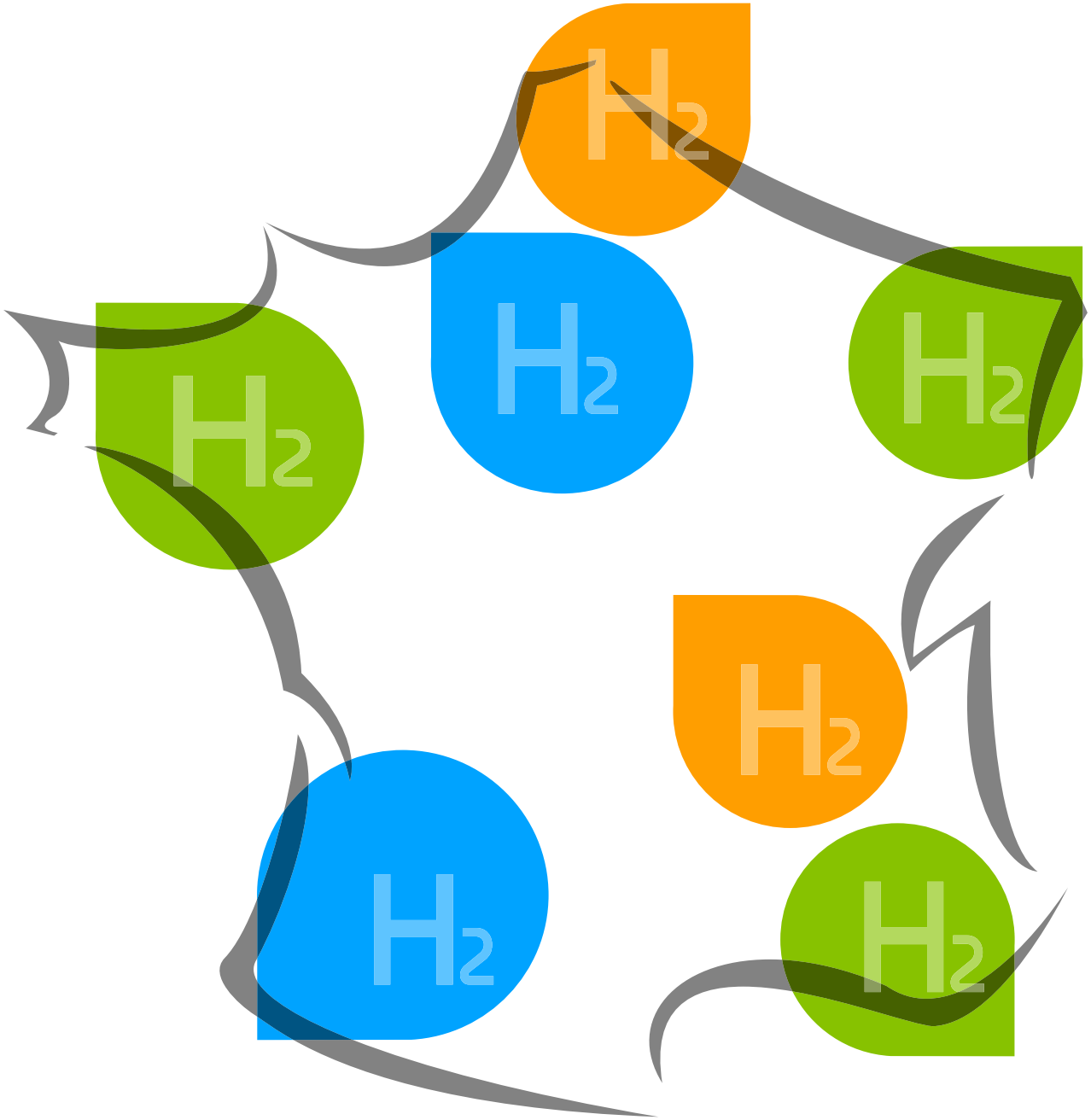
France Hydrogène

Engagée pour la transition écologique

A road-map for an ambitious Hydrogen strategy



The sector's contribution to implementing the 2030 Hydrogen Strategy

September 2021

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Methodological note

This document presents the findings of a study carried out by the Hinicio consultancy for France Hydrogène in partnership with the Comité Stratégique de Filière Automobile (a car industry body bringing together representatives from government, unions and manufacturers) and the Comité Stratégique de Filière Nouveaux Systèmes Energétiques (a body bringing together the state, energy transition stakeholders, unions and local government). Consequently, this document offers a simplified picture of the actual state of the market and the very wide range of client needs and potential supply arrangements. This study is based upon a sectoral and geographical analysis of hydrogen demand and a large-scale model of the supply chain necessitating the application of a number of simplifying assumptions (typical use cases, averaging etc.).

For each industry and transportation market segment, the extrapolated market size in 2030 is based on ***3 key assumptions:***

1/ *the size of the first production unit,*

2/ *the date this unit first enters service,*

3/ *a growth rate calculated on the basis of projected and potential market conditions.*

In relation to the energy market segment, a selection of re-electrification schemes currently under development has been factored into the two scenarios we have looked at.

Context

An unprecedented impetus has built up behind the expansion of hydrogen at both European and international level. Set against the backdrop of efforts to combat climate change and kick-start the post-pandemic global economy, France stepped up to the challenge in 2020, with the unveiling of a National Hydrogen Strategy placing the country well in the forefront in European and global terms as regards progress in this field.

Backed by 7.2 billion euros of public money over 10 years, this strategy aims to build 6.5 GW of installed electrolyzer capacity by 2030 and by doing so, reduce greenhouse gas emissions by 6 million tonnes of CO_2 annually. The key means by which the Strategy will be rolled out are as follows:

- decarbonize industry by building a competitive electrolytic hydrogen production sector in France,
- develop transportation (work vehicles, heavy vehicles and very frequently-used vehicle fleets, powered by renewable or low-carbon hydrogen,
- support research, innovation and skills development with a view to promoting future applications.

France Hydrogène, which brings together all hydrogen sector actors in France, wanted to play its part in making the implementation of this Strategy a success by drawing up a road-map setting out clear, costed production targets for 2030 and the geographical distribution of these clusters across France.

1 Two scenarios, two targets

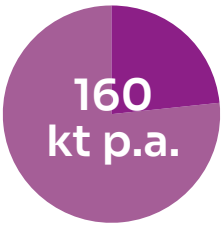
The French hydrogen sector has reiterated its vision for annual consumption of renewable or low-carbon hydrogen to reach 680,000 tonnes (680 kt) by 2030: the 'Ambition 2030' Scenario

The growing momentum behind the hydrogen sector, fuelled by French and European public policy not to mention powerful regulatory drivers already in place or to come (RED2, RED3, the carbon border adjustment mechanism, low-emission zones etc.) has cemented the decision of the actors of the French hydrogen sector to maintain their ambitious target, set last year, of an annual consumption of 680,000 tonnes of low-carbon or renewable hydrogen by 2030 (our 'Ambition 2030' scenario).

The breakdown by volume of the 'Ambition 2030' scenario is as follows:

680 kt as follows:

69.9%



23.5%

6.6%

(70%) for industry:

- As a replacement for H_2 derived from natural gas, currently used in refining, the chemicals Industry (ammonia production) and a variety of industries.
- To meet the needs of new applications in the shape of the decarbonization of the steel-making industry and the bulk chemicals sector, the reshoring of methanol production to France (for traditional uses but also for use as a fuel additive in the transportation sector) and the creation of a synthetic fuel production industry (ammonia, e-kerosene,...).

(23%) for the transportation sector, equating to:

300,000 cars and vans

5,000 heavy vehicles

65 ships and boats

100 trains

(7%) for the energy sector (distribution networks, energy storage, re-electrification, etc.)

This target could be raised by 60% in the event of positive changes to the regulatory environment: the 'Ambition+ 2030' scenario

More ambitious climate change policy initiatives at French and European level could significantly expand the target market by 2030, resulting in sights being set higher in relation to the development of the market for hydrogen. This boost could be furnished by the implementation of the EU's 'Fit for 55' package and measures designed to encourage both the supply of and the demand for hydrogen which the European Union is planning to implement. In addition to more ambitious renewable energy targets, the imposition of renewable hydrogen quotas on industry of up to 50% of total hydrogen consumption by 2030 would be a major factor in stimulating production and lowering costs. The reform of the European carbon market (EU-ETS), most notably the inclusion of road transport, maritime transport and construction in the emissions trading scheme should lead to a rise in the price per tonne of carbon and make renewable and low-carbon hydrogen more competitive in relation to hydrogen made from fossil fuels: if the price were to reach 100€/tCO_2, the cost of hydrogen made from fossil fuels would rise by around 1€/kg.

The obligations imposed upon car manufacturers to reduce the CO_2 emissions of new light commercial vehicle models by up to 50% between 2021 and 2030 is a real incentive to develop fuel cell vehicle ranges. It is expected there will be a significant increase in the choice of such vehicles in the coming years. As regards the share of renewable hydrogen in the transportation sector by 2030, a goal of 2.6% has been set, which will encourage the supply of hydrogen to heavy vehicles. These measures are further backed up by the obligation that all 27 EU member states are now under to ensure that there is at least one hydrogen refuelling station every 150km along the TEN-T core network of European motorways. Finally, the new EU directives, ReFuelEU Aviation and FuelEU Maritime will place a direct obligation upon airlines and ship owners to make a gradual switch to renewable and low-carbon fuels to reduce their emissions. The main alternatives are e-kerosene derived from hydrogen in the aviation sector and hydrogen, ammonia and methanol for shipping.

The '**Ambition+ 2030**' scenario raises the bar in terms of targets, opening the way to potentially achieving the kind of growth rates achieved in similar sectors. The target could be increased to **1,090,000 tonnes per year,** in the event of more stringent regulations being introduced.

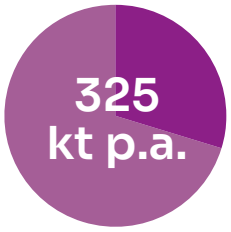
The breakdown by volume for the 'Ambition+ 2030' scenario is as follows:

1090 kt as follows:

58.3%

(58%) for industry:

- As a replacement for H_2 derived from natural gas, currently used in refining, the chemicals Industry (ammonia production) and a variety of industries.
- Meeting the needs of new applications in the shape of the decarbonization of the steel-making industry and the bulk chemicals sector, the reshoring of methanol production to France (for traditional uses but also for use as a fuel additive in the transportation sector) and the creation of a synthetic fuel production industry (ammonia, e-kerosene,...).



29.8%

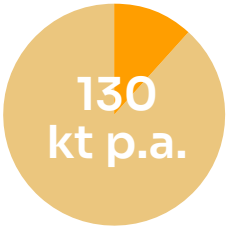
(30%) for the transportation sector, equating to:

450,000 cars and vans

10,000 heavy vehicles

135 ships and boats

250 trains



11.9%

(12%) for the energy sector (distribution networks, energy storage, re-electrification, etc.)

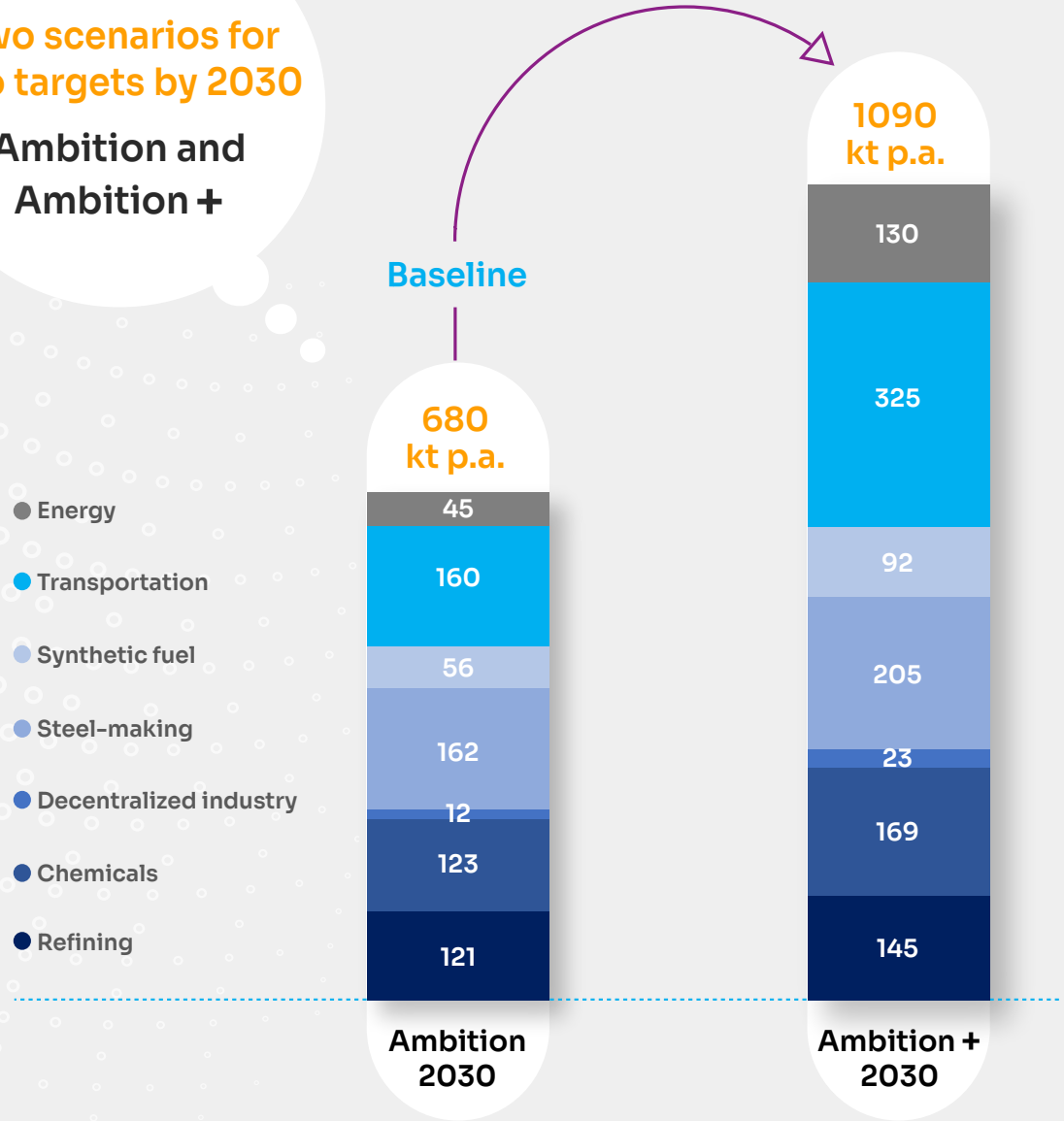
This goal could give rise to sales of hydrogen worth **2.5 to 4 billion euros annually** by 2030. Although **the transportation sector** would account for only a small proportion in terms of volume sold, **it would represent 50 to 60% of the overall value of sales** given higher unit sales prices[1] as a result of higher production costs[2] .

1 - The difference between the proportion of sales by volume and the proportion of sales by value generated by the transportation sector arises out of differences between selling prices on different market segments. The sales price of hydrogen varies between 4 and 9 € per kg in the transportation field, compared to 2 to 3.5 € per kg in the industrial sector.

2 - Taking into account costs of distribution (refuelling stations) and supply that are higher than for large-scale industrial applications (smaller-scale on-site (distributed) production vs centralized production or delivery from a central source giving rise to costs associated with logistics and delivery.

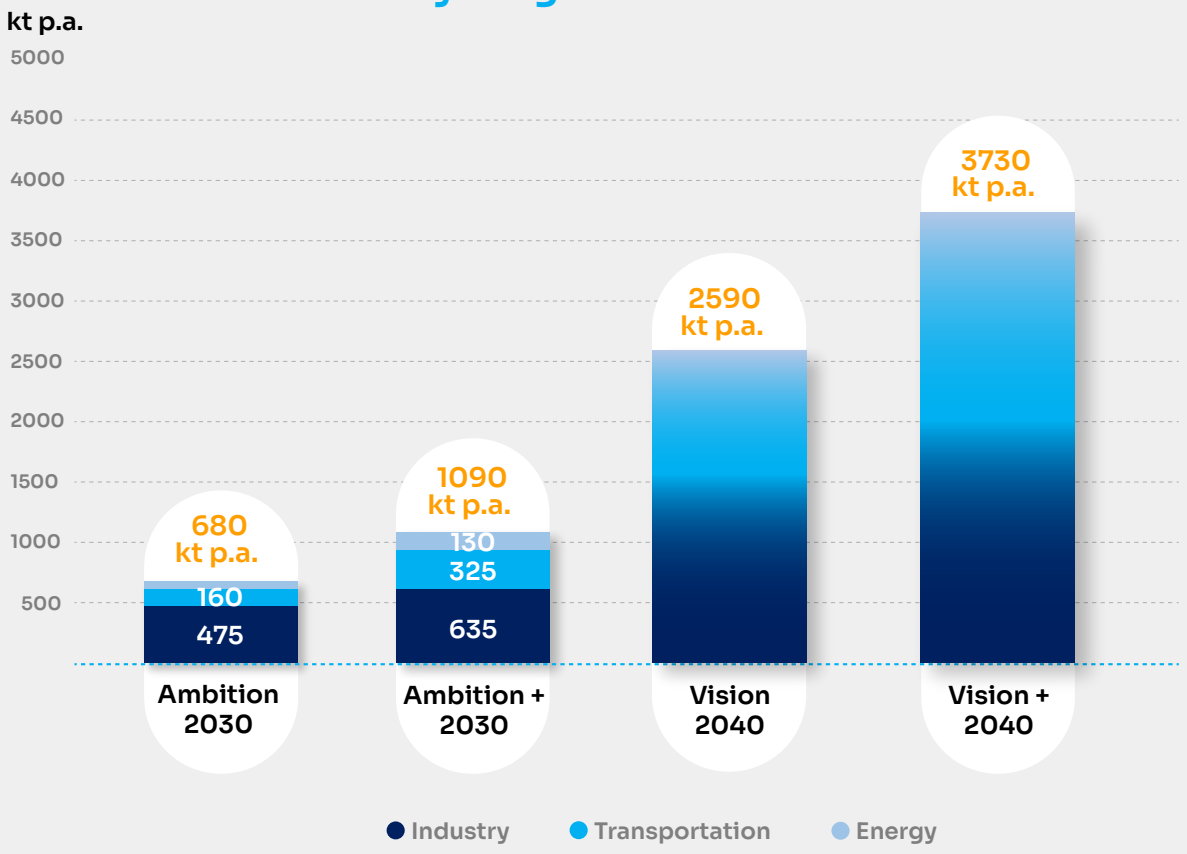
Two scenarios for two targets by 2030

Ambition and Ambition +



This production, mostly destined for industrial purposes during the ten year period 2021-2030, will help lay the foundations for a national hydrogen supply chain and reduce costs for the end consumer in anticipation of the large-scale expansion of the use of hydrogen in the transportation sector in the years after 2030, once there Is a full range of hydrogen-fuelled transportation methods (road, maritime, rail and air) available on the market. By 2040, the transportation sector is expected to become the main driver of growth In the French hydrogen market.

Projected demand for decarbonized hydrogen in France



2 Seven large clusters driving cost reductions

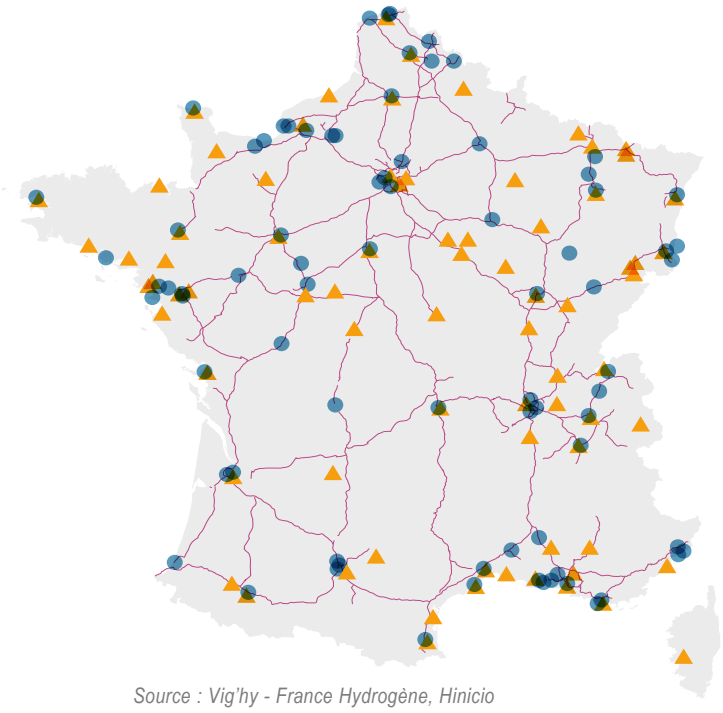
Taking account of projects already underway and the sectors being targeted, decarbonized hydrogen consumption will be concentrated for the most part in 7 major clusters which will, over the longer-term, represent 85% of all demand. Implementing an integrated supply chain to serve these clusters will enable cost reductions through the pooling of production serving similar sectors in a specific geographical area and the leveraging of economies of scale.

What criteria have been used to designate these 7 clusters?

The steps used to identify clusters:

A. Creating an inventory: identifying projects in France due to be completed by 2030 as well as the demand centres showing most potential for growth in the light of the objectives of the National Hydrogen Strategy. These sites will first be geographically located, then categorized according to market segments.

Map of H_2 projects and major demand centres in 2030



Source : Vig'hy - France Hydrogène, Hinicio

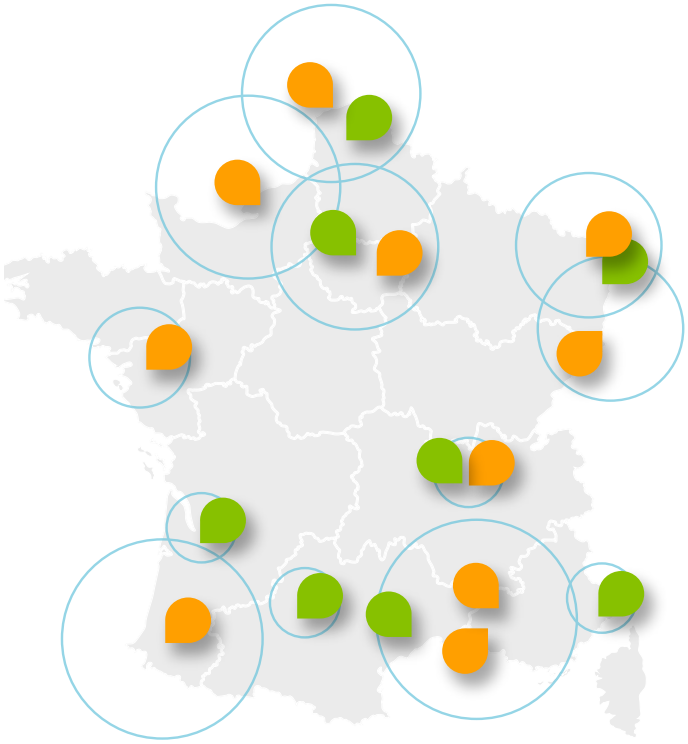
Between now and 2030, the major H_2 production sites will cluster around the main demand centres.

H_2 projects currently under development are laying the groundwork for the H_2 supply chains of the future. These projects feature on-site (distributed) production or semi-centralized production for the transportation sector.

Major demand centres by 2030
According to the Ambition 2030 scenario, new industrial and transportation sector hydrogen demand centres will emerge, mostly in major urban centres, ports and airports.

By 2030, other hydrogen projects and demand centres focusing on industry and transportation will emerge in a geographically less concentrated fashion. These projects are not shown on the map.

B. Clusters: Identifying '**geographical hubs**' corresponding to areas exhibiting the greatest growth potential in terms of both demand and production with a view to matching hydrogen supply and demand. Production in these hubs may also bring benefits to neighbouring areas. This phenomenon is referred to as a '**zone of Influence**'.



Main demand centres in 2030

Demand centres are defined as one or more areas featuring high levels of H_2 consumption, mostly dominated by large industrial customers or an assortment of transportation-related needs.

The zone of influence[3] of a production hub may be defined as the geographical area within which the cost of production and distribution of hydrogen from this production hub is the most cost-competitive option for the supply of so-called decentralized users (local government fleets, low-level industrial consumption etc.). As a result, the zone of influence helps flag up opportunities for partnerships between projects. However, the zone of influence is a function of several different factors: scale of production and demand, geographical distances, chosen supply/distribution method option (pipeline or cylinders, compressed or cryogenic).

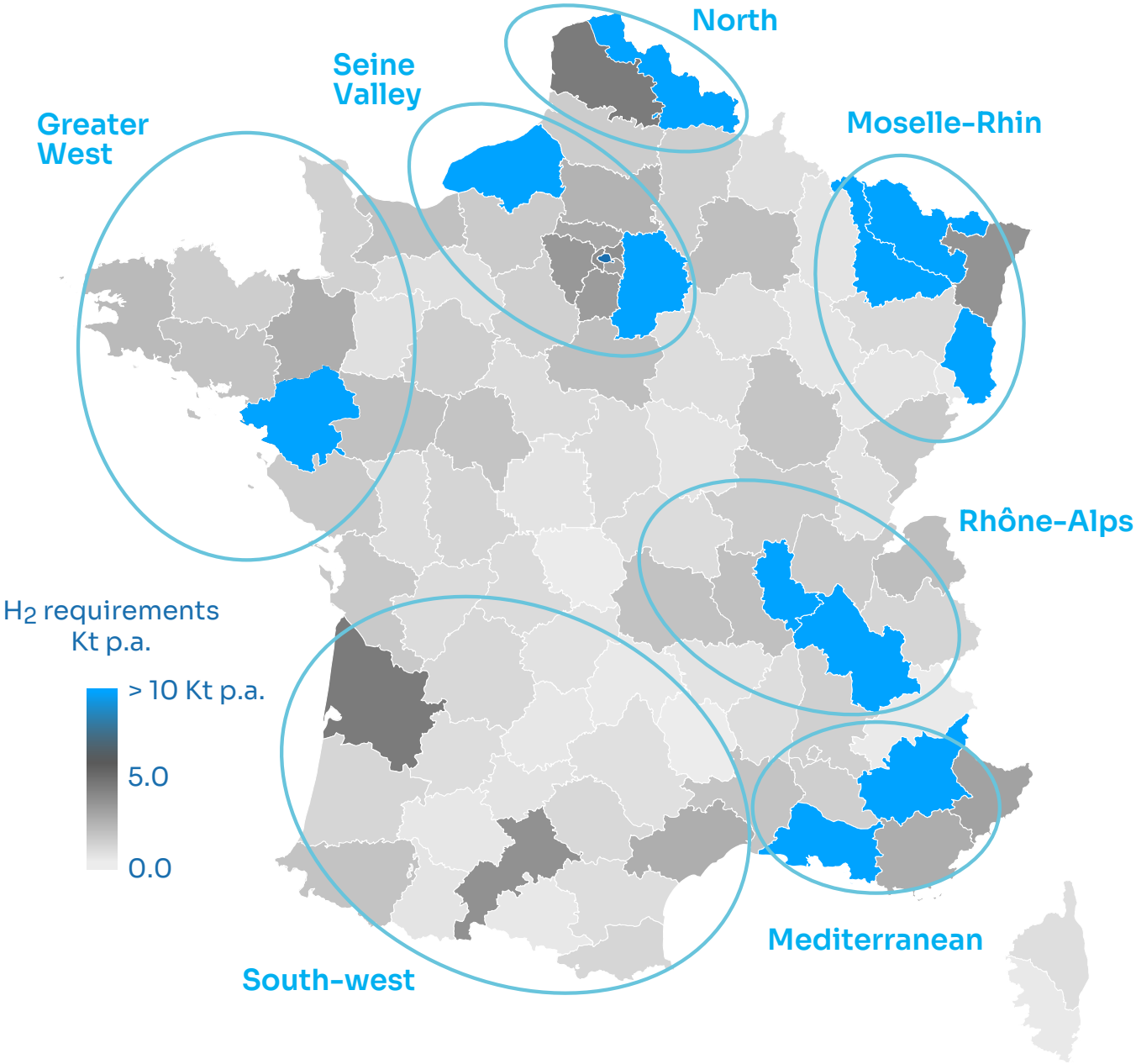
C. Pooling resources: Identification of **7 major clusters** where the implementation of an integrated, end-to-end supply chain based upon the main production sites would be a key driver for increasing the sector's rate of expansion.

The exact coverage of the zone of influence is determined by the size of the main production units (in MW) and the needs of the decentralized users.

Likely sources of demand in 2030 will concentrate around the main industrial and transportation hubs (e.g. major urban centres, ports and airports, logistics hubs).

3 - See annex 3 - Quantifying a zone of influence

This grouping together of large demand centres and their logistical zones of influence constitute **France's 7 large hydrogen clusters.**



French *départements* which will require significant supplies of H_2 for industrial needs in 2030

French *départements* which will require significant supplies of H_2 for transportation needs in 2030

D. Design and scale: Depending on each cluster's individual characteristics, 3 main supply chain approaches[4] may be envisaged (on-site (distributed), centralized and semi-centralized).

4 - See annex 1 – The scale of the French hydrogen supply chain by 2030

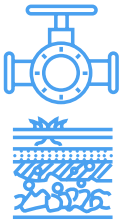
Geographically-concentrated demand creates **opportunities to harness economies of scale through the pooling of production on a very large-scale around major demand centres (large-scale industry). These centralized production sites would be able to supply a large proportion of the decentralized consumption within the cluster area (specifically, public refuelling stations) at competitive prices, if dedicated storage and distribution facilities were put in place.** This streamlining of operations also presupposes that the necessary resources would be allocated to ensure that end customers would not experience supply issues, such as the use of pipelines and underground hydrogen storage. Within the area of the clusters decentralized consumers with significant daily requirements such as bus depot refuelling stations (on average 2 tonnes per day) should nonetheless opt for on-site (distributed) production due to the practical impossibility of ensuring that enough hydrogen trailer deliveries can be carried out.

Outside these clusters, many projects are also under development some of them being very large in scale. These mostly revolve around transportation. **Representing 15% of total demand, they play an important part in the growth of the hydrogen sector and will help ensure that the supply network covers the entire country.** However, given their geographical isolation from the large production and demand centres, which means that they lie outside their 'zones of influence', these projects will focus on decentralized production, either on-site (distributed) or pooled with several local projects so as to increase production volume and thus leverage economies of scale.

This vision is reliant upon the implementation of a hydrogen supply chain by 2030:

6.5 to 10 GW **of total installed hydrogen production capacity** are needed to meet the requirements of the 2 targets under consideration

685 km **of pipeline,** linking the key industrial hubs and underground storage facilities[5] (underground hydrogen storage capacity of 15 to 20 kt to meet the needs of Industry)



5 – Matching the objectives outlined in the European Hydrogen Backbone (600 km) to which 85 km of pipeline has been added in specific regions to ensure supply chain reliability for large industrial sites.

800 to 1,000

transportation units[6] to deliver 90-120 kt per year to decentralized consumers in the zones of influence of H_2 production sites .

1,000 to 1,700

refuelling stations of which 90% will be open to the public (large urban areas, major road networks) and 10% located in depots for the use of so-called 'captive fleets' of heavy vehicles.
The roll-out of refuelling stations outside cluster areas is particularly important in order to provide adequate geographical coverage in terms of supply (long-distance journeys) and to prepare the ground for the large-scale expansion of the use of hydrogen in the transportation sector in the years after 2030.

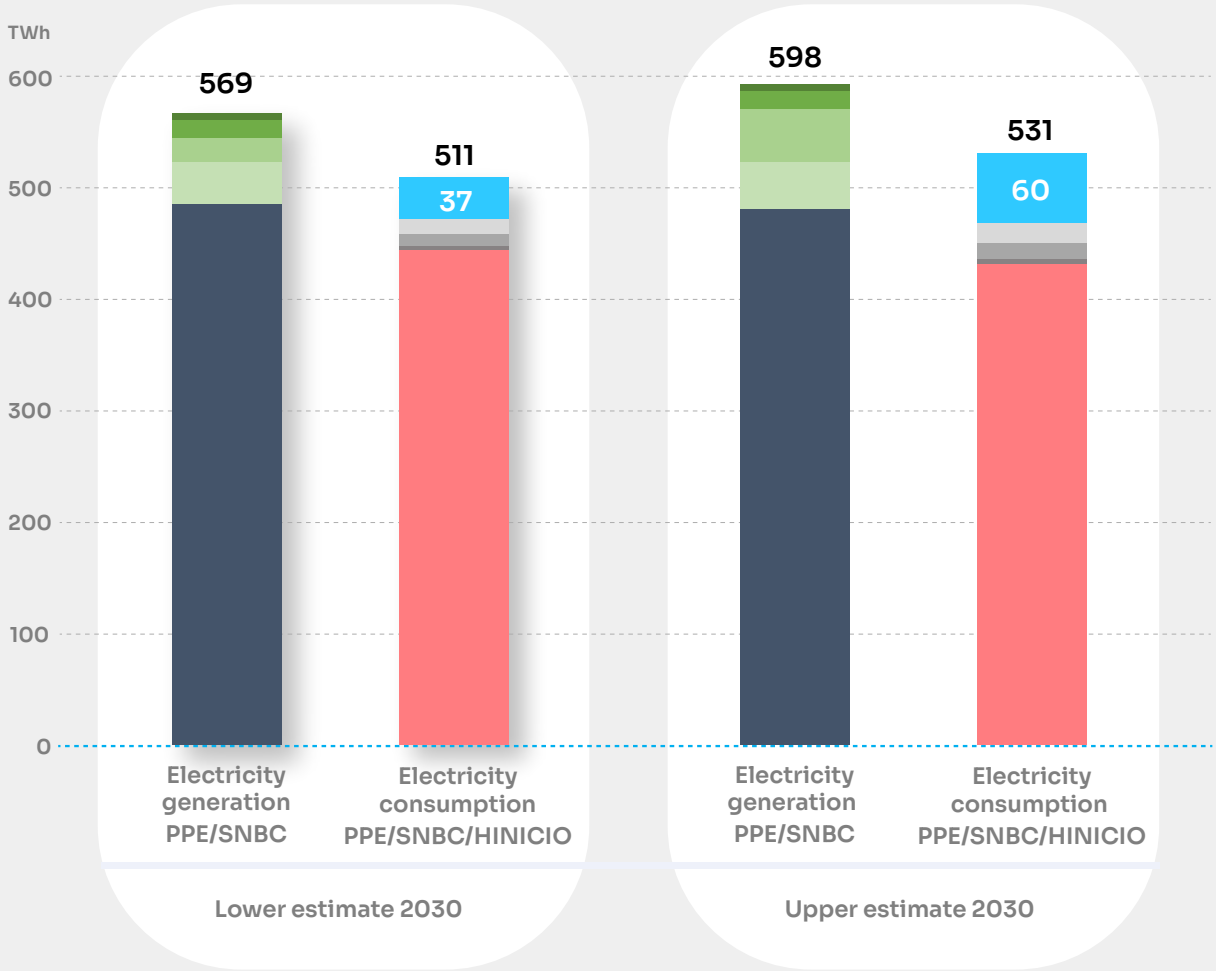
3 Meeting the demand for primary energy

If the goals of the Multi-Annual Energy Plan (PPE) are met, national electricity generation in 2030 will be sufficient to meet the electricity requirements of the hydrogen sector

The RTE, (the French equivalent of the UK's National Grid plc) has adopted the objectives of the Multi-Annual Energy Plan - PPE). Its projected electricity supply estimates for 2030 are such that there is provision for 37 to 60 TWh for the purpose of hydrogen electrolysis, on the basis of hypotheses as to efficient energy use as applied to final electricity consumption.
Final electricity consumption will remain below that of national generation. Likewise, the load balancing of the electrical power distribution system will not be impaired, as electrolyzers can be curtailed during hours of peak demand.

6 – By transportation units we mean mobile storage units used for transporting hydrogen by road, river or rail (e.g.: compressed hydrogen tube trailers).

Projected figures for electricity generation and consumption in France in 2030



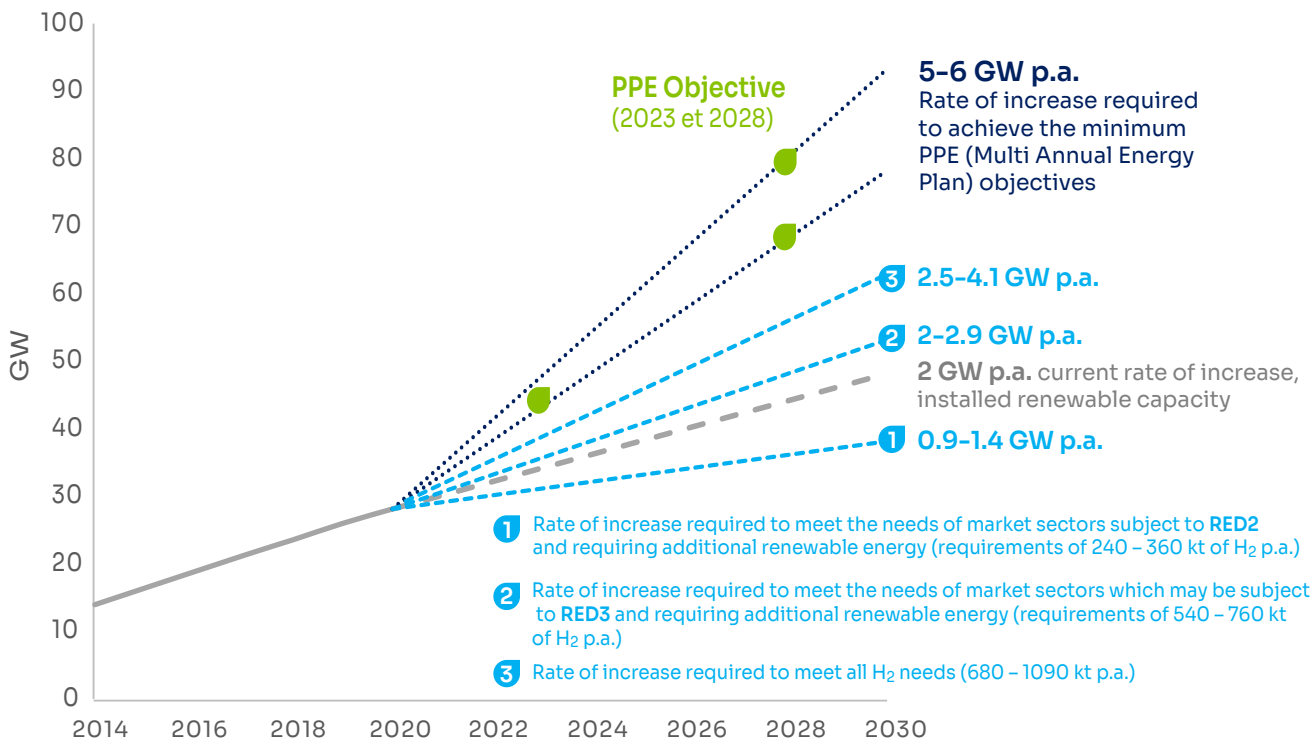
Additional renewable energy generation

- Hydro
- Off-shore wind
- Solar
- On-shore wind
- Grid electricity (France 2019)

Consumption

- Hydrogen production
- Charging electric vehicles
- Electrification for residential and tertiary uses
- Electrification of industrial processes
- Consumption (2019)

Rate of increase of installed capacity of on-shore wind power and solar PV in France*



**Allowing for an average capacity factor for on-shore wind and solar PV of 2,050 full-load hours per year and 1,200 full-load hours per year respectively. The target for off-shore wind set by the PPE Is for 6 GW of Installed capacity by 2030. This has not been considered in our calculations as it Is deemed to be of little consequence given the immense figures we are dealing with.*

Source: RTE projected electricity supply estimates, 2021-2030, overview of renewable electricity 2020 and quoted in Hinicio's study.

The current rate of the increase in installed capacity of renewable energy (on-shore wind and photovoltaic energy) – 2 GW annually – **is adequate to meet the additional renewable energy needs of the applications subject to RED2.** However, **the extension of the scope of RED2 to the industrial sector, through the implementation of RED3**, will increase the need for both new renewable electricity generation capacity and an **acceleration of the rate at which renewable energy installed capacity is being added**, as this is currently lagging behind where it needs to be to meet the objectives of the PPE.

To achieve the reductions in emissions expected in the market segments that are not bound by RED2 and RED3, **hydrogen production must be bolstered by specific additional installed capacity (from renewables or nuclear power)** because using existing installed capacity to produce hydrogen would result in a net increase In European emissions (source: RTE).

The purchase of additional low-cost renewable electricity from cross-border sources (southern Europe) through PPA7- Power Purchase Agreements, is a possible alternative but one that **is constrained by electricity interconnection capacity and the complexity of physical cross-border PPAs** (allocation of interconnector capacity rights, identifying the renewable electricity to be used in the production of hydrogen for the purposes of RED2/3,...).

By offering new commercial openings, the **hydrogen sector helps renewable energy projects** to overcome funding difficulties, even if, as also applies to other projects, renewable energy projects are also subject to other, significant obstacles (finding suitable sites, zoning, delays in planning permission being given, legal action and public acceptance).
Furthermore, electrolyzers can be used for load curtailment purposes through the storage of hydrogen, helping boost the power system's resilience by delivering power system flexibility without impacting upon the supply of H_2 to consumers. At a local level, hydrogen production units can help integrate renewable energy into the grid and negate or delay the need for upgrades to the electricity distribution network such as those that would have been required due to the rolling-out of new installed capacity such as off-shore wind farms off the Normandy coast (1.5 GW of Installed capacity by 2025).

7 - Power Purchase Agreement: contracts between two parties, a producer of renewable electricity and a buyer

4 Defining and adapting the regulatory framework

A loosening of the criteria governing the compliance of hydrogen production within the RED-2 framework, easier access to renewable electricity PPA8 and the opportunity for hydrogen producers in receipt of grants to possess guarantees of origin and demonstrate traceability are needed.

The criteria governing compliance that feature in the delegated acts of the RED2 directive currently being debated (additionality, temporal and geographical correlations), which are the main factors Influencing the development of renewable H_2 production, must be **made more flexible (through delegated acts)**. An overly-strict application of these criteria will slow the roll-out of new production projects and increase renewable hydrogen production costs in a way that has the potential to put both the emergence and the competitivity of the renewable hydrogen sector permanently into doubt. Additionally, the ban on renewable energy generation schemes in receipt of public funding from producing renewable hydrogen by electrolysis, will, if it is maintained in its current form, also make the sector less financially competitive during the initial phase of a burgeoning hydrogen market.

Hydrogen producers need to be able to highlight the renewable or low-carbon nature of their product to their customers and the authorities. The French 'Ordonnance du 17 février 2021 relative à l'hydrogène' makes provision for the French state to auction Guarantees of Origin and Guarantees of Traceability for hydrogen production facilities that are in receipt of government grants. This creates considerable uncertainty for producers who are unsure whether or not they will be able to market their product as 'renewable' or 'low-carbon' to their clients or even the authorities in the framework of compliance with RED2. It is important to give producers of renewable and low-carbon hydrogen the chance to purchase Guarantees of Origin (GO) so as to allow the hydrogen market to develop independently and optimize the amount of value they can add to the hydrogen produced through its 'renewable' or 'low-carbon' nature. To avoid the risk of double counting, producers with a GO may cancel this guarantee in exchange for the issuance of a certificate under the provisions of the European Commission's Union Data Base project (provided for in RED2).

Moreover, because of the relative dearth of hydrogen infrastructure at this time, the trade in the climate value represented by the 'renewable' or 'low-carbon' nature of the energy must be decoupled from the trade in the physical energy as it travels from production sites to end customers (book and claim system).

8 - Power Purchase Agreement: contracts between two parties, a producer of renewable electricity and a buyer

Further flexibility and adaptations are needed to ease the development of the sector

Regulatory constraints on all stages of the hydrogen supply chain need to be loosened and adapted to facilitate the development of the hydrogen sector. It is important to avoid the kind of over-regulation which could imperil the sector's development.

Hydrogen production by electrolysis, which is governed by French regulations in relation to facilities requiring an environmental impact assessment (ICPE 3420), requires official authorization as soon as any hydrogen is produced.

The adoption of a hydrogen production threshold would give project owners a clearer understanding of the administrative formalities they needed to complete and accelerate the roll-out of electrolyzers. Currently, each project is dealt with on a case-by-case basis by the authorities, which slows the processing of applications.

Hydrogen storage is regulated by ICPE 4715 and requires official authorization as soon as 1,000 kg or more of hydrogen is stored on one site. The first feedback from the field demonstrates that a fleet of more than 20 heavy vehicles (buses or lorries) would require larger storage capacity than this limit. Serious thought must be given to the modification of thresholds, the streamlining of the official authorization process and the introduction of new storage norms. Moreover, the European Union 'Pressure Equipment Directive' (PED) does not directly reference technical requirements as they apply to hydrogen tanks, meaning that it is not possible to carry out appropriate checks with regard to this directive during in-service monitoring.

The standards currently applicable to the use of hydrogen in the transportation sector are also acting as a brake on growth. The technical provisions of ICPE 1416 relating to hydrogen refuelling stations pose real technical challenges and lack flexibility. For instance, the minimum separation distances between fuel pumps are ill-suited to multi-fuel/multi-energy service stations located in urban areas. Amendments to the 2018 ministerial decree relating to hydrogen refuelling stations would allow for greater flexibility. ICPE 1416 could be extended to cover rail, sea and river transportation. Furthermore, the appearance of hydrogen-powered heavy vehicles should be accompanied by an increase in the current thresholds for dispensing pressures and flow rates, which are both too low in view of the quantities of hydrogen required by such vehicles. Liquid hydrogen refuelling must also be taken into account. Regulations governing the operation or parking of hydrogen-powered vehicles in road tunnels and underground car parks, as well as related safety standards must be laid down.

Moreover, standard governing the transportation of hydrogen are going to be changed from 2023 with the entry into force of the ADR EN 17339 standard.

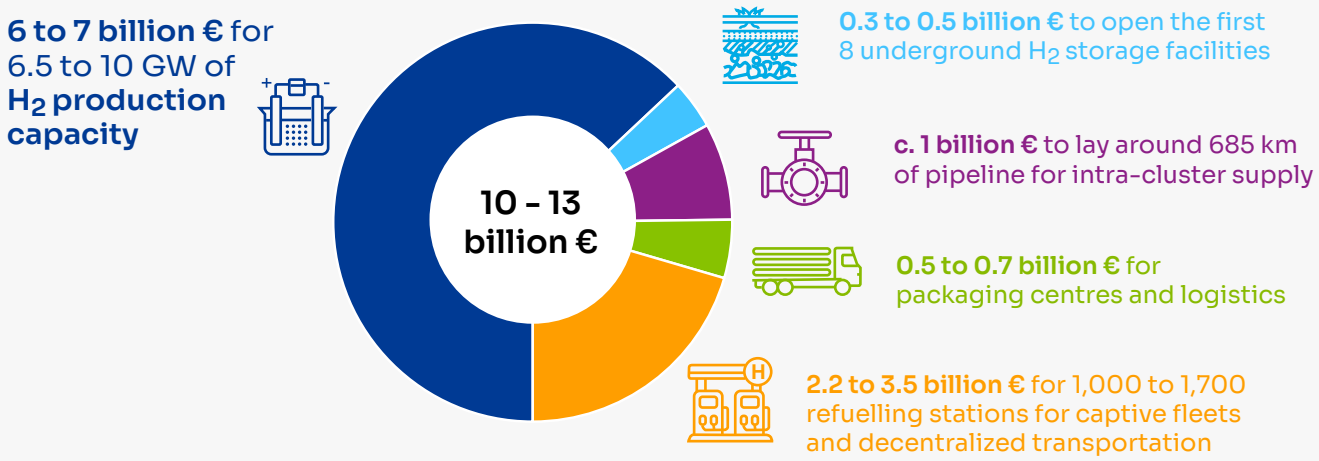
It allows for hydrogen to be stored under higher pressure than was previously the case, meaning that larger quantities of hydrogen can be stored and transported. It would be good if this standard were brought into use earlier.

Challenges relating to measurement and measuring methods will emerge at the same time as new applications for hydrogen requiring precise quantification as part of a distributed power generation system. The hydrogen sector needs to obtain details of the deadline for existing hydrogen refuelling stations to comply with the ministerial decree of 18th December 2020 relating to compressed hydrogen measuring equipment in refuelling stations (l'arrêté ministériel du 18 décembre 2020 sur la métrologie de ces stations).

5 Funding the supply chain

To roll-out a national hydrogen supply chain will require 7 to 12 billion euros of funding. This can be supplied by the market through regulatory incentives or by the state through public money.

Total investment in the French H_2 supply chain required to meet H_2 demand of 680 – 1090 kt p.a.



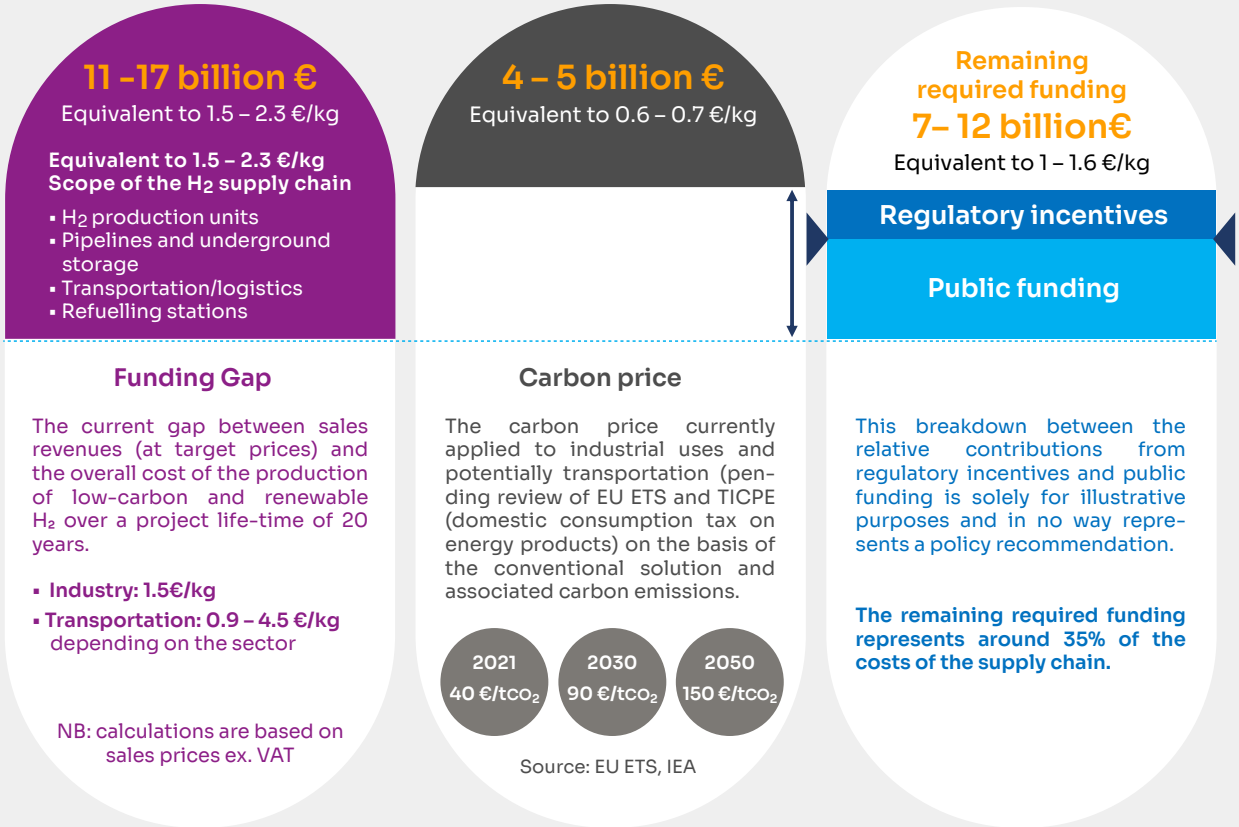
These sums do not include additional investment in hydrogen-related applications with the goal of achieving the Ambition 2030 target:

- Upstream applications (e.g. investment in renewable energy)
- Downstream applications (e.g. decarbonizing industrial processes, hydrogen vehicles)
- Upscaling manufacturing capacity
- R & D and training

The establishment of a hydrogen supply chain (production, transportation, storage, packaging, delivery) requires **combined public and private investment of 10 to 13 billion euros by 2030,** depending on which scenario is implemented (Ambition or Ambition+). 60% of this will be invested in hydrogen production through electrolysis.

The rolling-out of this chain could lead to a funding gap[9] of 11 to 17 billion euros because the income generated by the sale of low-carbon or renewable hydrogen will probably not cover all the start-up and operating costs of the supply chain. This funding gap could be partly offset by **carbon pricing (4-5 billion euros)** levied on actors who are obliged by law to use hydrogen (which could have an impact upon their value chain in the future). **The 7 to 12 billion euro funding gap** could be plugged by two means:

- **Regulations** forcing the market to cover the additional costs (mandatory participants and their clients) by increasing the sales price of hydrogen by creating a legal obligation to comply;
- **State aid** (subsidies, grants...) will help reduce these additional costs and associated risks for both hydrogen producers and consumers, and, in tandem with regulations, can help reduce the cost of compliance for those subject to it.



9 – See annex 2 for the definition of the funding gap

With regard to hydrogen production, help with capital expenditure (CAPEX) and operational expenditure (OPEX) is the best solution to offset the negative gross profit margin relating to the low valuation of low-carbon or renewable hydrogen in comparison to its production costs, especially that of the electricity used in the production process. The sector is just beginning its learning curve and rapidly needs to become more competitive. **The premium tariff planned by the state can be a perfect solution** but has to be allocated through calls for tenders which will be classed according to project requirements, the technology used to produce energy and their location - within the clusters or outside them. **Support for capital expenditure should be put in place for production units helping to drive technological progress,** especially where this may facilitate the scaling-up process.

Once production has begun, state aid may be applied to some sections of the value chain in the shape of **grants towards capital expenditure**, in the event that most of the funding gap stems from CAPEX.

Generally speaking, accessing capital expenditure grants and the premium tariff mechanism via the same 'one-stop-shop' would be helpful in avoiding situations where funding is sourced from multiple bodies requiring multiple applications and complex administrative formalities, thus aiding the process of putting the necessary funding in place for projects.

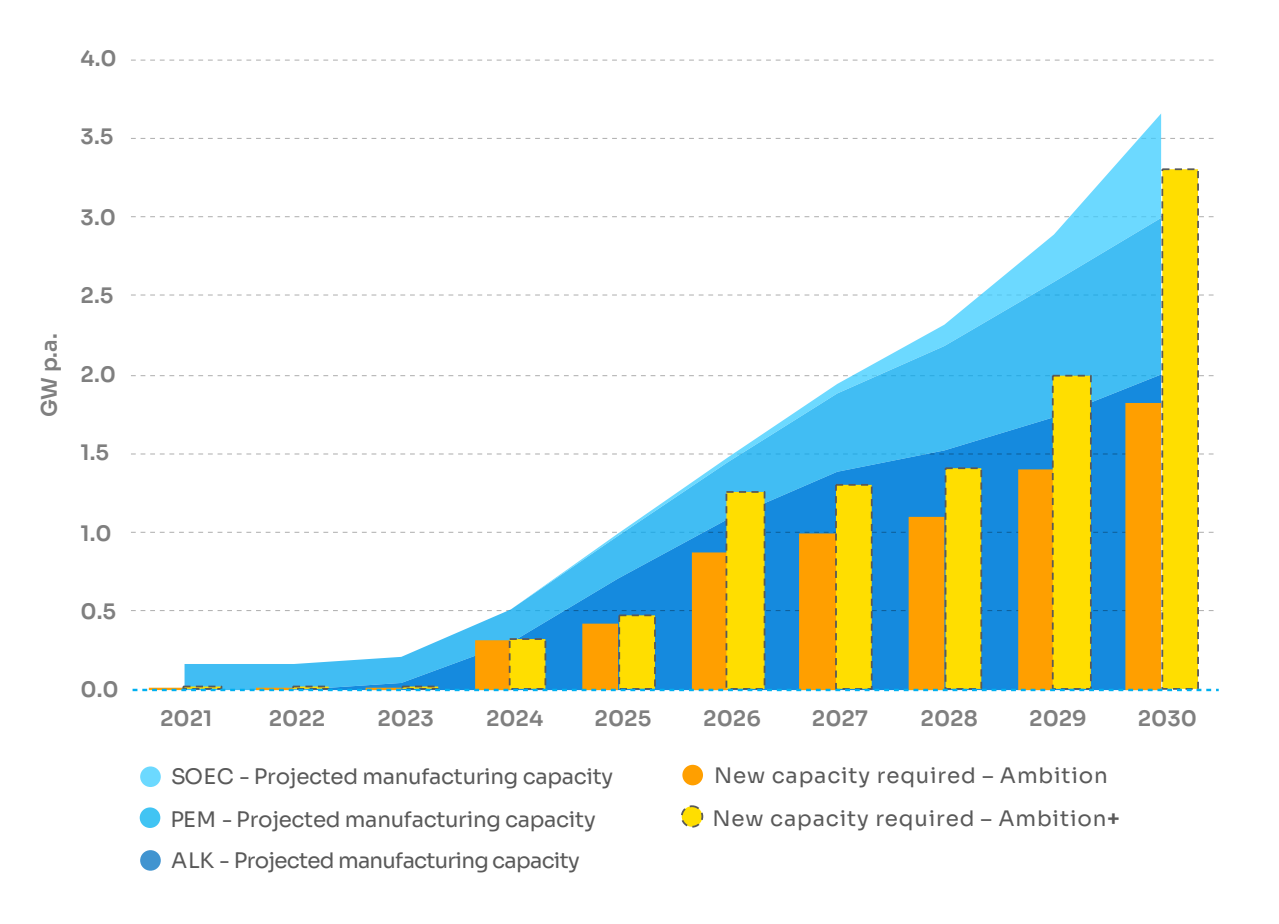
6 Developing the hydrogen sector: an opportunity to re-industrialize at a nation-wide level

The rapid growth of the low-carbon and renewable hydrogen market in France represents an opportunity for the local manufacturing sector to re-industrialize, focusing on high value-added technologies that are suitable for export.

- **In terms of electrolysis**

The implementation of this road-map will require between **0.5 and 2 GW of installed electrolysis capacity to be added every year between 2024 and 2030.**

Comparison between French electrolyzer manufacturing capacity and yearly requirements for installed electrolysis capacity



Calendar of national requirements up to 2030

Up to 2023: <50 MW p.a. for demonstration projects currently under development (e.g. ADEME call for projects).

2024 to 2025: 300-500 MW p.a., reflecting the emergence of larger demonstration projects, notably relating to the first industrial and heavy transportation projects.

2026 to 2029: 1-1.5 GW p.a., stemming from the rolling out of large industry projects needing production units with a capacity running into hundreds of MW.

In 2030 : 1.5-3 GW p.a., mostly for large-scale projects.

The opening up of Gigafactories between 2025 and 2030 in France, which Is conditional upon state aid (IPCEI), should enable the French industrial sector to lay claim to significant market share in France whilst also putting it in a strong position to export to Europe and the rest of the world.
In the absence of this kind of manufacturing capability, this road-map would Inevitably entail the need to import electrolyzers capable of producing 0.1 to 1 GW of electricity per year by 2024 and around 1 GW from 2026 onwards, mostly from Europe, China or the United States.

Manufacturers of electrolyzers are warning of specific risks arising from deficiencies in French industrial capabilities in some key elements of the electrolysis value chain.

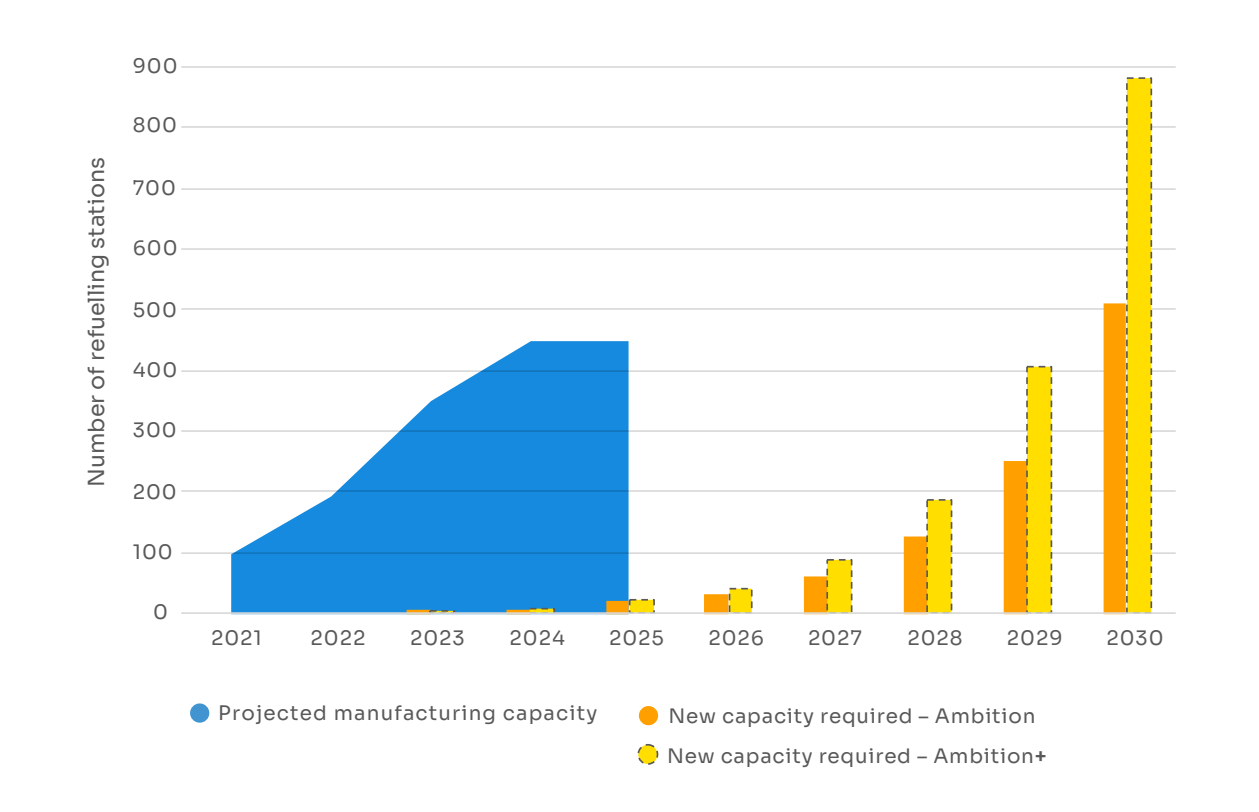
A national or Europe-wide strategy is needed to secure supply chains of sub-components that are critical to the manufacture of electrolyzers. Some of these, such as power electronics and membranes are nearly all imported at the present time.

It is also important to **establish industries able to recycle rare materials** like iridium, which are essential ingredients in electrolyzer manufacture and to support R & D into the next generation of units (increased capacity, more energy-efficient, smaller physical footprint etc.

▪ In relation to hydrogen refuelling stations

The French manufacturing sector's own projections as regards its capacity to make refuelling stations should be adequate to meet the needs of the French transportation sector.

Comparison between French refuelling station manufacturing capacity and yearly requirements for new stations



Calendar of national requirements up to 2030

Currently: There are **almost 50 hydrogen refuelling stations** in France.

Up to 2027: **<100 stations p.a.**, reflecting the emergence of larger demonstration projects, notably relating to the first heavy transportation projects.

2028 to 2030: **100 to 800 stations p.a.**, reflecting the acceleration in the pace of the roll-out of the public refuelling station network.

In 2030: **1,000 to 1,700 stations built.**

French manufacturers of refuelling stations are currently focussing on assembling components, including the most critical components, which they are sourcing from European markets or further afield. **The creation of a French compressor manufacturing industry would help reduce the dependency of the French manufacturing sector on imports of this vital component, especially as bottlenecks in the supply of this item are foreseeable. This would also represent a chance to make value-added products in France, driven by the expansion of the hydrogen-powered transportation sector both nationally and in export markets.**

Support for R & D, the development of next generation refuelling stations (bigger capacity, more reliable, smaller physical footprint...) will also be required to help French manufacturers keep up with a growing market in France and abroad. It is also important to plan for the dispensing of liquid hydrogen in stations, in line with the Alternative Fuel Infrastructure Regulation (AFIR) Proposal for a Regulation, part of the 'Fit for 55' package. Hydrogen liquefaction technology must be a priority field for France.

Supporting French actors on the international scene: another opportunity to grow the sector

Over 30 countries possess strategies for growing their hydrogen energy sector. This creates new opportunities abroad which can enable French companies to become leaders in this field. France's hydrogen strategy would benefit from cooperation with international partners, which would act as a boost to French manufacturing companies competing on this international stage. Partnerships with non-EU countries in the area of renewable hydrogen, for example, Chile or Australia, would create the most favourable conditions for achieving the objectives of the French strategy.

It would be worthwhile **developing mechanisms to support projects outside the EU** which are led by French companies as long as these projects tally with the priorities for the sectors in question laid down in the French strategy. They should also be of mutual interest to both France and the host country. Aid from the French state destined for companies involved in projects abroad would offer a real boost to firms involved in calls for projects abroad and more generally to the wider hydrogen sector in France.

7 Towards a European hydrogen market

An analysis of the geographical distribution of hydrogen demand in France highlights a concentration around large industrial and transportation hubs: ports, airports, large urban areas, manufacturing and logistics centres.

Grouping together these major centres of demand and their logistical zone of influence creates a total of 7 clusters in France, which will represent almost 85% of demand for hydrogen by 2030. Within these clusters, gas pipelines for transporting hydrogen will be needed. According to the study, 'European Hydrogen Backbone' carried out by 23 European natural gas transmission system operators, almost 700 kilometres of pipeline will be required in France by 2030.

In order to reduce costs by identifying shared needs and pooling resources, it is recommended that this organizational approach be generally adopted all over Europe.

In the Netherlands, for example, the HyWay 27 study by PwC in partnership with the Ministry of Economic Affairs and Climate Policy, the Ministry of Finance, electricity transmission system operators (Tennet) and natural gas transmission system operators (Gasunie), makes it obvious that there is a clear advantage in converting part of Gasunie's natural gas transmission network to transport hydrogen and connect the 5 main industrial clusters, thus offering consumers flexibility and security of supply. On the basis of this study, the Dutch government has asked Gasunie to go ahead with this conversion project.

In the United Kingdom, there are plans to develop a network spanning more than 2,000 km, linking 5 industrial hubs.

In Italy, 50% of planned investment by SNAM, the natural gas transmission system operator, over the period 2022 to 2024 has been allocated to preparing the conversion of the network to hydrogen.

In Sweden, a country with an electricity generation mix that is as decarbonized as France's thanks to nuclear power and hydropower, a study carried out by Energiforsk demonstrated the need for a national hydrogen backbone linking hydrogen production sites and centres of demand.

Furthermore, some countries have clearly set down their vision as regards imports and exports in their national strategy.

In Spain, the government has clearly signalled its intention to develop ambitious plans for a hydrogen sector by making the most of the country's renewable energy resources. At this moment in time, the country has plans to add 430 gigawatts of new solar and wind capacity, subject to receiving authorization for connection to the electricity grid. The Spanish national energy and climate plan only envisages 90 GW of this capacity being connected to the national grid, leading project owners to seek out alternative outlets for the renewable electricity they produce, in particular, the production of renewable hydrogen.

Germany has already stated that local production of renewable hydrogen will not be sufficient to decarbonize its economy. At the same time as publishing its hydrogen strategy in June 2020, the German government announced that it would allocate 2 billion euros to the development of partnerships with countries with substantial renewable energy resources with a view to importing renewable hydrogen from these nations. Countries such as Morocco, Chile and Australia were mentioned.

In France, the Comité Stratégique de filière Nouveaux Systèmes Energétiques (which brings together different stakeholders in the fields of energy efficiency, energy storage, renewable energy and intelligent energy networks) commissioned a study which highlights the important part that hydrogen distribution infrastructure plays in the development of the sector as a whole.

We can therefore see that European countries are making preparations to implement a single market for hydrogen. Hydrogen is still viewed for the most part as a chemical product. However, with new applications being developed, it is well on the way to becoming a commodity which, just like electricity or natural gas, will need an established infrastructure enabling its transportation from hydrogen producers to hydrogen consumers. It's with this goal in mind that 23 natural gas transmission system operators have been working to create a European Hydrogen Backbone which will consist of 27,000 kilometres of pipeline by 2030 and 40,000 kilometres by 2040.

For producers and consumers, being able to access a market through an interconnected transportation and distribution infrastructure is a key ingredient in delivering cost efficiencies and price transparency. Consumers will benefit from competition between different suppliers, enabling them to purchase hydrogen at lower cost.

Furthermore, the ability to access huge quantities of hydrogen stored underground through this distribution infrastructure ensures that the supply of renewable or low-carbon hydrogen will always be adequate to meet the minimum, ongoing needs of consumers in the manufacturing and transportation sectors via the process of load following.

In the case of **France,** its specific geographical location, between countries with large renewable energy resources which are capable of very large-scale (and cheap) renewable hydrogen production (Spain, Portugal, North African countries) and northern European countries with a very large appetite for low-carbon or renewable hydrogen (Germany, the Netherlands) could make it into a transit country for hydrogen produced in the south of Europe going to consumers in the north of Europe. France's hydrogen transportation infrastructure would also ensure French consumers would have access to low-cost hydrogen.

It is obviously too early to draw up a timetable for the development of interconnectors between French clusters and hydrogen transportation networks in neighbouring countries (Spain, Germany). This will develop in line with client demand. With this in mind, France's two natural gas transmission system operators opened a market consultation exercise. Similar steps have already been carried out in other European countries (Germany, the Netherlands, Belgium).

Nonetheless, it is important to stress that heavy infrastructure projects such as gas transportation infrastructure are very much long-term in nature. Given that it takes at least 5 years to implement these kinds of investment decisions, it's important to think about how the French National Hydrogen Strategy can be swiftly finalized and readied to respond to the demands of the market. This will secure the delivery of a reliable, competitively-priced supply of hydrogen to the French consumer, derived from a variety of sources. This will also safeguard the ongoing growth of some manufacturing concerns and perhaps even protect local businesses from closure.

8 REALIZING THE HYDROGEN STRATEGY'S FULL POTENTIAL: RECOMMENDATIONS

This road-map will not become a reality without the **implementation of public policy initiatives which are equal to the tasks in hand and which provide long-term clarity for relevant stakeholders** in the energy sector.

We recommend the following actions:

The roll-out of the hydrogen sector:

- **Implement multi-regional plans** for the roll-out of a hydrogen supply chain (production, pipelines, underground hydrogen storage, packaging centres, refuelling stations) that will be sufficient to serve each individual cluster, keeping in mind expected changes in applications. This should be planned in tandem with the natural gas and electricity distribution networks to deliver optimal efficiency and eliminate duplication.
- **Enable producers to express themselves regarding the quality of their product, despite them being in receipt of public money,** whilst avoiding 'double claims' (for example, via pre-emptive rights to purchase Guarantees of Origin at auction at market price).
- **Simplifying and speeding up the administrative formalities** required to roll out the supply chain (refuelling stations).
- **Work pro-actively at European level on the provisions of RED3** to help keep French manufacturers a step ahead of European and international competitors.
- **Ensure that the premium tariff mechanism for hydrogen production is compatible** with **1/** the need to secure upstream investment for renewable energy and **2/** the ability of producers to express themselves on the quality of their product (to consumers).
- Encourage the roll-out of hydrogen in the transportation sector by **retaining plug-in car grants and setting more ambitious targets for replacing public and private vehicle fleets** with zero-emissions vehicles.
- **Support the development of a dense network of refuelling stations along major road networks,** in particular by extending concessions awarded by motorway operators to petrol retailers.

Growing the French hydrogen sector's industrial muscle:

▪ **Support the development of Gigafactories (for electrolyzers, fuel cells) with the help of capital expenditure grants (in the framework of IPCEI regulations)** to cater to national demand and make the most of export opportunities.

▪ Draw up a **national strategy to secure sub-components** for French or European manufacturers.

▪ Adapt and improve the rare materials **recycling sector.**

▪ **Support investment in R & D and an increase in manufacturing capacity relating to key sections of the value chain** (in particular, electrolyzers, refuelling stations, effective hydrogen liquefaction technology) to allow French manufacturers to maximize their share of the domestic market and boost their presence on the export market.

▪ Support the development of a **French compressor manufacturing sector**.

▪ **Support and promote the involvement of industrial actors in the sector,** especially SMEs, by funding industry experts' research into developing and setting standards**.**

▪ **Introduce a standard-setting aspect to project assessment** and eligibility of expenditure.

▪ **Raise stakeholders' awareness of issues relating to standards** and the implications of their choices regarding standards.

▪ **Support French actors abroad by implementing a funding mechanism for hydrogen projects outside the EU undertaken in partnership with the host country. These projects must tally with France's strategic priorities for the sector and be of mutual interest for both France and the host country.**

Meet the hydrogen sector's needs for primary energy:

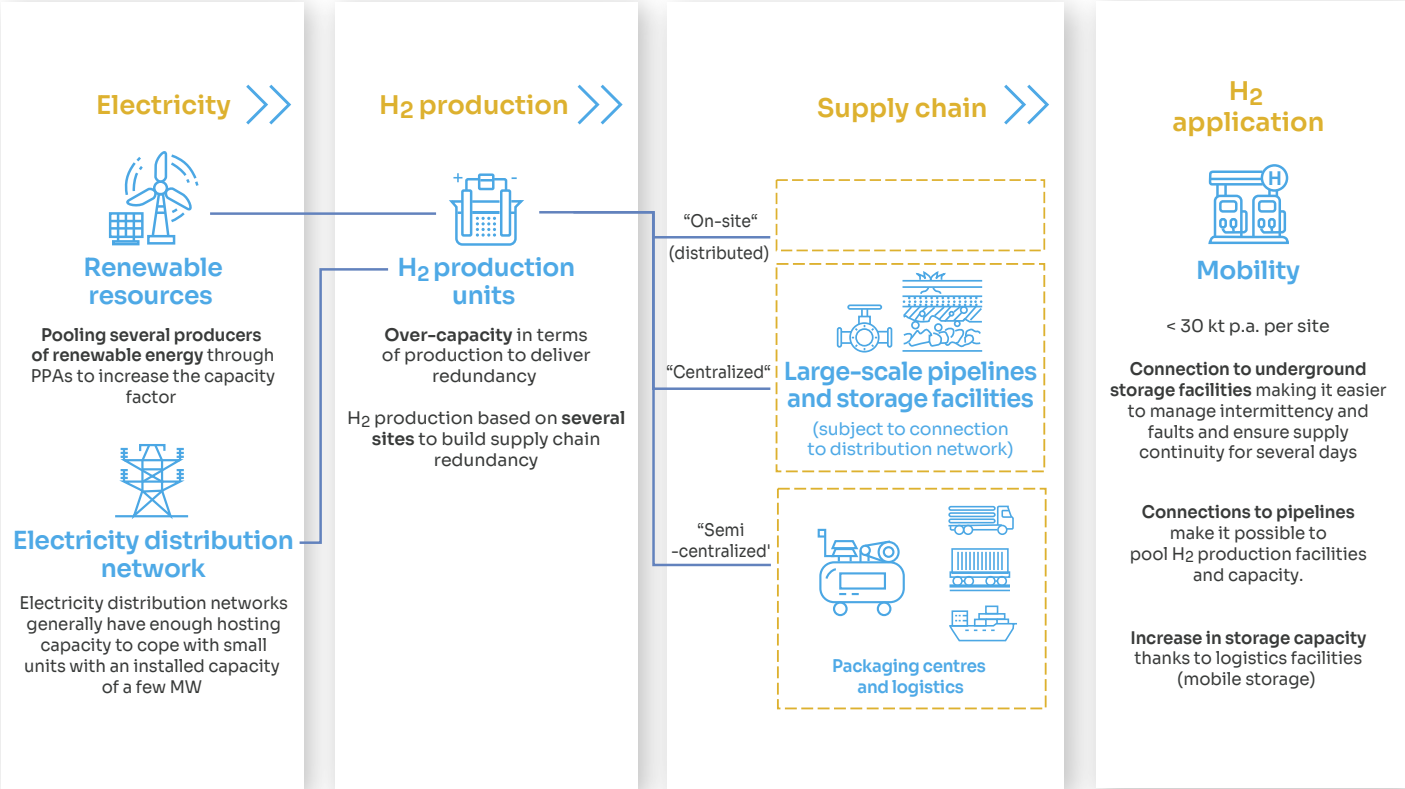
▪ **Accelerate the roll-out of renewable energy** to meet additional demand for H stemming from RED3.

▪ **Acknowledge and encourage the recognition that low-carbon electricity, regardless of how it is produced, has an important role to play in producing hydrogen.**

▪ **Review the criteria to be complied with regarding the production of hydrogen using renewable electricity** within the framework of RED2/3.

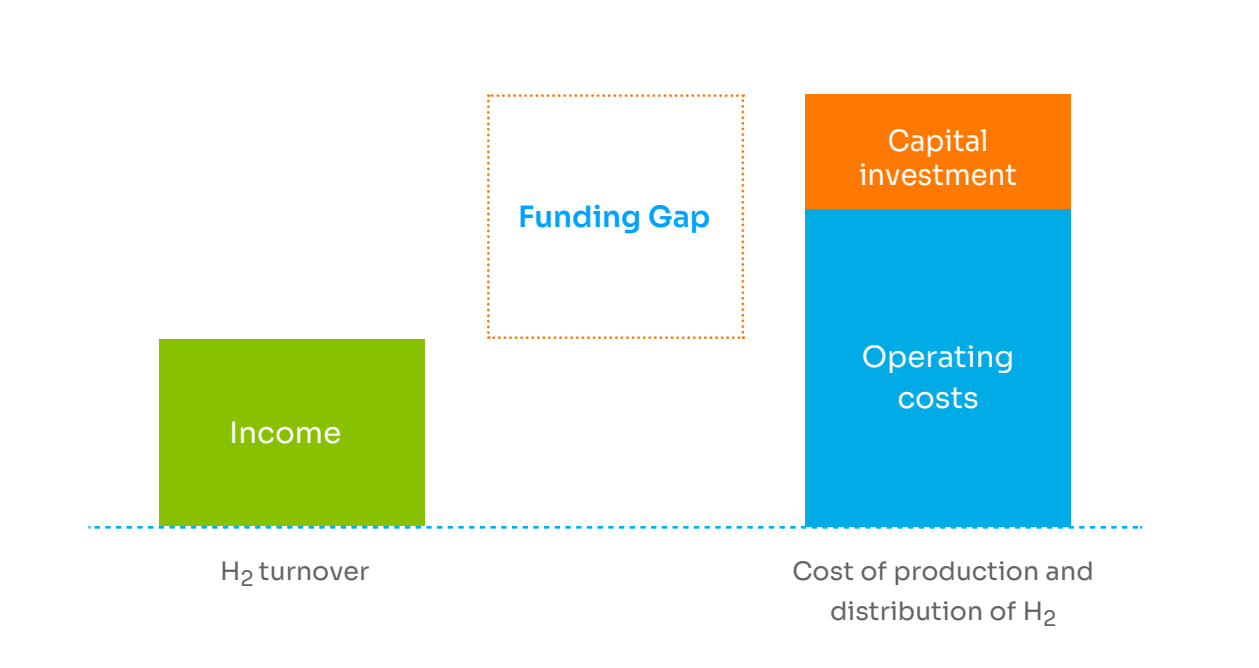
▪ Implement a **framework to safeguard investment in additional renewable energy capacity** earmarked for hydrogen production.

Annex 1 The scale of the French hydrogen supply chain by 2030



Annex 2 What exactly do we mean by a funding gap?

- **The funding gap is the funding required to roll out the low-carbon and renewable hydrogen supply chain and deliver hydrogen at a cost that's acceptable to consumers.**
- It represents the **gap between the low-carbon and renewable hydrogen sector's turnover and the cost of producing and distributing hydrogen** (capital investment, energy, operating costs, maintenance etc).
- **Turnover** is calculated by **multiplying hydrogen sales and the price of hydrogen** of different low-carbon and renewable hydrogen market segments.
- **Production and distribution costs** encompass **capital investment** in and **operating costs** of the renewable and low-carbon hydrogen supply chain.



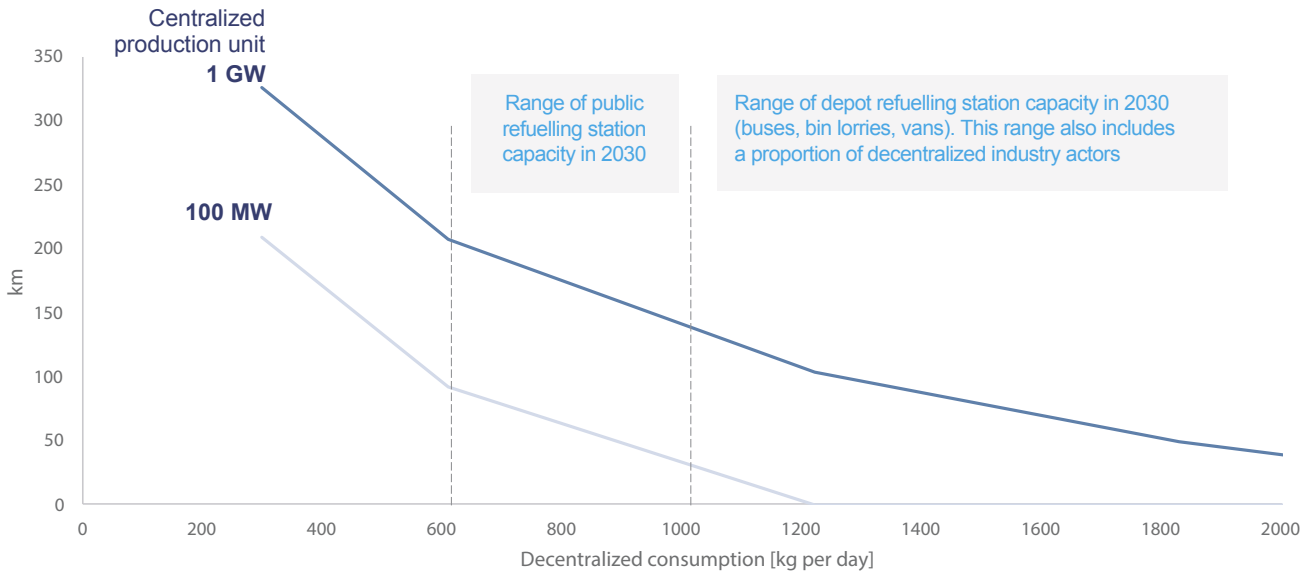
These sums do not include additional investment in hydrogen-related applications with the goal of achieving the Ambition 2030 target:

- AUpstream applications (e.g. investment in renewable energy)
- Downstream applications (e.g. decarbonizing industrial processes, hydrogen vehicles)
- Upscaling manufacturing capacity
- R & D and training

Annex 3 Quantifying a zone of influence

The 'zone of influence' of a production cluster may be defined as the geographical area within which the cost of production and distribution of hydrogen from this cluster is the most cost-competitive option for the supply of so-called decentralized users (local government fleets, low-level industrial consumption etc.). As a result, the zone of influence helps flag up opportunities for partnerships between projects. However, the zone of influence is a function of several different factors: scale of production and demand, geographical distances, chosen supply/distribution method option (pipeline or cylinders, compressed or cryogenic hydrogen).

Maximum distance it is economically viable to transport hydrogen (depending on consumption and capacity of production unit - 100 MW or 1 GW)



These estimates look at the example of a joint hydrogen production unit of 100 MW capacity and one of 1 GW capacity supplying 10 decentralized sites.
The analysis is based on transportation elements with a carrying capacity of 1 tonne operating on a once every three days delivery cycle.

- A site consuming 600 kg H_2 per day (horizontal axis) less than 100 km (vertical axis) from a production unit of 100 MW capacity (light blue curve) would be well-advised to establish a connection with the larger production unit rather than trying to develop its own production capability if it wants to offer hydrogen at a competitive price.

- A site consuming 1,400 kg H_2 per day (horizontal axis) 250 km (vertical axis) from a production unit of 1,000 MW capacity (dark blue curve) would be well-advised to develop on-site (distributed) production capacity in order to benefit from hydrogen at the most competitive rates.

Notes

Notes

www.france-hydrogene.org

Contact :
info@france-hydrogene.org
Tel. +33 (0)1 44 11 10 04

The following organizations contributed to this study:

Nouveaux Systèmes Énergétiques
Comité stratégique de filière

Comité Stratégique de Filière Automobile

PFA FILIÈRE AUTOMOBILE & MOBILITÉS

France Hydrogène
Engagée pour la transition écologique

50 avenue Daumesnil - 75012 Paris
Contact : info@france-hydrogene.org
Tel. +33 (0)1 44 11 10 04

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