of the electricity mix) **on fossil fuels** (mainly coal and gas), **making it necessary, at this stage, to develop low-carbon electricity generation capacities dedicated specifically to supplying electrolysers**.

Much the same issue can be observed across the logistics chain, due chiefly to the difficulties raised by the potential use of natural gas networks for hydrogen's transmission to end-users. While there is a clear economic benefit in that it would of itself open up end-uses for hydrogen, this solution faces two technical hurdles: first, for reasons having to do with safety, there are limits to the proportion of hydrogen that can potentially be blended with natural gas and piped using existing networks (generally up to 10% for transmission networks and 20% for distribution networks[6]); second, in the mobility and industrial sectors, where the use of hydrogen would be of direct interest in the decarbonisation of the economy (see above), the molecule needs to be supplied in its purest form, therefore ruling out its transmission over natural gas networks. These factors explain both the emergence of a logistics chain dedicated to hydrogen (with, in the case of land transport, compression stations, dedicated vehicle fleets and refuelling stations) and the development of projects to concentrate at one specific geographical location both hydrogen production and end-uses (see below).

This synthetic view does not include the logistics value chain associated with the international supply of green hydrogen, which requires a liquefaction or conversion in ammonia, transport by sea, re-gasification or reconversion into hydrogen at the point of import. Similar to the one for liquefied natural gas (LNG), the logistics value chain for hydrogen concerns as yet very limited volumes (chiefly between Australia and Japan), but it can be expected to expand substantially as part of the development of a global market and a specialisation by country/region across the value chain. Worth $5bn, **the NEOM project in Saudi Arabia announced in July 2020[7] illustrates the case of an international value chain largely replicating that of LNG and involving long-term international buyers (Air Products) set to develop in the years to come**.

(ii) **Sector cost competitiveness is still no match for incumbent, even emerging solutions in the industrial and mobility sectors**. In the report it published in January 2020 on the sector's cost perspective[8], the Hydrogen Council estimated that approximately $70bn of investments would be needed for hydrogen

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[5] Of which $80bn can currently be considered "mature" according to this report.

[6] Dealt with at greater length in the abovementioned study published in October 2020 by Natixis, "**What role for natural gas in the transition towards a low-carbon economy**".

[7] There is a detailed analysis of this project in the abovementioned study published in December 2020 by Natixis, "**Low-carbon hydrogen: sensing the path to large-scale deployment**".

[8] **https://hydrogencouncil.com/en/path-to-hydrogen-competitiveness-a-cost-perspective/**, January 2020.

technologies to achieve cost parity with their lowest cost low-carbon alternative. It also estimated that for there to be cost parity with their lowest cost fossil fuel alternative, $150bn of investment would be needed.

This lack of cost-competitiveness is particularly crying when it comes to the production of low-carbon hydrogen compared with the dominant process (steam methane reforming without CCS). The production of blue or green hydrogen remains considerably costlier than the production of gray hydrogen (1.5 to 5x costlier for blue hydrogen, 2x to 7x costlier for green hydrogen - see table below).

Comparison of production costs for gray, blue and green hydrogen

(€/kg)	Gray hydrogen	Blue hydrogen	Green hydrogen
BNEF	0,71-2,29	1,34-3,34	2,53-4,57
Gas4climate	1,05	1,42-1,52	2,64-3,71
IEA	N/C	1,42-2,26	2,87-7,35

Sources: BNEF (2020), Gas4Climate (2020), IEA (2019)

The insufficient cost-competitiveness of the hydrogen production sector is also an issue not just compared with natural gas, but also, albeit less so, compared with its quasi-renewable substitute, biomethane (see table below).

Comparison of production costs for the different types of hydrogen and biomethane, and with natural gas import prices in Europe (TTF - Netherlands)

(€/MWh)	Biomethane	Gray hydrogen	Blue hydrogen	Green hydrogen	TTF - natural gas price ref. (1)
BNEF	N/C	19-61	35-90	67-123	17 (2)
Gas4climate	70-90	28	37-41	70-100	
IEA	c.60	N/C	37-61	76-198	

(1) Netherlands-based importation price reference / (2) Public price at 12/02/2021

Sources: BNEF (2020), Gas4Climate (2020), IEA (2019)

(iii) A corollary of the previous factor, **the sheer size of the asset base that will be needed across the value chain to achieve effects of scale and enable the sector to move nearer to cost parity**. In its 2020 report, the Hydrogen Council estimated that 70GW of electrolyser capacity would need to be deployed worldwide for green hydrogen to be competitive, equivalent to an investment of $52.5bn based on a unit cost of $750/KW in 2019.

1.2. Business models and funding arrangements still heavily dependent on public sector support

The sector's development still being at a very early stage and responsible for the lack of cost competitiveness compared with the dominant processes/technologies in the energy, industrial and mobility sectors, this has **direct implications for project structuring and financing**:

(i) **In the private sector, projects involving green hydrogen in the energy and industrial sectors (chemicals manufacturing and refining activities) are still at the pilot phase, initiated by energy producers and industrial concerns keen to develop a learning curve in this promising, but still nascent activity**. These **private sector sponsors** (generally international groups that are leaders in their field and enjoy privileged access to the capital markets)[9] raise their **own financial resources, hoping that at a later development stage they will benefit from the recently announced aids at national level** (such as the France Relance 10-year plan) and at **European level** (EU Green Deal) (see below);

(ii) **In the mobility sector, the deployment of electrolysers and refuelling stations** (see detailed presentation of value chain below) **combined with rolling stock fuelled by hydrogen** (buses, taxis, waste collection trucks, trains, etc.) **generally concerns captive fleets providing a public service**, hence managed by public sector bodies or private firms under concession agreements. These services generate revenues that are fixed or regulated by the authorities. At local and national level, deploying captive

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[9] Our understanding is that this is the financing arrangement chosen by Engie and Total for the development of the MassilHYa project announced at the start of the year (production of green hydrogen using electricity generated from solar photovoltaic energy, with the production supplied to begin with to Total's La Mède bio-refinery). Note that the credit ratings of both Engie (BBB+/Baa1/A) and Total (A/Aa3/AA-) are solidly anchored in the Investment Grade category, for which reason both groups have very broad access to the capital markets in a near zero interest rate environment that is kept this way by the QE policy being continuously pursued by the European Central Bank (see below).

hydrogen-powered fleets is therefore likely to depend on the commitment of local authorities/governments to decarbonising public transport/infrastructure. In these cases, **the funding of hydrogen projects is very largely public, in the form of subsidies granted by the national government and/or the European Union, combined with public and private partnerships**, with the creation of ad-hoc legal entities to roll out electrolysers and the signing of long-term purchase agreements to supply hydrogen to local public transport firms (a case in point being the Dijon Métropole Smart EnergHY project[10]) (see below insight into public support schemes).

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[10] The €6.5m investment for the project's first phase will be funded for more than 50% by ADEME (€3.4m). There is a detailed analysis of this project in the abovementioned study published in December 2020 by Natixis, "**Low-carbon hydrogen: sensing the path to large-scale deployment**".

2. Business models still being bedded down across the value chain

With a multitude of projects around hydrogen and the gradual structuring of government policy to provide long-term support, a green hydrogen sector is emerging.

For project developers and potential funding providers, gaining an understanding of the sector is complex in that it sits at the crossroads between the energy, industrial and mobility sectors and brings together different interlinked segments, each with one if not more business profiles. A structuring of each of these segments is under way around business models that are themselves likely to undergo a profound evolution over time, prompted by the likely transformation of the logistics chain (development of hydrogen-specific transport infrastructures expected from 2030 in Europe).

Concurrently with the emergence of business models in the different segments of the value chain, public support is intensifying, taking on an increasingly more “systemic” form. In Europe, for instance, to initial mechanisms focused on the deployment of equipment used in the production and utilisation of green hydrogen are being added gradually mechanisms to support hydrogen demand, with also a start being made to defining a regulatory framework for assets across the value chain.

2.1. Complex value chain spanning several business lines...

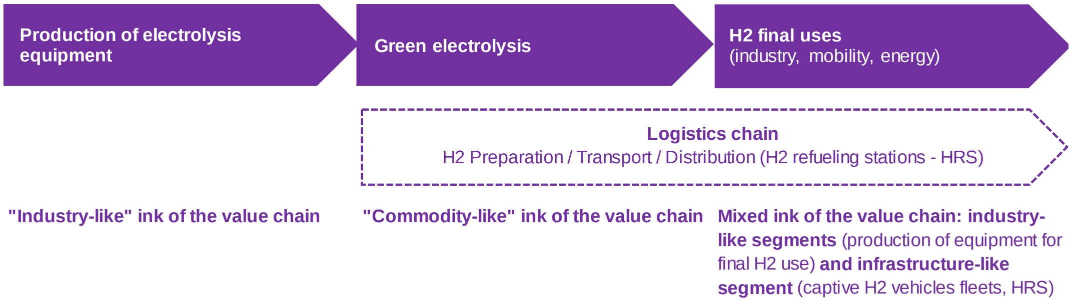
Gaining an understanding of the green hydrogen value chain is challenging, for three main reasons:

(i) It harnesses **assets from three different sectors** (energy, industry and mobility);

(ii) It **spans interlinked activities each with their own business profile, even two quite distinct types of activities in the case of the downstream segment**, in terms of the market being served and the underlying operational risk.

While the upstream segment has an industrial business profile, activities in the downstream segment are composed of assets/equipment in the nature of infrastructures (refuelling stations, collective equipment such as buses or waste collection trucks) along with industrial activities to manufacture these assets/equipment.

Green hydrogen value chain: business profile of different segments



Source: Natixis

For project developers and potential funding providers, the value chain’s different segments and their eventual sub-segments present risks that are specific as well as interdependent. That is the case of the markets for electrolysers and downstream equipment: both face specific threats and challenges, but both are also dependent on the level of global demand for hydrogen.

(iii) Finally, the value chain is currently **structured around a logistics chain that is susceptible of undergoing a substantial evolution in coming years and decades**.

Hydrogen is still consumed predominantly at the location where produced, through closed industrial circuits. Otherwise, since recourse to gas networks does not allow the transmission of hydrogen in its purest form through to end-users in the industrial and mobility sectors (see above), **the hydrogen logistics chain is structured around land transport using trucks (the hydrogen needing to be compressed before transport) and maritime transport using tankers**, in as yet far smaller quantities in the second case (see above). Keep in mind that, when using land conveyance, **compressing and trucking hydrogen to refuelling stations accounts for nearly 20% of the cost borne by the end-user**[11].

For this reason, **the option being currently privileged for the development of green hydrogen is to concentrate its end-uses around its production site**, with closed-circuit industrial projects or territorial

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[11] https://hydrogencouncil.com/en/path-to-hydrogen-competitiveness-a-cost-perspective/, January 2020. See also the abovementioned study published in December 2020 by Natixis, “Low-carbon hydrogen: sensing the path to large-scale deployment”, p. 26.

hubs bringing together equipment/infrastructures for the production and application of this gas at a precise location or within a narrowly defined territory.

However, it is likely that **in a scenario where there is a broader dissemination of hydrogen in the economy and an expansion of demand, this would ultimately lead to the deployment of autonomous onshore and subsea transmission systems**. This deployment, which is conceivable from 2030-2035, would bring about a sharp reduction in transport costs and means that end-use markets could be some distance away from hydrogen production sites.

2.2. ... each with their own threats and challenges

As indicated above, **the green hydrogen value chain can be analysed as the combination of three different types of activities**:

(i) **Industrial activities** in both the upstream segment (manufacture of electrolysers) and in the downstream segment (manufacture of equipment for hydrogen end-use applications) of the value chain.

(ii) **Production activities**, using low-carbon electrolysis to supply an energy commodity.

(iii) **Infrastructure activities**, to enable the conveyance of hydrogen to end-use markets and its distribution to collective equipment used for public transport (buses) and municipal waste collection (trucks).

Business profiles across the green hydrogen value chain: addressable markets and associated threats/challenges

Business profile	Segments / assets concerned	Addressable market	Associated risks / challenges
Industry	• **Manufacture of electrolysers** (components, assembly) • Manufacture of downstream equipment allowing final use of H2 (industry, mobility, industry)	• **Global market** given the multiplicity of potential green H2 production areas	• **Inadequacy of the products offered with the demand** (cost, specifications) • **Overcapacity** • **Competition within the segment** (price, technical specifications) • **Competition** from established or alternative equipment and technologies
Commodity production	• **Green electrolysis** (electrolysers + low-carbon electricity sources)	• **Market today local** through the conclusion of hydrogen purchase contracts under private law (HPA) • **At some point in the future, market partly national** with the expected introduction of public support systems (additional remuneration following calls for tenders) • **Potentially global market** depending on the development of global demand and transport infrastructure	• Save for very specific instances, **lack of cost competitiveness compared to the gray hydrogen sector** • **Technical risk** (construction and operation of electrolysers) • **Double counterparty risk**: seller of low-carbon electricity and buyer of green H2 • **"Merchant" risk** in the event of a mismatch between the duration of the contract for the purchase of green H2 and the lifespan of the
Infrastructure	• **Compressor stations and transport trucks** • **H2 charging stations** (HRS) • **H2-fueled collective equipment** (buses, dumpsters, taxis) • **Eventually**, depending on demand, **dedicated infrastructures for the delivery of H2** (transport and distribution networks)	• **Market for the moment local** (near the electrolysers) for recharging stations and collective equipment • **At some point in the future, national and international market** in the event of changes in demand justifying the development of transport infrastructure dedicated to H2 (land and submarine networks, logistics chain for maritime transport)	• **Economic "value" dependent on the end use** of the molecule it supports: • **Oversized**, the infrastructure induces an **additional cost** for the end user / community (when the development cost is shared) • **Undersized**, it constitutes a **bottleneck** for the development of the sector • For charging stations, **potential competition from various deployment methods**, putting de facto assets in competition

Source: Natixis

As highlighted by the table above, for project developers and potential capital providers, these **three main sectors of activity have specific characteristics, in turn presenting specific challenges and threats**.

Broadly speaking, **firms present in the "industrial" segments of the value chain operate in what is a global market**. **Challenges/threats are essentially of a commercial nature, being those typically associated with any competitive market**: having a product offer that is tailored to demand, sizing the production base/volumes produced to the size of the addressable market, and fending off competition within this sector of activity from peers as well as from incumbent processes/technologies (hence more cost effective at this nascent stage in the development of hydrogen[12]) and emerging alternatives.

As regards **the actual production of green hydrogen using electrolysis, this can be assimilated to the production of a commodity in that it concerns a gas that can be used as an energy source (in the energy and mobility sectors) or as an input (in the industrial sector)**. As was the case for renewable energies (wind, solar photovoltaic) a decade and a half ago, this activity is battling with its lack of cost competitiveness compared with gray hydrogen (see above). For this reason, but also due to specific constraints concerning the transportation of hydrogen (see above), there follows that **the development of**

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[12] For downstream equipment, the issue of cost competitiveness is illustrated by the price differential between fuel cell electric vehicles (FCEV), battery electric vehicles (BEV) and conventional internal combustion engine (ICE) vehicles. In the case of medium-sized sedans, after stripping out subsidies, the Toyota Mirai sells for twice the price of a BMW Series 3 (ICE) and for 50% more than the Tesla 3 (BEV).

low-carbon electrolysis capacity is being conducted at local level, with the buyer(s) willing to accept an extra cost associated with the mode of production. **Recently announced projects in Europe fall into two broad distinct categories**:

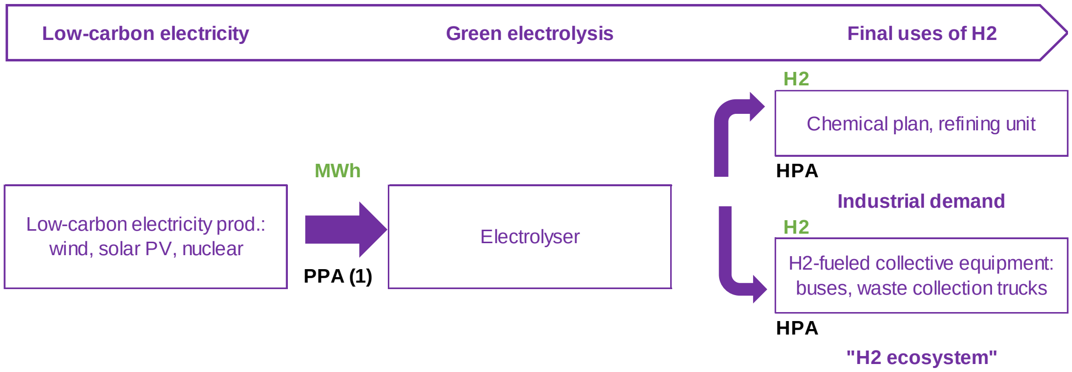
(i) **Territorial hubs**, as aforementioned, the intention being to concentrate hydrogen end-uses around local public services (public transport, waste collection).

(ii) **Closed-circuit industrial projects**, where hydrogen is produced to meet a specific industrial need; there follows that electrolysers will be located in the immediate vicinity of the industrial site transforming/using the hydrogen that has been produced (one illustration is the partnership between Iberdrola and Fertiberia for a project at Puertollano in Spain involving the production of green hydrogen relying on a solar photovoltaic energy source, this hydrogen then being supplied to the nearby ammonia plant)[13].

In both cases, green hydrogen is sold to the end-user(s) under a long-term hydrogen purchase agreement (HPA), with a term that will be as near as possible that of the power purchase agreement (PPA) between the electrolyser's operator and the producer(s) of the low-carbon electricity needed for the production of the green hydrogen. The HPA will obviously reflect the conditions governing the purchase of electricity under the PPA (alternatively the cost of production of the electricity when the electrolyser's operator is an autoproducer of low-carbon electricity).

Save in the case where the low-carbon electricity and green hydrogen are produced by the same party[14/15], **structuring local green electrolysis projects implies establishing a double chain, both physically and contractually**. Within this framework, the challenges and threats are much the same as for the development of renewable energy projects, but in effect are doubled up given the existence of this dual physical and contractual chain: technical risk during the construction and operation of the electricity generation plant and green hydrogen production plant, counterparty risk in the execution of the PPA and HPA, residual merchant risk for the operator of the electrolyser when the term of the HPA is less than the life of the green hydrogen production plant.

Green electrolysis: physical and contractual flows for current local projects



(1) PPA between the operator of the electrolyser and the low-carbon electricity supplier when these activities are not carried on by the same player.

Source: Natixis

Finally, the different infrastructure activities of the sector's value chain bring together engineering works/equipment forming the logistics chain from the hydrogen's production to its end-uses (currently compression stations, transport vehicles, tube trailers, hydrogen refuelling stations, but in time dedicated transmission and distribution networks - see above), along with **hydrogen powered collective equipment** (buses, waste collection trucks, etc.).

By definition, **engineering works/equipment** constitute a series of infrastructures serving a specific purpose (transport, heating, etc.) in a given territory. For this reason, infrastructures **need to be both**:

(i) **Correctly sized to serve this purpose such as it is now**, the intention being to avoid extra costs being incurred by the user/local authority if oversized, but also bottlenecks hampering the development of end-uses if undersized; and

(ii) **Designed to be scalable in order to keep pace with the upturn in end-uses**.

In the case of green hydrogen, and as indicated above, part of the civil engineering works/equipment making up the current logistics chain (compression stations and tube trailer fleets for onshore transport) will become

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[13] There is a detailed analysis of this project in the abovementioned study published in December 2020 by Natixis, "**Low-carbon hydrogen: sensing the path to large-scale deployment**".

[14] For certain green hydrogen production projects responding to a strictly industrial demand such as those, mentioned above, linking Iberdrola and Fertiberia, on the one hand, and Engie and Total, on the other hand, we note that the production of renewable electricity and that of green hydrogen are provided by the same entity (Iberdrola in the 1st case, Engie in the 2nd). From the point of view of the development of low-carbon electrolysis projects, this partial vertical integration scheme avoids the complexities linked to the existence of a double physical and contractual chain (PPA then HPA) for production and the sale of green hydrogen.

[15] An alternative model to these operational and contractual schemes that could be envisaged in France given the national electricity mix (see above), would be the development of grid-based electrolysis.

redundant once demand has reached a level justifying financially the development of networks dedicated to the transmission of hydrogen from its production site to end-users.

Furthermore, as is generally the case for infrastructures, engineering works/equipment would not face competition, in any given territory, from similar engineering works/equipment since their duplication in this territory would not bring about a reduction in the unit cost. For this reason, **the costing of these engineering works/equipment is not determined through the play of competition but reasoning in terms of their tarification**[16]**/**[17]. The price for their use is generally determined such that the operator covers investment and operating costs and earns a margin reflecting the business profile/extent of the underlying risk. **Ultimately, therefore, it is the user(s) of the infrastructure (individual, firm or local authority) that pay for the development and maintenance of the infrastructure**. For collective equipment providing a public service (public transport, waste collection), billing for its use is through a local authority agency or a private contractor under a concession agreement[18].

From the standpoint of the sector's general development, the interest of deploying collective equipment powered by green hydrogen lies in the possibility to pool extra costs linked to its production and end-uses under a precisely-defined legal and financial framework for the different stakeholders: all the different costs supplying the service (production of green hydrogen, installation and maintenance of refuelling stations, deployment and maintenance of the captive vehicle fleet) can be passed on to the user in an exhaustive and transparent manner.

The analysis of the emerging green hydrogen value chain therefore reveals there are three main sectors of activity, whose current development is exposed to specific challenges/threats:

(i) For **industrial activities**: **weak global demand for hydrogen outside existing end-uses** in industry as an input in the form of gray hydrogen, **narrowness of market** for upstream and downstream equipment, and still **limited degree of industrialisation for production processes**, in turn leading to **steep equipment costs** for end-users[19].

As a consequence, these activities still generate small, if not negative operating cash flows for the different players concerned[20], this being manifest for specialised players, as highlighted by the table below that covers a representative sample of sector players:

2017-2020 operating cash flows for a sample of players involved in hydrogen industrial activities

Local currency (thousands)	2020	2019	2018	2017
Ballard (CAD)	N/D	-14 230	-31 688	-9 768
Gaussin (EUR)	N/D	-621	-8 145	-8 379
McPhy (EUR)	N/D	-7 495	-7 015	-6 701
Nel (NOK)	-220 297	-204 429	-172 239	-120 769

Source: companies

(ii) **Green hydrogen production**: **lack of cost competitiveness** compared with the production of gray hydrogen.

(iii) **Infrastructure activities**: **steep transport and distribution costs for green hydrogen**[21] on account of the currently weak demand, **steep costs operating collective equipment**, **hence difficulties for local authorities to finance the equipment and/or pass on the extra cost to the end-user**.

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[16] This does not preclude there being competition between firms to build/install these engineering works/equipment, accomplished by staging public tenders.

[17] This general principle applies to so-called natural monopoly infrastructures which include all assets with fixed costs such as to make any competition in the market in question impossible. This is the case with electricity and gas transmission and distribution networks. In the hydrogen sector, charging stations, which currently cost around $2,000/kg capacity, do not fit into this scenario. The risk - theoretical at this stage - mentioned in table p.7 of situations of competition between charging stations must therefore be taken into consideration, with, on the one hand, the equipment deployed by local authorities within the framework of regional hubs, and, on the other, similar equipment deployed by private groups in the energy sector pursuing a vertical integration strategy in the hydrogen sector.

[18] Public service delegation in France.

[19] As illustrated in the passenger car market (see above).

[20] The construction of electrolysers is an activity carried out by independent specialists (such as Norway's Nel or France's McPhy) or the subsidiaries of diversified industrial groups (such as Siemens Energy and ThyssenKrupp). Much the same typology for the manufacture of hydrogen powered vehicles/equipment, with independent specialists (such as Canada's Ballard and France's Gaussin for fuel cell systems) and full-line carmakers (such as Japan's Toyota and South Korea's Hyundai).

[21] According to the study published in January 2020 by the Hydrogen Council (see above), for a total production cost of $4/kg, the full transportation costs (land transport and distribution) would represent almost two thirds of the cost borne by the end-user, of which 40% in respect solely of distribution costs (refuelling stations).

3. Public sector to play a crucial role in the sector's coming of age, with conditions set to evolve over time

As indicated in the introduction, **the last 18 months have seen quite a change in the scale of the support extended by governments to the hydrogen sector**, with massive packages of measures announced last autumn in Europe as part of the economic stimulus plans. The €7.2bn of measures recently announced by the French government through 2030 is in stark contrast with the €100m promised for the sector back in 2018. All in all, out of the $70bn in public funding pledged by the different governments to support the sector (see above), more than half is from EU Member States in coordination with the European Commission (see table below).

EU-28 and leading Member States: stimulus plans announced in Q3 and Q4-20 and measures to support hydrogen

	Overall recovery package	H2 support plan	Main H2 development objective
EU-28	€750bn	N/D	Electrolysis capacity of 40 GW by 2030 (2)
France	€100bn	€7.2bn	Electrolysis capacity of 6.5 GW by 2030
Germany	€130bn	€9bn	Electrolysis capacity of 5 GW by 2030
Italy	€209bn indirectly (1)	€10bn	Electrolysis capacity of 5 GW by 2030
Spain	€140bn indirectly (1)	€9bn	Electrolysis capacity of 4 GW by 2030

(1) Italy and Spain have been allotted €209bn and €140bn, respectively of the EU's €750bn Recovery Fund / (2) In addition to this objective of deploying 40 GW of electrolysers, the EU has set for iself is an objective of contracting 40 GW of capacity with third-party countries

Sources: various, Natixis

Broadly speaking, **support measures announced by governments** seek to address the three large categories of challenges/threats mentioned above to which are confronted players present in the different segments of the value chain, **the objectives being of three orders**:

(i) **Contribute to lowering cost of production for low-carbon hydrogen**, thereby bringing usage cost nearer levels for more established technologies/solutions

(ii) **Encourage the dissemination of hydrogen end-uses** in the industrial and mobility sectors.

(iii) **Improve equipment performances**, in particular for the electrolysis process in order to speed up green hydrogen's path to cost competitiveness[22].

While these three main objectives generally feature in the plans announced by OECD+ countries[23], the intensity of the public sector effort can vary significantly from one country to the next, depending on the national strategy defined for hydrogen. Not being endowed with much by way of natural resources (wind and solar energies), Japan is banking rather more on supporting demand for hydrogen to stimulate its manufacturing sector (production of vehicles and capital goods using hydrogen as an energy source) than on the development of low-carbon electrolysis capacities at national level.

A quick review of the different government announcements these past 18 months shows an **overlap in the two main types of government support**, between measures that are already in place and others that are to be implemented gradually. **This situation reflects a more systemic approach to the use of hydrogen in the decarbonisation of the industrial and mobility sectors, with also as a corollary the ambition to gradually normalise conditions for the development and operation of assets/equipment across the value chain**.

3.1. Direct support for equipment deployment across the value chain

For the first level of support for the development of the hydrogen sector through 2020, **the objective of the authorities is to facilitate the deployment of assets/equipment across the value chain by extending direct or indirect subsidies, the underlying logic being to co-finance projects**. This deployment rests on three complementary pillars:

(i) **Supporting large-scale electrolysis projects (i.e. so-called giga-factories)**: the objective here is to achieve economies of scale in the upstream segment of the value chain so as to lower the production cost for green hydrogen and thereby stimulate demand through a convergence of economic fundamentals for downstream uses towards those for incumbent technologies.

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[22] Electrolysis being an energy-intensive process whose cost competitiveness is determined more by the cost of the electricity used (opex) than the initial cost of the equipment (capex), an improvement in the load factor of the electrolyser will act as a powerful lever in driving down hydrogen's cost of production. The load factor for electrolysers currently reaches between 50% and 70%. Scenarios that see the cost of production of green hydrogen landing at $2/kg by 2030 are generally based on an improvement in the load factor to between 80% and 85%.

[23] Full members of the OECD + China that participates as a member, associate or participant in several OECD bodies.

At European level, inclusion of hydrogen projects[24], **in particular through the development of giga-scale electrolysers in the framework of Important Projects of Common European Interest (IPCEI)** will enable Member States, alone or working together, to finance initiatives beyond the limits normally governing state aid set by European regulations. It is pursuant to this initiative that France intends to extend €1.5bn of support to develop the upstream segment of the value chain by 2030.

(ii) **Supporting the development of green hydrogen-centric local ecosystems**. Through the EU **Hydrogen Valleys** initiative bringing together pioneering European regions and the European Union, as well as through the support being extended to local authorities to promote hydrogen **territorial hubs** as part of its national economic stimulus plan, the goal pursued by the French government is to concentrate the production of green hydrogen and its uses at local level, in so doing fostering hydrogen's use in the industrial and mobility sectors.

In this case also, **support mechanisms take the form of hydrogen-centric project co-financing** involving various public sector players (European Union, Member States and local authorities, from regions all the way down to urban agglomerations and towns[25]) and private sector players providing and/or operating the installations (a good illustration of this support mechanism is provided by the Dijon Métropole Smart EnergHY project).

(iii) **Supporting the nascent market for fuel cell electric vehicles (FCEV), by setting development objectives for the fleet and providing direct subsidies to users**, thus encouraging investment in the country's automotive industry. In this area, China stands out for having a particularly ambitious programme for the deployment of fuel cell electric vehicles.

OECD+: typology of public support mechanisms for the deployment of equipment across the hydrogen value chain

Type of public support	Relevant link in the value chain	Illustrations	Nature of public support
Electrolysers deployment targets	Upstream	**EU:** electrolysers capacity of 40 GW by 2030 **France:** electrolysers capacity of 6.5 GW by 2030	Direct subsidies to build upstream equipment ("Giga factories")
FCEVs deployment targets	Downstream (mobility)	**China:** FCEVs ≥ 1 million by 2030	Central and local financial subsidies
HRS deployment targets	Downstream (mobility)	**China:** HRS >1,000 by 2030	Hydrogen refueling station incentive through central government subsidies to local authorities (29 cities part of a pilot programme
PPPs at local level for green H2 mobility	Downstream (mobility)	**France** (métropole de Dijon): development of green H2-centric mobility ecosystem	Take-or-pay contractual arrangement between an H2 producer and a municipality deploying an H2-fueled fleet of buses, garbage trucks, etc.

Sources: various, Natixis

3.2. "Systemic" support to massify demand in the industrial and mobility sectors

Concurrently with the announcement of plans to support the deployment of equipment across the value chain, governments have launched other measures aimed at stimulating demand for hydrogen over the long term.

3.2.1. National measures to support demand in Europe…

Broadly speaking, as highlighted in the table below, these measures are of three types:

(i) **Fiscal incentives rewarding the use of green hydrogen in the industrial and mobility sectors**, in the form of exemptions from mandatory contributions (in France's case, from the energy climate contribution that can be assimilated to VAT on energy products) or tax credits for investment in the industrial sector to substitute hydrogen as an input for fossil fuels by (the case in the Netherlands).

(ii) **Subsidies for low-carbon investments in certain industrial sectors determined by valuing carbon emissions avoided thanks to the use of green hydrogen**. A programme under the name of Carbon Contracts for Difference (CfD) was announced last autumn by the German government, the intention being to use it in connection with pilot projects for the production of climate-neutral steel.

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[24] Analogous to the initiative already launched in the field of battery cell manufacturing.

[25] In France, note that the potential involvement of the different administrative levels (State, region, department, municipality) can cause an overlap in public aid.

(iii) **Use of public systems guaranteeing the origin of the hydrogen produced**. France has just announced the introduction of this type of mechanism through the issue of guarantees of origin and guarantees of traceability. With these certificates, the intention is to inform the buyer that the hydrogen is low-carbon and that, by purchasing this guarantee, the buyer is supporting the development of a virtuous industry.

European Union: typology of public sector support mechanisms for the development of hydrogen, more particularly low-carbon hydrogen

Type of public support	Targeted H2 use	Illustrations	Nature of public support
Direct tax benefit (companies)	Industry (refining)	**France:** exemption from the Climate Energy contribution	Tax exemption for companies replacing gray H2 with green H2 in the production of fuels
Direct tax benefit (companies)	Industry	**Netherlands:** tax credit on investments linked to H2	Tax credit of up to 45% on investments made to substitute hydrogen for fossil fuels as a raw material in industry
Subsidies for the use of green H2 linked to carbon allowance prices (companies)	Industry	**Germany:** pilot project of "carbon contract for difference" (CfD) in steel production	Subsidy mechanism applying to industry decarbonisation investments with green H2 calculated by the difference between the cost of the decarbonisation project and the cost of the carbon quotas that the installation would bear
Green H2 certificate of origin / traceability systems for buyers of the molecule	All	**France:** guarantees of origin (GO) and traceability (GT) of H2	System of certification of the origin of the hydrogen consumed without mixing (GT) / with mixing (GO) since its production. GTs cannot be sold regardless of the underlying quantity of H2 / GOs can be auctioned with a minimum sale price

Sources: various, Natixis

3.2.2. ... set to be ratcheted up in anticipation of expected tightening of EU ETS…

These measures to support hydrogen demand, particularly in such hard-to-abate sectors as industry and mobility, **constitute a first phase in the explicit "valorisation" by the public authorities of the hydrogen sector's contribution to combating climate change**. **As yet limited, these national initiatives** (particularly the carbon CfD programme in Germany) **are set to be levered up through "systemic" mechanisms implemented at the level of the European Union in order to achieve carbon neutrality by 2050**[26]**, in particular the EU Emissions Trading Scheme (ETS)**.

Having entered phase 4 (covering the period 2021 to 2030) this January, **the EU ETS is set to undergo profound changes in 2021 in order to address the European Union's new intermediate emission reduction target announced last December** (which is now to reduce greenhouse gas emissions not by 40% but by 55% below their 1990 level by 2030). As indicated in our recent analysis of the political developments underlying the world's different carbon markets[27], the adoption of more ambitious decarbonisation targets is set to have significant implications for the EU ETS. Expected evolutions should concern the sectors covered, the volume of emission allowances auctioned and the volume of free emission allowances allocated to sectors in theory covered by the mechanism (steel, cement, chemicals, refining, etc.) but which in practice circumvent the carbon constraint by virtue of the carbon leakage rule[28].

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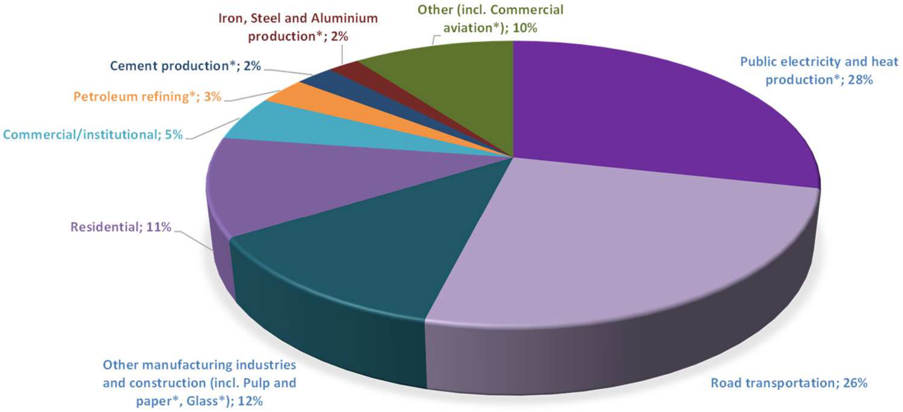
[26] It will be recalled that, according to the scientific community, attaining this objective is a necessary condition for the realisation of the Paris Climate Agreement signed in December 2015.

[27] See Natixis study: "**Strong political momentum for carbon markets**" (February 2021)

[28] Although theoretically within the scope of the EU ETS since its creation in 2005, a number of industrial sectors (steel, cement, chemical, glass, paper, refining, etc.) that might otherwise relocate their production outside the European Union (EU) receive special treatment in the form of a high share of free allowances, in effect covering a significant proportion of their carbon emissions.

Breakdown of carbon emissions in the European Union by sector of activity in 2017 (%)



* *Denotes sectors currently falling within the scope of the EU ETS*

Source: European Environment Agency

The European Commission (EC) is currently working on an overhaul of the EU ETS with a view to releasing a proposal for a directive this summer. Some changes are likely to be adopted earlier than others in order for European industry to have as much time as possible to adapt to new emission limits before 2030.

Changes envisaged are of three main orders:

(i) **Inclusion of new sectors in the EU ETS**. The EC wants to include the intra-EU emissions of the maritime transport sector, possibly those from other sectors such as building and road transport, extending potentially to all activities using fossil fuels as an energy source. Alternatively, the public consultation indicates that these sectors could be covered by a new ETS, eventually with links to the existing scheme.

(ii) **Accelerated reduction in the allocation of free allowances**. The EC envisages accelerating the reduction in the volume of free allowances allocated to sectors receiving special treatment under the carbon leakage rule. Concurrently, it is considering a mechanism that would result in the taxation of imports in these sectors, the so-called Carbon Border Adjustment Mechanism (CBAM).

(iii) **Reduction in the volume of carbon allowances auctioned each year**. This could be accomplished in a variety of ways, for instance by increasing the reductions in the cap at more than the current annual pace of 2.2% (as set in 2017) and/or making more aggressive use of the Market Stability Reserve (MSR) mechanism. The latter is currently being used to reduce the surplus of emission allowances in circulation by withdrawing from the market a fixed part of total allowances having been auctioned (currently 24% until 2023). Another option being considered by the EC is the mandatory cancellation of allowances for the emissions of coal-fired power plants at the time of their closure.

In light of these different elements, **the upcoming ETS overhaul should end up creating a dearth of emission allowances, causing their prices to trend higher**, which is what is suggested by their recent evolution (see chart below) as well as the base-case market scenarios out to 2030 provided by a group of analysts at the request of the EC, with prices of between €56/t and €89/t[29]).

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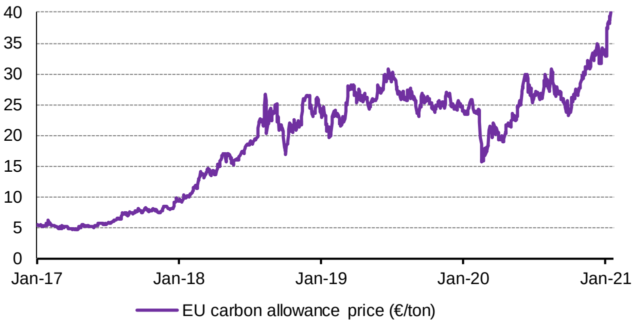
[29] See **https://www.spglobal.com/platts/en/market-insights/latest-news/coal/120320-analysts-see-eu-carbon-prices-at-eur56-eur89mt-by-2030**

ETS: change in the price of carbon allowances since 2017 (€/t)



Source: Bloomberg

Hard-to-abate sectors that have been excluded from the EU ETS (transport) or receive a special treatment (industrial activities exposed to a relocation risk) **are therefore very likely in coming years to face the emergence of a carbon constraint or its intensification**, which will prod these sectors into making significant investments to decarbonise their asset base. **The opinion of all ETS observers is that the underlying objective with the ongoing reform is not just to have carbon-emitting sectors bring in-house the cost of their climate externality but to encourage them**, through the price signals sent by carbon allowances, **to undertake the investments needed to reduce and, ultimately, eliminate their carbon footprint**.

Within the European Union, these expected regulatory developments constitute a powerful lever to potentially support demand for low-carbon hydrogen, particularly green, in the industrial and mobility sectors in coming years.

3.3. Are we set for regulated mechanisms across the value chain?

In Europe, in addition to these policies to support the deployment of equipment and the development of demand, **initiatives are starting to dawn to boost directly the profitability of the electrolysers**. **These developments deserve to be underlined, as they could pave the way for the introduction of regulated mechanisms in the infrastructure segment of the hydrogen value chain**.

In France, a statutory instrument (“ordonnance”) was published on 17 February 2021 by the French government[30] that defines a framework intended to support low-carbon hydrogen and guarantee its traceability. Besides the introduction of a system of guarantees of origin and guarantees of traceability to support low-carbon hydrogen (see above), this instrument introduces a direct support mechanism for low-carbon electrolysis capacities. This mechanism consists of two phases: a first phase to preselect offers; a second phase to institute a competitive dialogue, so as to select candidates and adjust support to those having been chosen under a contract offering an additional remuneration, and, depending on the circumstances, investment aids. **The precise conditions of the support extended by the government remain to be defined, but the general understanding is that**:

(i) Contracts entered into by the State and parties having been selected will not be for periods in excess of 20 years.

(ii) It will be possible to benefit from both this mechanism and other fiscal aids (not stipulated at this stage, but these will probably consist in full depreciation over one year of the cost of the electrolyser) so long as the return on capital employed does not amount to more than what would be considered a reasonable remuneration.

In practice, **the additional remuneration granted under this mechanism would function as a subsidy covering the difference between the cost of the green hydrogen produced and the reference cost for the production of gray hydrogen**.

Concurrently, **other avenues are being explored in France to devise mechanisms to support low-carbon electrolysis by acting on the cost of electricity**, bearing in mind it accounts for some 70% of the total cost of an electrolyser. Two possibilities are being considered:

(i) **Implementation by the French State of a regulated price for the electricity supplied to low-carbon electrolysis** (i.e. powered by electricity obtained from renewable or nuclear energy sources). In practice, this could take the form of a subsidy paid to the operators of electrolysers, corresponding to the difference between the regulated price and the actual price of the electricity supplied (under a PPA with dedicated capacities, directly from the national grid or under an agreement with an electricity supplier).

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[30] See **https://www.legifrance.gouv.fr/jorf/jo/2021/02/18/0042**

(ii) Extension of **special off-take rights to the operators of electrolysers to supply off-peak electricity produced by hydro-electric power plants**.

Another mechanism envisaged would be to award electrolyser operators a bonus corresponding to the energy storage value offered in the electricity sector. The storage value for an electricity system can be considered as being expenditure to strengthen the grid avoided as a result of the storage of excess renewable energy, also as the value of the electricity produced from nuclear energy during off-peak periods in terms of demand (such as the summer) to supply electrolysers.

As regards hydrogen-specific infrastructures, the above statutory instrument mentions a "specific regime" for assets dedicated to the transmission and distribution of hydrogen, but does not elaborate. Our understanding of this regulatory initiative is that it opens the way over an unspecified horizon for the implementation of a regulatory framework for hydrogen-specific infrastructures. As indicated above, the evolution in demand will in time lead to the development of dedicated networks for hydrogen transmission and distribution connecting the different territorial hubs across France and Europe, **a development justifying the pooling of hydrogen's transport costs, on the lines of what has been done for the transmission and distribution of natural gas**. Typically, this transport cost pooling logic is already what underpins aid mechanisms to the sector being developed at European level, with the inclusion of hydrogen transport projects within the scope of the IPCEI (see above).

4. Mobilising private finance, a condition precedent for the sector's development

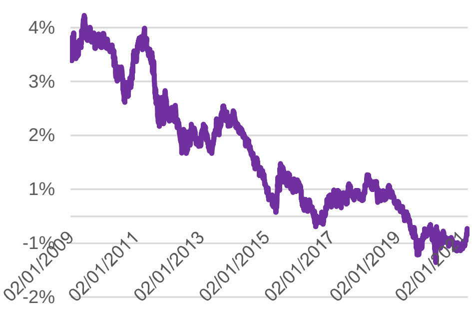
The involvement of the public authorities[31] will be indispensable at the take-off phase and will then have to be ramped up in the next few years, **but whether it be in Europe or in the rest of the world, it will not be enough to cover the investments needed for the massive deployment of the different types of equipment across the length of the value chain,** paving the way for the generation of economies of scale and a massive reduction in costs in both the upstream and downstream segments.

Most of the $300bn of investments in the hydrogen sector expected by 2030 will therefore have to be financed by the private sector. The vast amount of capital to be raised to make investments on the scale needed to drive down costs in the different segments of the value chain will be a major challenge.

In this respect, **recent evolutions afoot in the global financial sector provide encouraging signals, if one considers**:

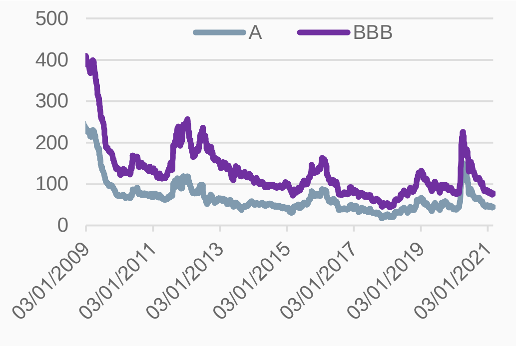
(i) **The current monetary environment and attendant conditions for financing the real economy**. An unprecedented abundance of liquidity in the global capital markets (as a result of the multiplication of quantitative easing policies pursued by leading central banks since the 2008 crisis) and the low level of long interest rates (despite the first signs of an upturn since the start of the year) mean that financial conditions remain very attractive for the different economic agents.

Change in 10-year Bund rate since 2009 (%)



Source: Bloomberg

Change in the 10-year credit spread of € A and BBB rated issuers since 2009 (bp)



Source: Bloomberg

(ii) **The increasing involvement of the different players of the financial sector in the real economy's decarbonisation process**. This involvement is highlighted by the **spectacular development of the green bond market** since 2013[32]. It is also perceptible in the way **climate and environmental issues have come to have an increasingly greater bearing on the financing/investment policies of commercial banks and asset managers**[33]. The last three years have been marked by a raft of announcements signalling a gradual phase-out of fossil fuel financing/investments (coal obviously, but also shale oil and gas). These policies to exit fossil fuels should in time free up considerable amounts of private capital that can be channelled into funding the ecological and energy transition, notably emerging sectors such as green hydrogen.

While it is the financial sector's intention to participate in the development of these emerging sectors of the economy, in their strategy for allocating funding/investments, capital providers cannot ignore the challenges facing these sectors. From the standpoint of these funding providers, the specific challenges facing green hydrogen are mainly of two orders:

(i) The different segments of the value chain will, in the coming decade(s), still be battling with a lack of cost competitiveness compared with incumbent processes/technologies.

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[31] $70bn envelope expected to be mobilised worldwide by 2030 (see above).

[32] Total outstanding green bonds have jumped from the equivalent in euro of less than €20bn at the start of 2013 to the equivalent in euro of more than €1,000bn at the end of 2020. For more details, see the Natixis study on this market: "**Green Bonds Review: What to expect for Green & Sustainable Bonds in 2021?**"

[33] By way of illustration, for its financing activities, Natixis has developed the Green Weighting Factor, an internal analytical tool intended to channel the allocation of capital to companies/projects most virtuous from a climate standpoint. Based on rating grids for each company and sector being financed, this tool thus favours financings that are most virtuous for the climate and an energy transition towards a low-carbon economy. On the other hand, it penalises financings presenting environmental risks. The tool has been applied since 2019 to all new financings across all sectors of activity.

(ii) As indicated above, firms present in the industrial segment of the value chain are currently at the point where they are investing and building their experience curve, and as yet these firms generate negative free cash flows[34].

In this respect, the different public support mechanisms for the hydrogen sector that have already or will be put into place (direct subsidies paid to producers and/or equipment users, public-private partnerships for green hydrogen projects and associated collective equipment, mechanisms based on carbon quotas and/or the taxation of carbon emissions, national mechanisms to support green hydrogen production through calls for tenders, etc.) are **instruments for attenuating hydrogen's current lack of cost competitiveness and for reducing the financial risk for capital providers across the different segments of the value chain that are concerned, ultimately opening the way for a targeted but pertinent adjunction of private capital**.

This last section of the present study therefore seeks to identify under what framework and conditions private capital can be effectively mobilised to participate in the financing of the sector.

4.1. Hydrogen sector's development to rely on asset-based financing wherever possible

Far from forming a homogeneous sector, green hydrogen equates to an extended value chain at the crossroads between three sectors (energy, industry, mobility) that brings together three business lines (upstream/downstream equipment manufacturing, hydrogen production and infrastructure required for its end-uses), each with their own challenges and specific risk profile.

These characteristics present **two challenges if the financial sector** is to participate in the hydrogen sector's lift-off, which are to:

(i) **Develop instruments with features adapted to the challenges and level of the risk underlying each of the assets/entities financed across the value chain.**

(ii) **Replicate** wherever possible across this chain the **least costly financing arrangements already massively deployed in other sectors of activity**, drawing on the business models and nascent public support mechanisms.

The table below offers a synthetic vision of the main equity and debt instruments available for financing economic assets[35] or companies.

Typology of main capital and debt instruments and assessment of risk for capital provider, ranging from 1 (very low risk) to 10 (very high risk)

Asset class	Instrument	Key source of risk for capital proviers	Instrument's maturity	Seniority in claim in the event of a liqudation	Overall risk level
Debt	Senior secured debt	Credit quality of the financed asset	Usually in line with that of the financed asset	Very high	1
	Senior unsecured debt	Credit quality of the borrowing company	Up to 100 years	High	2-4
	Hybrid debt	Credit quality of the borrowing company + legal clauses specific to the instrument	≥60 years or even perpetual	Average to low	3-8
	Subordinated debt (2)		≤ 10 years	Average to low	4-8
Equity	Preferred shares	Ability of the company to ensure its continuity of operations and to remunerate its shareholders	Non applicable	Very low	9
	Ordinary shares			Very low	10

(1) Priority level of the holders of the instrument relative to the other instruments making up the capital structure of the company going into liquidation / (2) The most widespread illustration of subordinated debt is provided by the "mezzanine" debt placed in place during leveraged buy-out (LBO). Mezzanine debts are inserted in the structure of the company subject to LBO between senior debts and shareholders' equity. In the event of liquidation of the said company, holders of senior debt are always satisfied before holders of mezzanine debt / (3) 100-year maturity observable in certain instruments on the bond market. In practice, the maturities of unsecured senior bank debts rarely exceed 15-20 years / (4) Theoretical maturity applying to hybrid debts on the bond market. In practice, however, these debts are repaid on the 1st call date provided for in the prospectus, i.e. 5 to 12 years after their issue.

Source: Natixis

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[34] Being the sum of the cash flow from operating activities and the cash flow from investing activities.

[35] Or rather the ad-hoc legal entity whose sole purpose is to operate these assets. In the same way as a company with a more general corporate purpose, the ad-hoc legal entity can in theory issue all debt and capital instruments listed in the table. In practice, however, as demonstrated with the development of renewable energies, this entity will typically issue for 20% of equity instruments and for 80% of secured senior debt instruments when the cash flow generation profile for the underlying assets is sufficiently solid.

The table above highlights the **variety of risk exposure levels underlying each instrument, influencing the returns required by creditors (debt instruments) or shareholders (equity instruments)**, which from the standpoint of the development of the hydrogen sector calls for two observations:

(i) The **most efficient way of minimising the cost of the financial resources** mobilised for the sector's lift-off **is to privilege as much as possible financings based on the cash flow profile of the assets/equipment** rather than the credit quality of the companies that will operate them.

These financings generally take the form of secured senior debt instruments[36]. The servicing of these instruments (interest payments and repayment of principal) is thus based on the cash flows generated solely by the assets being financed. In return, in the event of the liquidation of the legal entity carrying these assets, holders of secured senior debt instruments have priority over other funding providers (holders of unsecured senior debt instruments, shareholders). The use of these instruments does suppose, however, that cash flows for the engineering works/equipment being financed are both of a sufficient amount and also stable/predictable over time to ensure there are no hiccups in the debt servicing. Meeting these conditions appears conceivable for hydrogen production and for the infrastructure activities of the value chain (fuelling stations, hydrogen-powered collective equipment) (see below).

For the **deployment of equipment** entering into the production of hydrogen or its end-uses (commercial vehicles, collective transport), **an alternative approach would be for financing to be provided directly by the supplier of the equipment (or by commercial banks)**, in the form of **leasing agreements** (with a flat annual payment) or **pay-per-use arrangements** (where the annual payment would be linked to the extent to which the assets being financed are used). Nascent amongst car and truck manufacturers selling vehicles equipped with fuel cells[37], pay-per-use models can be expected to play a crucial role in the development of territorial hubs structured around the production of green hydrogen and its end-uses. The main benefit for the equipment operators is to avoid making an upfront payment corresponding to their entire cost. For the development of collective transport fleets (buses) or commercial vehicle fleets (taxis, waste collection trucks, etc.), the interest presented by this model is to base payments on the effective use of the equipment concerned, with the cost being passed on in a transparent manner to the end-user (see below).

(ii) Apart from senior secured debt instruments used to finance engineering works/equipment, the other instruments available, mainly **unsecured senior debt instruments and common equity, address conventional corporate financing requirements**.

In the hydrogen sector, companies present in the industrial sector (i.e. manufacturers of electrolysers and downstream equipment) can be expected to depend chiefly on these sources of financing in addition to eventual subsidies received from the authorities at national and/or supranational level (i.e. EU) (see above). Furthermore, to speed the development of their industrial base and to build their experience curve, these companies will probably go to the capital markets, staging initial public offerings or rights issues.

Note in this respect that, last autumn, **McPhy raised €180m by opening its capital to new shareholders** (Chart International Holdings and Technip Energies), **its existing shareholders** (EDF Pulse Croissance Holding and Fonds Ecotechnologies, managed by Bpifrance Investissement under the French State's Investment for the Future Programme) **taking up their entitlement**. This fundraiser was intended to enable McPhy to invest in R&D, but especially upscale its industrial activities[38], notably through the construction of its electrolyser giga-factory[39].

From a broader perspective, **within the industrial segments of the value chain, one would expect the equity financing requirements to be met by a multitude of different players**: leading international industrial groups entertaining ambitions in the hydrogen sector and forging strategic partnerships with specialist players, but also para-public financial institutions (such as BPI in France) serving the general interest as well as venture capital providers, this last category being more likely to be involved at an early stage in the development of the equipment (R&D and production phases before starting up real assembly lines).

Another way of providing capital to these segments could come from the development of debt instruments blending the characteristics of debt instruments and equity instruments. One example is the venture debt developed at the level of the European Union by the European Investment Bank[40] as part of a blended finance approach[41]. In practice, for borrowers, venture debt constitutes quasi equity and is remunerated as such (more than 10%). Broadly speaking, venture debt provides a cushion against the combined effects of the investment cycle and the build-up of the experience curve in equipment manufacturing through contractual arrangements that adjust debt servicing to the cash flows being generated by the borrower. For the industrial segments of the value chain, the benefit of venture debt is that

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[36] Also called non-recourse project debt.

[37] Already the case of Hyundai, which proposes financing of this type for hydrogen trucks marketed in Switzerland (see https://hyundai-hm.com/en/unser-angebot/).

[38] Manufacture of electrolysers and hydrogen refuelling stations.

[39] Final investment decision for this project was announced on 9 March 2021.

[40] https://www.eib.org/fr/products/equity/venture-debt.htm

[41] Blended finance covers all financing mechanisms that make a strategic use of public financings/guarantees with a view to attracting private capital to help fund the development of projects with a positive climate, environmental and social impact. One characteristic specific to blended finance is its "additionality": but for the involvement of the public authorities (national governments, local authorities, international organisations), the characteristics of the projects concerned are such they would not have attracted private capital at what would be considered as "normal" conditions.

it provides loss-absorbing capital[42] if need be, without a dilutive effect for the existing shareholders of the companies concerned. Despite facilitating the funding of companies at the start-up phase in the hydrogen sector, supplementing proceeds raised through the issuance of capital instruments and/or senior debt instruments, the provision of venture debt will remain very targeted, since intended in priority to finance SMEs positioned in as yet niche activities during the growth stage.

These different elements suggest that **the main challenge in funding the sector in the next decade will be the development of mechanisms to mobilise private capital on the assets themselves, helping to lower deployment costs for engineering works/equipment across the value chain**. The next paragraphs therefore focus on these mechanisms and the conditions required for a massive mobilisation of private capital.

4.1.1. Conditions created for the development of renewable energies in the world could act as a guide...

An observation of the worldwide development of renewable energies (onshore and offshore wind energy, solar photovoltaic energy) in the past 15 years **offers a good illustration of the role as a trigger played by private finance (through asset-based lending) in shaping an industry that was technologically immature at the onset, but in receipt of public sector aid in various forms**.

In all developed economies, renewable energies have benefited since the early 2000s from support mechanisms offering visibility on project cash flows over the entire life of the production assets[43]. In Europe, support mechanisms first took the form of feed-in-tariffs also referred to as renewable purchase obligations (EDF was the obligated entity in France in its capacity as the electricity supplier) at a fixed price set by the State, before a shift in 2017 towards mechanisms offering an additional remuneration (feed-in-premium) for projects selected through public tenders.

The role of private finance in the development of renewable energies was perceptible through two main channels:

(i) Widespread recourse in the different segments of the value chain concerned to asset-based financing via ad-hoc legal entities, not therefore carried on the balance sheet of the private corporate “sponsors”. With this type of arrangement, the risk linked to the asset is ring-fenced as well as curtailed (compared with the risk attached to a general purposes corporate loan[44]).

For those renewable energies for which cash flows generated by assets provided visibility thanks to public support mechanisms, financing arrangements of this type made it possible to maximise the proportion of project debt financing (proportion of debt to total project costs of 70%, even 80% observed in the renewable energy sector, a level of leverage rarely observed at companies operating state-regulated infrastructures such as electricity transmission systems – RTE in France, Terna in Italy or REE in Spain – for which the proportion of debt relative to the regulated asset base tends to reach between 50% and 70%). Maximising the proportion of debt financing relative to the total project costs led to a **reduction in the cost of the capital raised to finance the project** as, for a given asset, the return required by equity investors is always greater than the one required by lenders on account of the risk/reward profile detailed above. The standardisation of these financing arrangements ultimately enabled **institutional investors to participate in the development of the renewable energy sector**, either in the form of direct injections of equity financing through specialist infrastructure funds, or as a result of the farming out of project debt financing by the arranging banks to infrastructure investors (pension funds, insurers) looking to de-correlate over the long term the performance of their portfolios from changes in interest rate levels.

In an environment in which interest rates have been low by past standards ever since 2009 (see above), **the reduction in asset/project financing costs and the mobilisation of collective savings, spurred by institutional investor demand, contributed to lowering the total cost of projects and their general risk level, with knock-on effects then leading to a reduction in development costs for new projects in the renewable energy sector**.

No overall quantification of the impact of these financing arrangements on the level of development costs[45] in the renewable energy sectors has been released, but IRENA estimates that for newly commissioned utility-scale solar PV projects, the weighted-average Levelized Cost of Energy fell by 82% between 2010 and 2019[46] (see chart below). **That said, still according to this agency, for utility-scale solar PV projects, and all other things being equal, a reduction in WACC from 7.5% to 5% in OECD countries would even now lead to a 20% reduction in the total development cost of renewable energy projects**[47].

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[42] In financial theory, potential loss absorption capacity is a criterion that is generally based on the distinction drawn between universes: senior debt on the one hand, and subordinated debt and equity on the other hand.

[43] In addition to an elevated level leading to the generation of “incentivising” returns on capital employed and on shareholders’ equity, encouraging investments in these sectors of the value chain.

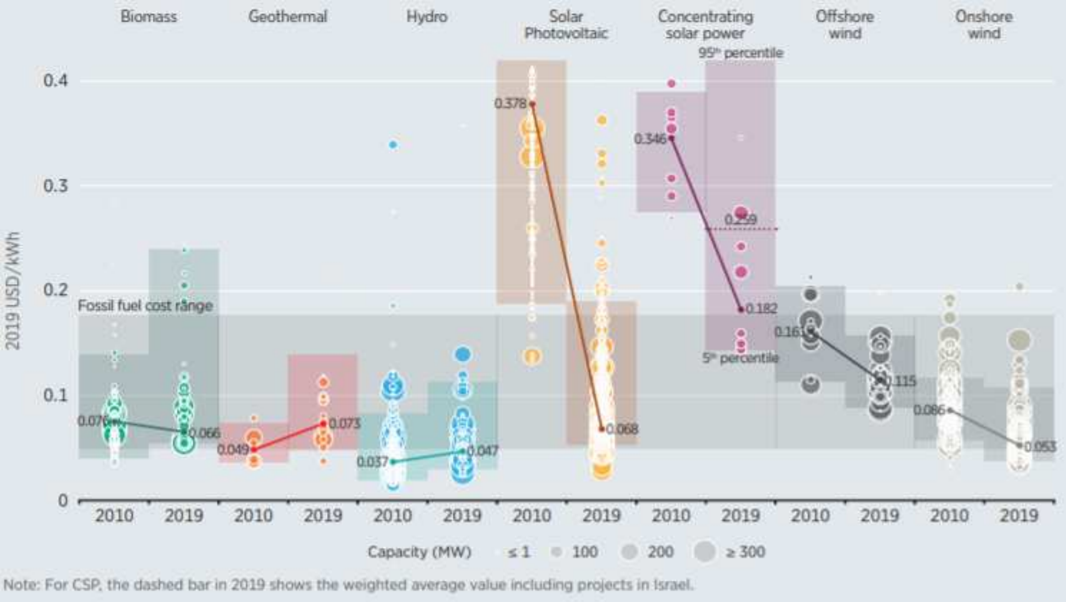
[44] Form of borrowing intended for general corporate purposes.

[45] Levelized Cost of Energy, expressed in $/MWh. It measures the sales price for electricity needed for an individual project to reach breakeven point over its life (nil net present value) after covering investment and operating costs and applying a discount rate that is representative of the cost of the capital employed to develop the asset. The weighted average cost of capital used by IRENA for its estimate is 7.5% for OECD countries and China, 10% for other countries.

[46] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jun/IRENA_Power_Generation_Costs_2019.pdf

[47] Op. cit.

Renewable energies: global LCOEs[48] for newly commissioned utility-scale renewable power generation technologies, 2010-2019 ($/MWh)



Note: For CSP, the dashed bar in 2019 shows the weighted average value including projects in Israel.

Source: IRENA (2020)

(ii) The boom of the green bond market to a lesser extent[49]. The structuring of this market is under way at European level, with the elaboration of an EU taxonomy for sustainable activities and an associated EU Green Bond Standard. **The development of this market has drained an increasingly more significant proportion of global savings, channelling these into projects with a clearly defined climate and environmental impact**.

The explanation for this market's spectacular growth can be found in the specific characteristics of the debt instruments. First, **proceeds from the issuance of green bonds are specifically earmarked for assets/projects having been identified beforehand**. In so doing, issuers (international groups or, more rarely as yet, ad-hoc project vehicles - see above) **are accountable to investors over the manner in which proceeds are applied, but also over the environmental and social impacts of projects/assets being financed or refinanced**, with various reporting requirements.

These two main characteristics of green bonds have led to an **increasingly elevated level of confidence in the different commitments given by issuers and the positive climate and environmental impact of the projects/assets being financed or refinanced**, ultimately contributing to the **long-term involvement of investors in funding energy transition**. It is in this framework that, since 2014, leading global energy utilities, in particular European groups, have gone to the green bond market to finance or refinance an increasing proportion of their investments in renewable energies. At end-2020, European energy utilities (mainly Iberdrola, Enel, EDF, EDP, Engie) accounted for 14% of total outstanding green bonds (€77bn out of a total of €537bn), this proportion reaching 60% of total outstanding bonds issued by corporates.

4.1.2. … and are largely replicable in the green hydrogen sector … albeit under certain conditions

The recent development of the renewable energy sectors in developed economies offers insight into the way in which the mobilisation of part of the private capital needed for the deployment of engineering works/equipment across the hydrogen value chain could come about. As mentioned above, **this mobilisation through recourse to asset-based financing is conceivable, under certain conditions, for hydrogen production and infrastructure activities**.

For the first activity (low-carbon electrolysis), at this early stage in the sector's development, **hydrogen production using low-carbon electrolysis is under a bilateral contractual framework**, i.e. HPA (see above), **between**:

(i) **A producer** (potentially operating low-carbon electricity generation capacities powering the electrolyser); and

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[48] Values in the chart represent the weighted average total installed cost of the different assets in the year of commissioning.

[49] From the standpoint of the financing of renewable energies, the "additionality" from having recourse to the green bond market is in fact limited. It is rather unlikely that it was recourse to this market that enabled the financing of projects that would not have gone ahead otherwise, as green bond issuers are international groups with broad access to the capital markets.

(ii) **A buyer, which can be an industrial or a public/para-public entity** (in France, companies providing collective transport services or household waste collection services under public service delegations).

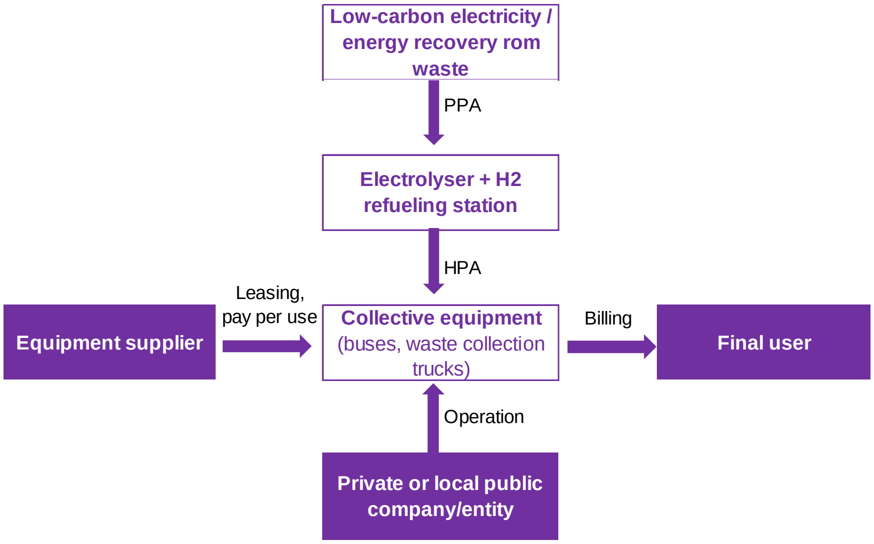
For the second activity (infrastructure segment of the value chain), the intention is that the cost[50] **of all the engineering works** (refuelling stations) **and equipment** (buses, waste collection trucks) **contributing to the end use of hydrogen be passed on to the end-user through the tarification of the service** (see above), **the logic being that applied to public infrastructures**.

In both cases, costs for the production of the hydrogen and its use will be reflected in the tariff or contractual framework binding the various parties.

For green electrolysis, **hydrogen purchase agreements binding the parties will obviously contain a clause defining the unit price for the hydrogen, but also a clause defining the minimum volume to be purchased** (take-or-pay clause[51]). There follows that a green hydrogen producer will benefit from guarantees covering both the price and volume of the hydrogen sold.

For **engineering works/equipment for the collective end-use of hydrogen, the cost of acquisition/development as well as the operating costs of the assets concerned will be passed on to end-users through a contractual chain**, as illustrated in the flow chart below:

Flow chart for the repercussion of costs for green hydrogen collective end-uses to the user



Source: Natixis

These emerging operational/contractual mechanisms in the hydrogen sector open the way to two main forms of financing:

(i) **Financing in the form of secured senior debt instruments for the electrolysers, but also for the refuelling stations.**

As regards the financing of electrolysers, and abstraction made of eventual technical problems (see below), **price and volume clauses in the HPA in theory offer good visibility on the asset's cash flows, especially if the term of the HPA corresponds to the asset's estimated useful life** (20 years), thereby avoiding any merchant risk. An alternative to the financing of electrolysers with secured senior debt instruments would be for national governments to develop mechanisms offering an additional remuneration (see above), similar to those in place to support renewable energies in Europe.

The financing of refuelling stations with secured senior debt instruments is also conceivable, but probably requires a pooling of assets to create a territorial hub. As the flow chart above suggests, refuelling stations would be coupled to electrolysers to supply hydrogen to entities operating collective equipment. From a financial standpoint, this coupling would maximise visibility for hydrogen volumes supplied by refuelling stations. As refuelling stations supply vehicle fleets providing public services (buses, waste collection trucks, also light commercial vehicles used by public sector enterprises such as the Post Office, etc.), they offer good visibility on the volumes consumed by what are captive fleets, in turn on the revenues expected to be generated by refuelling.

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[50] And hence the extra cost relative to equipment currently powered by fossil fuels.

[51] In gas supply agreements between producers and suppliers, notably those involving liquefied natural gas (LNG), the take-or-pay clauses they contain typically concerns 80%-90% of the quantity ordered. Under such an agreement, the supplier commits to purchasing a minimum quantity of gas, whatever the supplier's actual needs for the period concerned. In return, the producer commits to supply this same minimum quantity of gas on the agreed dates. This two-way guarantee is accompanied by reciprocal risk sharing. The buyer bears part of the uncertainty linked to the variable nature of its energy needs. The seller assumes the risk linked to any change in the market prices, as the price fixed in the contract is immutable, whatever happens.

From the standpoint of the arranging banks, **financing provided through secured debt instruments is governed by a series of precise and rigorous criteria so as to cover the three main sources of risk for the asset concerned: the technical risk** (during the construction phase, then during the operational phase), **the credit risk per se** (incapacity of the asset financed to generate cash flows needed for the servicing of the debt) and, the **counterparty risk** (mainly a default in the obligations of the buyer, of the equipment supplier or the electricity supplier, in instances where the power plant supplying the low-carbon electricity and the electrolyser are operated by distinct entities).

Recourse to secured senior debt instruments: typology of risks and risk prevention criteria considered by arranging banks

Source of risk for debt holders	Features of risk materialization	Source of risk mitigation
Technical risk	• Delay in commissioning the asset (construction risk) • Technical fault (s) affecting the performance of the asset after its commissioning (operating risk)	• Guarantees provided by the subcontractor during the construction phase and then the operation of the asset
Credit risk	• Insufficient cash flow generation to service the debt (P + I) during the life of the asset	• Soundness of the underlying contractual / regulatory / economic scheme (price, volume) guaranteeing the stability of cash flows + equivalence between the duration of the scheme and the life of the asset • DSCR (1)> 1.2, so as to create a safety cushion in the event of unforeseen events
Counterparty risk	• Default of the buying counterparty on its obligations (disappearance, questioning of the contract, etc.) • Default of the electricity supplier and the equipment supplier	• Credit quality of the buying counterparty of H2 (financial strength, history in the execution of similar contracts, etc.) • Existence of other potential counterparties

(1) DSCR (debt service coverage ratio): cash flow available for debt service / debt service maturity (principal + interest + arrangement fees). It is generally calculated on a semi-annual basis

Source: Natixis

(ii) **Lease/pay-per-use financing for collective equipment**. While presenting the advantage of avoiding an upfront payment by the operator covering the total cost of the equipment, this type of financing presents problems in practice. In France, the State subsidises local authorities for the acquisition of hydrogen-powered vehicles[52] but not for their operation. Local authorities resorting to this type of financing will therefore have to pass on to the user all extra costs linked to the choice of this equipment.

Note that in addition to financing solutions being put together by equipment suppliers, lease-type financing should be developed by commercial banks for a broader range of assets: electrolysers, collective transport vehicles and light collective vehicles.

4.2. Emergence of asset co mechanisms at territorial level.... replicable in other sectors

In France, the development of green hydrogen-centric territorial hubs is leading to the emergence of a financing model in the hydrogen sector bringing together public sector and private sector players. This model largely replicates the one in place for 15 years in the renewable energies sector.

This model relies on the creation of an asset co in one of the legal forms provided for under French law[53] permitting recourse to both private and public capital for the development of local collective equipment (public transport, household waste collection). Entities of this type continue to be majority controlled by the sponsoring local authority or authorities, but allow for the involvement of various private sector players in the deployment of the assets: equipment suppliers, infrastructure funds, commercial banks. The sole restriction to the scope of the private partners involved in the creation of an asset co concerns banks having arranged secured senior debt instruments financing the equipment.

In the flow chart below illustrating this mechanism, **the asset co will develop and operate the electrolyser and refuelling station**, which implies entering into a PPA for the supply of the low-carbon electricity

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[52] This subsidy corresponds to 50% of the price differential between a hydrogen vehicle and a diesel vehicle.

[53] Two types of legal entities exist under French law that allow local authorities to adopt an entrepreneurial approach in the pursuit of a project in the public interest and attract capital coming from the private sector: the Société d'Économie Mixte (SEM) and the Société d'Économie Mixte à Opération Unique (SEMOP).
Both legal structures make it possible to combine shareholders from the public and private sectors, with the proportion of the capital held by public sector shareholders being limited to at most 85%. The SEMOP differs from the SEM in two main respects:
(i) A SEMOP is established for the execution of a single operation and, accordingly, will be dissolved upon the realisation of this operation or the execution of the contract that it has been awarded.
(ii) It must necessarily be established by a single local authority or a single grouping of local authorities.

produced upstream. There could be cases when the asset co could enter into a lease/pay-per-use financing agreement, even purchase directly the collective equipment (buses, waste collection trucks) on behalf of the collective service providers, billing to them the cost of this service.

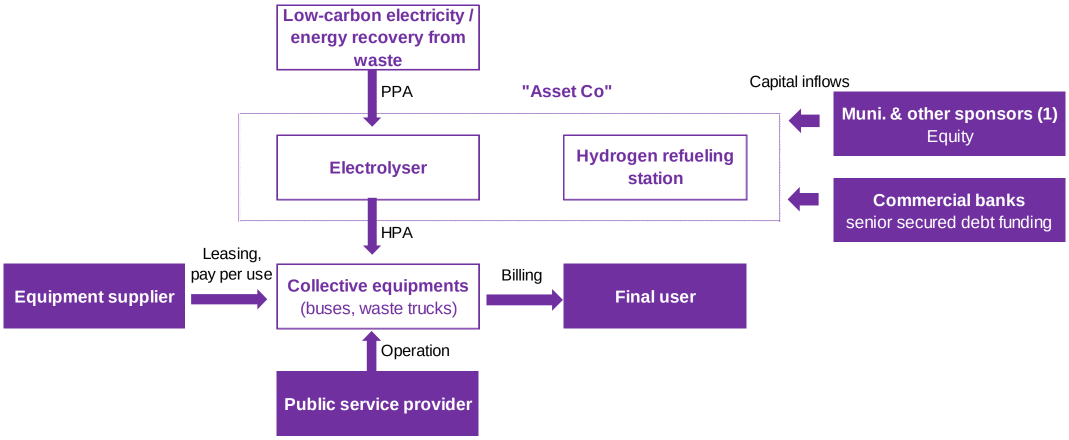
At operational level, **the asset co will sell the green hydrogen to the collective service providers and bill them for the use of the refuelling station**:

(i) **At conditions reflecting the costs to develop and operate the equipment**, in such a way as to service the secured senior debt instruments issued to finance the equipment.

(ii) **Under a HPA, the terms of which will be as closely as possible aligned with the useful life of the different assets**[54], once more to achieve the utmost predictability for the equipment having been financed by issuing secured debt instruments.

The cost of the collective services is ultimately borne by the end-user, either directly by billing each use, potentially supplemented by public subsidies (collective transport services), or indirectly via the local taxes (household waste collection) under the contract binding the local authority and the service provider.

Simplified flow chart of Asset Cos emerging at local level for the development of hydrogen used for collective equipment



(1) Industrial and energy companies, equipment suppliers, infrastructure funds

Source: Bloomberg

For the development of the green hydrogen sector, **the interest presented by this type of mechanism is threefold**:

(i) It enables a concentration of demand for green hydrogen in the immediate vicinity of the hydrogen production sites, adopting an evolutionary approach. The captive nature of the vehicle fleets removes all logistical constraints and it is possible to envisage the installation of the refuelling station on the site of the electrolyser. With the vehicle fleets catering to basic needs, the associated demand for hydrogen can be taken to be stable as well as predictable over time, hence generating cash flows for the electrolyser and refuelling station that likewise will be stable and predictable if the execution of the HPA proceeds without any notable hitch. At the same time, the modular nature of the electrolyser allows for a scaling up of green hydrogen production to accompany the expansion of end-uses, notably demand for industrial uses and personal mobility.

(ii) It ensures all equipment costs relating to green hydrogen are passed on in a transparent manner to the end-user.

(iii) The different legal forms under which an asset co can be established under French law make it possible for **institutional investors, such as infrastructure funds,** to be involved in the dissemination of green hydrogen uses in the economy. Depending on the level of the financial and operational risk that will determine the proportion of secured senior debt (potentially 80% for the best structured projects in technical, legal and financial terms), infrastructure funds are susceptible of providing equity financing for expected returns ranging from around 8% (least risky projects) to 12% (riskiest projects).

4.3. … notably other infrastructure sectors with the potential for concentrating demand

Recourse to asset co structures enabling the concentration of green hydrogen end-uses at local level lends itself to an extension to other environments, in particular airport infrastructures and port industrial zones.

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[54] Quite fortuitously, France’s energy code permits the negotiation of power purchase agreements (PPA) for a 20-year term, coinciding precisely with the estimate useful life of electrolysers.

Airport infrastructures are particularly suited for the replication of initiatives to disseminate hydrogen end-uses at the level of local authorities, for three main reasons:

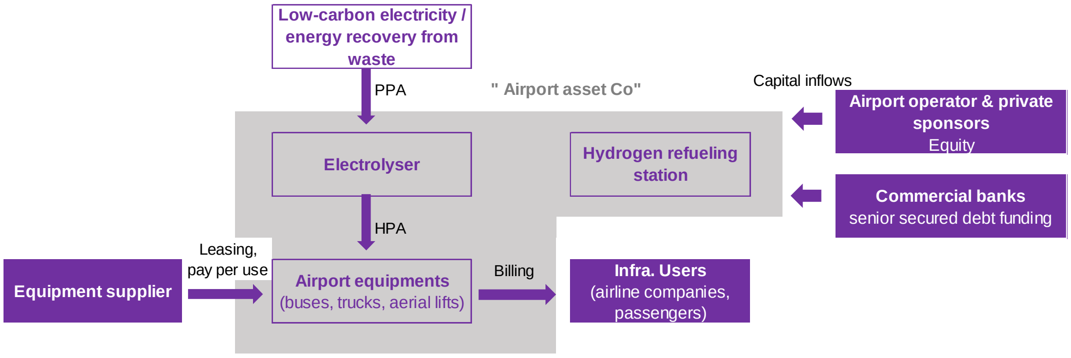
(i) **Airport infrastructures concentrate already significant potential hydrogen end-uses** given the many captive items of equipment needed for the daily operation of the runways and transport of passengers in and around the airport (passenger buses, luggage trucks, service vans, aerial works platforms, conveyor belts, lifts).

(ii) **Revenues linked to the development, operation and maintenance of engineering works and equipment used in air transport are regulated**[55], with the use of a tariff-setting mechanism similar to those for gas and electricity transmission and distribution infrastructures. This mechanism is intended to cover the operating costs and investments by the operator, as well as generate a fair return on capital employed by the operator to fund the regulated asset base. This tariff-setting mechanism, which is exhaustive in terms of cost coverage as well as transparent in its application, serves as a basis for the billing of airport services to end-users (airline companies, passengers). **The existence of this regulatory framework would allow costs for hydrogen uses to be passed in full to these end-users upon the public authorities having approved the operator's investment plan**.

(iii) **There would be potential (but not before 2035 - see above) for a greater concentration of demand if aircraft fleets equipped with hydrogen fuel cells were to come into service**. Were this to happen, the local production electrolyser capacity could be increased and/or supplemented by a nearby production site, which would require the development of dedicated hydrogen transport infrastructures.

The flow chart below illustrates the way an airport asset co could function. The major difference compared with a territorial hub is in the operation of the hydrogen-powered equipment. The asset co can be in charge of their operation, as in the flow chart, or be the responsibility of the airport infrastructure operator. In all cases, in the set-up below the HPA serves mainly as an internal billing flow ultimately justifying the cost of the services billed to the infrastructure's end-users.

Simplified flow chart for a potential airport infrastructure Asset Co



Source: Natixis

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[55] This is the case for Aéroport de Paris (AdP), whose operating profit from ordinary activities was €1,094m in 2019, including €458 million from regulated activities.

5. Conclusion: mobilisation of private finance to come about step by step

All in all, save for specific cases such as those offered by large international projects on the NEOM model (capital intensive value chain supported by long-term purchase contracts), the narrative developed above suggests that **harnessing private finance for the development of the green hydrogen sector will come one step at a time, with the coming of age of the value chain allowing increasingly broad swathes of the financial sector to get involved**.

As illustrated by the chart below, **this gradual mobilisation of private finance can be expected to both spur and follow the sector's maturing**, with two crucial watersheds:

(i) Transition from pilot projects to a commercial scale deployment of equipment. It is precisely this phase that has been ushered in by the ramping-up of public support, with the intervention of public authorities taking on a more "systemic" form: development of territorial hubs, start of direct support to low-carbon electrolysis on the part of governments, concurrently with the implementation of mechanisms to support demand for green hydrogen in the most challenging sectors to decarbonise (i.e. industry, mobility).

(ii) Gradual attainment of commercial viability across the different segments of the value chain through a multiplication of projects, a steady increase in demand, the industrialisation of the equipment production platforms and, ultimately, the generation of economies of scale to bring down costs throughout the green hydrogen sector.

From the standpoint of private capital providers, the coming of age of the green hydrogen value chain will offer possibilities for an increasingly greater involvement:

(i) At the onset, directly, in the form of **equity financing needed by specialist equipment manufacturers for their development**, or indirectly, in the form of **unsecured senior debt issued by the sponsors of the first projects and by full-line equipment manufacturers with ambitions in the sector**.

(ii) Then gradually, in **the form of asset-based financing**: **secured senior debt** for green hydrogen electrolysis and the ecosystems built around hydrogen, supported by public initiatives (territorial hubs, national, even international infrastructures, including airports), **lease/pay-per-use financing** for hydrogen powered equipment provided by the suppliers, ultimately by commercial banks.

(iii) In time, once the standardisation of asset-based financing has been completed, **in the form of a possible securitisation by the banks of the various credit instruments to institutional investors** (insurers, fund managers). Already observed in the renewable energies sector, this evolution will accelerate the development of the green hydrogen sector by lightening the balance sheet of the banks, allowing them to fund new projects/assets.

Green hydrogen sector: the path to the sector's maturity and financing mechanisms

Sector development stage	Pilot projects/demonstration projects	Early commercial deployment	Commercial viability
Underlying business model	**Importance of public involvement & financing**	**Investment phase for equipment manufacturers with cash flows << 0** Due to the sector's cost competitiveness deficit, the bankability of green H2 projects is supported by public support schemes: • Feed-in-premium (FiP) + green certificates for green H2 production • Direct subsidies / public investment for H2 mobility equipment / infrastructure	**Gradual decrease in equipment costs and standardization of uses of the molecule throughout the economy**
Associated financing scheme	**Own resources of project sponsors** potentially increased by direct grants from the EU and / or national government **Public-private partnerships**	**Gradual development of asset financing by third parties:** • Secured senior debt based on HPA / FiP schemes for green electrolysis • Development of leasing and pay-per-use schemes from equipment suppliers and commercial banks	**Generalization / standardization of asset-based financing schemes**
Source of associated credit risk	**Counterparty risk on the entity that develops the projects**	**Mix of "counterparty" and "asset" risk**	**Risk on assets with the exception of industrial segments of the value chain**

Source: Natixis

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