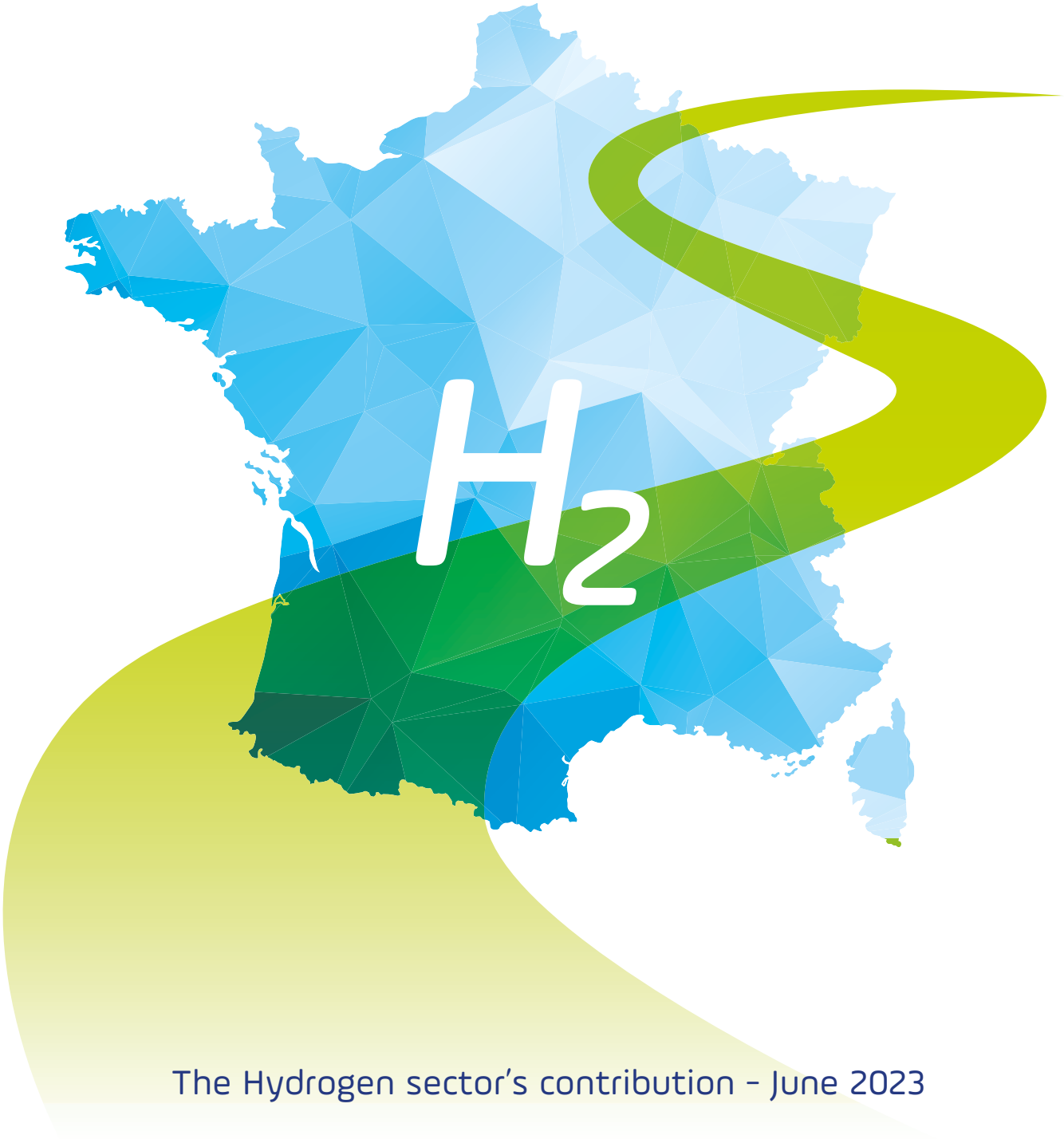
France Hydrogène

Engagée pour la transition écologique

NATIONAL HYDROGEN STRATEGY

Harnessing the hydrogen sector's full potential in pursuit of France's decarbonization and reindustrialization



The Hydrogen sector's contribution - June 2023

Editorial

The development of the hydrogen sector in France is critical to ensure the success of the green energy transition. It can also act as a vehicle for economic recovery and reindustrialization. This vision is promoted by France Hydrogène and the 460 hydrogen sector players it represents, as well as by the French government, which has made hydrogen a key plank of its long-term strategy and an investment priority. As a result, a National Hydrogen Strategy has been developed to support the production of renewable and low-carbon hydrogen with a view to decarbonizing industry, developing hydrogen-powered work vehicles and heavy vehicles and supporting research, innovation and skills development. Our study 'A road-map for an ambitious Hydrogen strategy by 2030', demonstrated that the goals of the Strategy were achievable and could even be exceeded, with industry and local government ready to turn their vision into reality, with over 250 hydrogen projects recorded.

We felt that there were two goals which were inextricably tied in with the evolving National Strategy: **hydrogen must be used to effect deep decarbonization of our economy whilst simultaneously helping to reindustrialize the country**. Keeping these two goals to the forefront of our minds will help bolster France's energy independence and industrial sovereignty. These two aims are by no means incompatible with each other. The large-scale decarbonization of the most significant greenhouse gas emitting industrial sites is necessary and unavoidable. However, mid-sized hydrogen production projects – measured in the tens of Megawatts – and the full range of applications, especially heavy or frequently-used vehicles, will enable the sector to expand over the next decade and successfully contribute to France's reindustrialization. This will be particularly evident in the field of road transportation, but also for other applications. Support for 'industrial standard-bearers' should facilitate the development of a wider manufacturing base. Hydrogen provides us with just such an opportunity – let's not let it pass us by!

Philippe Boucly, Chairman, France Hydrogène

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Background

The National Hydrogen Strategy (SNH), published in September 2020, aims to make France a leader in three areas of the 'decarbonized' hydrogen field:

- The creation of 6.5 GW of installed electrolyzer capacity by 2030, capable of producing 680,000 tonnes of renewable or low-carbon hydrogen every year,
- The decarbonization of industry and heavy and commercial-industrial transportation,
- Supporting the research, innovation and skills development that are critical to achieving this vision.

Three years after it was launched, significant developments in the spheres of the economy, energy, geopolitics and the environment beg the following question: does the national hydrogen strategy need to change with the times? By taking these developments into account in its strategy to decarbonize major greenhouse gas emitting industrial sites and the upcoming Multi-Annual Energy Plan (PPE), the government is signalling to all hydrogen sector stakeholders that it is time to consider this question.

An analysis of the intense activity undertaken by stakeholders in recent years – from government agencies to local authorities, start-ups and SMEs to large manufacturers, universities to research centres – helps us to assess progress towards a set goal and represents the starting point for this discussion.

In its capacity as a representative of the hydrogen sector, France Hydrogène would like to shed some light on the matter from three distinct perspectives:

1. An assessment of the first years of the roll-out,
2. A study specifically designed to identify the most effective approach to developing a hydrogen sector which can be scaled-up with a view to achieving the relevant economic, decarbonization and reindustrialization goals,
3. Recommendations for the ongoing progress of the roll-out.

1 AN ASSESSMENT OF THE FIRST YEARS OF THE ROLL-OUT

The construction of a system for producing and distributing decarbonized hydrogen alongside the geographical spread of different applications represent the main benchmark by which to measure the success of the French hydrogen sector strategy. This strategy has principally revolved around call for projects (AAP) style mechanisms, with selection criteria enabling certain goals and factors to be prioritized such as decarbonization, scaling up, the feasibility of the economic models used and heavy transportation.

1 – Building local networks

ADEME's Ecosystèmes Hydrogène call for projects gave rise to an **embryonic local network** and the genesis of hydrogen-powered applications in public transport, freight transport and waste collection (bin lorries). 91% of projects supported through this call for projects relate to the transportation sector. The hydrogen production capacity associated with these projects includes a total of 81 MW of decarbonized hydrogen production capacity[1]. This type of call for projects is designed to be renewed – the last dates to May 2023 – with specifications adjusted at each stage in order to ensure the road-map stays on course.

A simple extrapolation would suggest that a production capacity of 200-300 MW will be available by 2030 for projects of this kind.

2 – Industrialization of manufacturing and the large-scale production of decarbonized hydrogen

On a different scale altogether, **large-scale manufacturing sites or 'gigafactories'** have started to appear, specifically within the framework of the IPCEI[2] 'Hy2Tech[3]' programme with 10 French projects, 4 being for the production of electrolyzers and 6 for systems and technology relating to road and rail transportation, spread across 20 different sites in France. Additionally, thanks to the IPCEI 'Hy2Use[4]' programme and the CEEAG[5], **large-scale (1.4 to 1.8 GW)** decarbonized hydrogen production projects destined for a variety of uses could start to appear.

The imminent implementation of a support mechanism aimed at production projects with a combined capacity of 1 GW, running alongside several call to tender tranches, round off this summary of state support for the roll-out of hydrogen production.

This mechanism should help support mid-sized industrial projects (from a few dozen MW up to 100 MW) but will not cover transportation/mobility-related projects or synthetic fuels.

3 - Hydrogen production projects identified for participation in large-scale roll-out by 2030

Numerous other projects – both operational and planned – were recorded by France Hydrogène's study 'A road-map for an ambitious hydrogen strategy by 2030 part 2'[6] carried out in 2022. These projects represent **a potential renewable and low-carbon hydrogen production capacity of 8 to 9 GW,** mostly destined for synthetic fuel (decarbonizing air and marine travel) and road transportation. Subject to receipt of adequate funding, the French strategy's 6.5 GW target can be achieved and even bettered, especially given that certain sectors have not yet committed to any projects due to an insufficiently developed regulatory framework or immature technology. This is the case for biogenic CO_2 use, processes requiring high temperatures and flexible electricity and gas distribution networks operating in centralized or decentralized mode (building decarbonization).

CONCLUSION

In total, France Hydrogène estimates that between **2.6 and 3 GW of renewable and low-carbon hydrogen production capacity could be funded** with a high probability of this capacity being operational over the course of this decade.

France Hydrogène believes it is crucial to build on the foundations that have already been laid until the 6.5 GW target has been reached to achieve the National Hydrogen Strategy's other goal, that of reindustrialization. With this in mind, it's time to reflect upon which strategies to use for the roll-out of the hydrogen sector over the rest of the decade.

1 - Source: ADEME: 'Les premiers écosystèmes hydrogène', published in February 2023
2 - Important Project of Common European Interest
3 - IPCEI Hy2Tech – 2.1 billion euros will be invested in 10 gigafactories producing key systems, 5 of which relate to road transportation (fuel cells, fuel tanks, components)
4 - 5.2 billion euros of public funding from 13 EU member states will supplement 7 billion euros of private sector funding
5 - Guidelines relating to state aid directed at climate, energy and environmental issues
6- https://www.france-hydrogene.org/press_release/trajectoire-pour-une-grande-ambition-hydrogene-a-2030-volet-2-industriels-et-territoires-concretisent-les-ambitions/

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2 A STUDY TO IDENTIFY THE BEST APPROACHES TO ROLL OUT HYDROGEN PRODUCTION AND TO CONTRIBUTE TO REINDUSTRIALIZATION

The infrastructure projects supported by ADEME are based upon a 'decentralized' model. Hydrogen production by electrolysis is to cover all applications within the geographical scope covered by the infrastructure in question. It will amount to no more than 2MW, in line with the purpose for which these networks or 'ecosystems' were designed.

In contrast, large projects mostly destined for the heavy industry sector generally feature hydrogen production capacities running into several hundred megawatts, in line with the goal of upscaling production to maintain these industries' competitiveness through hydrogen-driven decarbonization.

1 - A more diverse range of projects with a view to assisting the reindustrialization process

A halfway house between ADEME's projects for the creation of a hydrogen ecosystem and major heavy industry decarbonization projects up to several hundred MW in size, the **development of an intermediate 'semi-centralized' network**, featuring ecosystems with production capacities in the tens of Megawatts, is vital for industrial and transportation applications over a large geographical area (measured in the thousands of square kilometres). This size of ecosystem offers the best compromise between geographical coverage, minimizing the distance hydrogen must be transported and the economic competitiveness of the sectors in question. This was shown by E-Cube's study for France Hydrogène during the first half of 2023, which included a case study of the Auvergne-Rhône-Alpes basin. Here are the key takeaways from this study:

- Having a wide variety of applications for hydrogen is crucial to the development of road transportation, biogenic CO_2 use, process heat and energy flexibility. This requires the development of hydrogen production systems and distribution networks operating in semi-centralized mode. It is important to consider these markets for decarbonized hydrogen for 4 reasons. Electric batteries cannot provide a solution for the decarbonization of heavy vehicles and frequently-used transportation due to energy density limitations and the length of time required for recharging. Besides, biogenic CO2 needs to be captured and, where possible, turned into synthetic substances which are increasingly sought after. Moreover, in cases where electrification is impossible, process heat cannot be decarbonized any other way. Lastly, energy flexibility, which is needed both to successfully integrate intermittent renewable energy sources into the French energy system and to help decarbonize buildings, is currently only feasible using hydrogen-based solutions.

- Currently, an electrolysis system starts to achieve economies of scale at around the 20 Megawatt mark. Where a larger consumer of hydrogen is to be found in a


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specific geographical area, they may be used as a launch-pad for the development of a wider variety of locally based applications, thus boosting the local economy.

▪ The additional cost per kilogramme of hydrogen produced through the semi-centralized model compared to the centralized model is largely offset by external benefits:

— **Creation of business opportunities that are crucial for the electrolyzer gigafactories** that have already and are still to emerge out of the hydrogen IPCEI. These will initially be tailored to serve the mid-sized market

— **The preservation and development of a manufacturing base that's strongly anchored in the local area**, like the road transportation sector with its local network of components manufacturers (gigafactory suppliers and maintenance professionals). Between 30 and 80% of French hydrogen sector businesses, (depending on region) possess skills relevant to hydrogen-powered transportation[7], adding to the likelihood that this sector will help the growth of the local economy and industrial fabric

— **The rapid, adaptable roll-out of** hydrogen production projects and applications whether in relation to construction lead times or reducing pressure on local infrastructure (connection to the electrical grid) or locally sourced production inputs (water, electricity), speeding the reduction in French greenhouse gas emissions.

CONCLUSION

Although large-scale electrolysis plants adjoining industrial sites producing substantial greenhouse gas emissions are a key component of the French strategy to develop a decarbonized hydrogen production sector, for the hydrogen sector to be genuinely integrated into France's industrial fabric will also require a **large-scale expansion in both the number of projects and applications**. This will make it possible to leverage hydrogen's full potential in terms of decarbonizing applications and reducing costs by means of a stable, open market. Under these circumstances, it will be possible to fulfil the goal of creating 50,000 to 150,000 jobs through the roll-out of 6.5 GW of decarbonized hydrogen production capacity.

7- Source : Survey carried out in April 2023 by France Hydrogène addressed at regional-level government and regional development agencies

3 AN ENVIRONMENTALLY FOCUSED STRATEGY DESIGNED TO MAXIMIZE OPPORTUNITIES

1 - Launch a strategy for the roll-out of hydrogen-powered road transportation

High intensity road transportation is one of the applications of hydrogen which could help bring about a hydrogen sector characterized by significant geographical coverage and rapid growth based upon the semi-centralized model previously described. It's noteworthy for two reasons - it is the **market that currently offers the best prospects for future development** and has the potential to be one of the main avenues by which the hydrogen sector could drive the process of reindustrialization. The two main French automotive manufacturers (Stellantis and Renault - along with its joint venture, Hyvia), have committed to hydrogen-powered light commercial vehicles in the long-term. Substantial public funding has been agreed (cf. the footnote relating to the IPCEI Hy2Tech on page 5) to ensure that key components – fuel cells, fuel tanks, vehicles – are manufactured on a large-scale in France. A whole network of small and medium-sized businesses and industries is built around these vehicles. Establishing a strategic lead in relation to hydrogen-powered light commercial vehicles could also give France a manufacturing and business edge in the rush to compete on the global hydrogen-powered vans market, enabling it to be one of the first countries to establish genuinely large-scale production lines for key components (fuel cells, fuel tanks...).

It's crucial that orders are placed without further delay to reach a critical mass of vehicles on the road. Manufacturers can use this as a springboard to serve a market (including an international one) without the need for public funding. This threshold could be reached quite quickly (2027 for light commercial vehicles, 2030 for HGVs). In the light of its tax revenue-generating and social benefits, the cost of this start-up phase seems reasonable. This is even more so the case if we factor in the potential for value creation in France if the market grows, or, conversely, the potential for public money to have been wasted if the gigafactories do not have access to a national market in the coming years.

Against this backdrop, France Hydrogène and the PFA (an industry body representing the automotive sector) are suggesting **a roll-out strategy using an innovative approach** which, through the creation of a **consortium** between the various stakeholders and the making of reciprocal undertakings, would provide the kind of long-term clarity needed in relation to expected sales between now and 2030. Thus, a combination of drastically reduced state funding and an innovative way of dealing in TIRUERT[8] certificates would make it possible to begin the operational roll-out of the three 'core market' hydrogen-powered transportation segments in the shape of:

- 50,000 light commercial vehicles on the road by 2027,
- 4,250 short-haul HGVs by 2030,
- 7,450 long-distance HGVs.

As regards hydrogen refuelling stations, in 2022 France Hydrogène, the PFA and the SystemX Institute for Technological Research modelled the refuelling network that would be needed. This has enabled the creation of a powerful tool which will allow **the relevant infrastructure to be planned** with optimal efficiency.

As far as the renewable and low-carbon hydrogen requirements associated with this strategy are concerned, a mid-case scenario estimates that 177,000 tonnes of hydrogen per year will be needed by 2030 – the equivalent of **1.3 GW** of electrolyzer production capacity using a mostly semi-centralized model.

2 - Build a synthetic fuel industry. This offers a major opportunity to reestablish energy independence and to significantly expand the hydrogen sector

Following the publication of road-maps for the decarbonization of the aviation and maritime sectors, the hydrogen-based synthetic fuel industry is one of the key sectors which needs to spring into action as of now. Moreover, the ReFuelEU Aviation measure sets quotas for a minimum share of 1.2% RFNBOs[9] in the aviation industry by 2030, increased to 5% by 2035. This represents some 50,000 tonnes of hydrogen in 2030 and 200,000 tonnes in 2035 earmarked for the aviation sector. With regard to sustainable aviation fuels, the book & claim scheme (which makes it possible to decouple physical products and the environmental benefit of using those products) will enable EU countries to fulfil their RFNBO quotas without having to actually use these products themselves. This opens up the potential for French projects to scale up their production plants to meet a market demand that will be initially greater than that of the French market, immediately making it easier to design and scale these production plants in a way that optimizes efficiency. This represents an incredible opportunity, given that the Hydrogen Strategy by 2030 part 2 flagged up project proposals representing the production of around 300,000 tonnes p.a. of marine and aviation e-fuels.

On the basis of this data, France Hydrogène forecasts **300,000 tonnes of hydrogen will be needed annually by 2030** in order to produce synthetic fuels for these sectors. This translates into a need for **2.3 GW** of decarbonized hydrogen production capacity by means of electrolysis.

To turn this opportunity into a reality, France Hydrogène advises that the relevant stakeholders come together to draw up a strategy focussing primarily on planning and organizational matters, as well as sourcing the non-biogenic and biogenic CO_2 needed to make these synthetic fuels.

3 - Increase the resilience and agility of the industrial sector established to serve the hydrogen sector

The development of the hydrogen sector and its associated industrial fabric must go hand-in-hand with increased efforts to secure supplies of energy and the relevant technology with a view to bedding down the success of the sector in the long-term.

8 -Tax incentives for the use of renewable energy in transport
9 - Renewable Fuels of Non Biological Origin, in this instance, renewable hydrogen and its derivatives

As a result, the ability to access cheap, plentiful energy (electricity, biomass) has become a matter of strategic importance, underlined by the events of recent months at both French and wider European levels (the French electricity distribution network under stress, reductions in the supply of natural gas, significant price rises). The supply of water, critical raw materials and control over their value chain, as well as technological sovereignty with regard to ancillary systems incorporating key technologies are all key issues for the sector, both in terms of reindustrialization and sovereignty.

Continuing in the same vein as government initiatives, notably calls for projects in the fields of technological components and critical metals, the Plan Eau (a water saving strategy), the launch of the OFREMI[10] and the EU's Critical Raw Materials Act, France Hydrogène proposes the creation of a transversal action plan. This would encompass boosting R&D&I and cooperation between different industry sectors, the implementation of closed-loop recycling and the diversification of hydrogen production methods, especially those based upon biomass conversion processes (gasification and pyrogasification).

4 - Plan the roll-out over the rest of this decade and beyond

Progressing with this roll-out, as far as it relates to the production and distribution of hydrogen, requires **coordination between all stakeholders**, including electricity and gas transmission system operators, as well as some sectors of industry, all under the aegis of the French government. 2030 remains a key milestone. However, we must extend our perspectives to encompass the following decade, which will witness the advent or further expansion of certain applications such as energy flexibility (centralized or decentralized), as well as the establishment of an international marketplace for hydrogen. Transportation infrastructure requires substantial investment over the long-term. As a result, it needs to be planned well in advance – in other words, during the current decade – and should run alongside the roll-out of the hydrogen sector already underway.

The specific challenges associated with the complex, highly-interconnected system anticipated at both European and global levels must be taken into account in the planning of the roll-out as of now.

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CONCLUSION

The review of the National Hydrogen Strategy is particularly timely given the upcoming Multi-Annual Energy Plan (PPE). As the main driver of the ongoing roll-out of the sector, the decarbonization of heavy road transportation, maritime transportation and aviation creates a window of opportunity that needs to be grasped without further delay. The quantities of renewable and low-carbon hydrogen this will require are enough to account for all of the 6.5 GW of production capacity scheduled by 2030. Moreover, other sectors requiring hydrogen which have already begun or are yet to begin their development still have to be taken into account. The expansion of semi-centralized hydrogen production infrastructure will nurture the development of hydrogen-powered transportation in the short-term, as well as that of the full range of applications expected towards the end of the decade.

Looking towards the period 2035-2040, the need for decarbonized hydrogen will be much greater, having increased by a factor of 2 or 3, then 4 or 5, depending on the different scenarios in the sector-by-sector decarbonization road-map. In response, France's operational hydrogen production capacity as of 2030 could be increased whilst at the same time being supplemented by imports of hydrogen and its derivatives (synthetic substances) in line with a range of parameters and limiting factors, chief of which is the availability of primary energy for the production of hydrogen.

10 - Observatoire Français des Ressources Minérales pour l'Industrie
(A French government body that monitors the availability of minerals for domestic industry)

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4 Conclusion

Towards a road-map that will harness the hydrogen sector's full potential in relation to decarbonization and reindustrialization

Summary of France Hydrogène's vision

Plan / Strategic focus	Decarbonize	Upscale	Reindustrialize
Strategy for the development of production-transport-distribution infrastructure ▪ Hit the 6.5 GW+ target by 2030 ▪ Coordinate transformations in infrastructure in the 2030 → 2040 period ▪ Plan the roll-out using an ambitious industrial strategy	▪ Decarbonize industries that are responsible for significant greenhouse gas emissions ▪ Tackle the decarbonization of decentralized applications and road transportation ▪ Nurture the development of e-fuels and gaseous or liquid hydrogen for the aviation and marine sectors	▪ 'Horizontal' scaling up using the semi-centralized model for transportation and decentralized applications ▪ 'Vertical' scaling up through the development of large projects, in particular, the production of e-fuels for the aviation and marine sectors	▪ French SMEs and middle-market companies that are strongly anchored in the local area ▪ Ensuring a good return from investment in gigafactories ▪ Boosting competitivity through a strategy that takes account of evolving technical capabilities → greater penetration of technological advances ▪ Raise the profile of the sector and improve forward planning in such a way as to ensure the jobs, skills and training needed by the sector are in place
Road transportation strategy ▪ A plan based on an innovative, effective strategy of reciprocal undertakings to make tangible progress on the adoption of hydrogen-powered LCVs, short-haul lorries and long-distance HGVs	▪ The only suitable decarbonization solution for some HGVs ▪ Accelerates the process of road transportation decarbonization, unachievable by means of battery-powered electric vehicles alone	▪ Quickly securing orders for 50,000 LCVs and 11,700 HGVs to reach a critical mass ▪ 1.3 GW to 2 GW of H_2 production capacity by 2030, which would also cater to the needs of decentralized industry by the end of the decade	▪ Business opportunities for French components manufacturers (fuel cells, refuelling stations, fuel tanks) are needed now ▪ Helps the LCV and HGV sectors to remain competitive (range and refuelling time) ▪ The opportunity to manufacture some or all of the powertrain domestically
Hydrogen sector service industry resilience and agility development strategy **Increase the resilience and agility of the industrial sector established to serve the hydrogen sector** ▪ Technological bricks – components – materials ▪ Inputs: water – electricity – biomass ▪ Diversification: biomass – natural H_2 – innovations ▪ Regulatory standards – industry best practices – metrology	▪ Ensure that French industry covers the entire value chain, secure supply chains of key components, invest in material procurement ▪ Mitigate potential shortages in water and materials (H_2 and the energy transition) through R&D&I, diversification and retrofitting vehicles: desalination, alternative H_2 production methods including natural H_2, photoelectrocatalysis etc ▪ Create a national, common multi-sectoral approach regarding regulatory standards and best industry practices as applied to hydrogen systems or facilities to make the supply chain more competitive		

LIST OF RECOMMENDATIONS THAT WILL ENABLE THE HYDROGEN SECTOR TO FULFIL ITS FULL POTENTIAL

Reviewing the National Hydrogen Strategy represents an excellent opportunity to build on the solid foundations that have already been established since this strategy was first launched in September 2020 - build on, and even move forward more quickly, making France a global leader in the decarbonized hydrogen field.

France already boasts multiple advantages: gigafactories for key hydrogen technologies are already under construction; a network of small and medium-sized businesses and industries are quickly gearing up around the industry at local level; French R&D&I in this field is one of the most dynamic anywhere in the world; and our low-carbon electricity generation mix should enable us to roll out hydrogen projects in different fields of application more quickly, thus facilitating the establishment of national champions who would have a long-term competitive edge. As if to confirm this potential, industrial actors have far exceeded the strategy's original targets (with over a million tonnes of decarbonized hydrogen in the pipeline). **The review of the national strategy comes at a critical moment, with a huge range of opportunities for the taking** and the chance to fulfil the three-fold potential of hydrogen in France in the shape of **multi-sectoral decarbonization, reindustrialization at local level** (closely linked to the diversity of applications made possible by hydrogen) and as a **catalyst for the energy transition.**

With this in mind, France Hydrogène makes the following recommendations to ensure the hydrogen sector fulfils its full potential:

1 - Applications

▪ **Launch the strategy for the roll-out of hydrogen-powered road transportation, as laid out by the hydrogen sector** (50,000 LCVs – 11,700 HGVs for the transportation of freight).

▪ **Facilitate the rapid roll-out of hydrogen derivatives production for marine and air transportation and industry:** as with the Transportation Plan, France Hydrogène is ready to work with government agencies on mechanisms that would help minimize the need for public sector funding by generally boosting confidence in the long-term viability and profitability of this market and leveraging regulatory incentives.

— This will help place this industry in pole position, capitalizing on the temporary strategic lead currently enjoyed by France, especially thanks to its low-carbon electricity generation mix.

— Combined with industrial projects already identified (2.6 to 3 GW) and the proposed Transportation Plan (1.3 GW), the launch of these projects will make a significant contribution to hitting the target of 6.5 GW of installed electrolyzer capacity laid down in the national strategy. This target is essential if French electrolyzer manufacturers are to be competitive on the international market.

— In addition to facilitating the leveraging of biogenic CO_2, **the geographical coordination of hydrogen derivatives production projects also has the potential to be a powerful driver of industrial synergies**. For industrial sites producing residual CO_2 which are unable to access CO_2 transportation or storage solutions, producing synthetic substances with locally produced hydrogen would seem to be the ideal decarbonization solution.

▪ **Decisions must be taken regarding which approaches to take in the implementation of decentralized industrial projects** such as process heat, the use of hydrogen to decarbonize buildings or energy flexibility.

@Hyvia

2 - Production

▪ Taking as our starting point the geographical locations of key hydrogen needs (industry – transportation – hydrogen derivatives), **draw up a hydrogen production plan incorporating both large-scale production sites and semi-centralized production sites:**

— Ensure a mix of large-scale hydrogen electrolysis projects (several hundred MW, only on a few selected industrial-port sites) and a denser, widely distributed network of mid-sized projects (20-100 MW). These projects will be critical to French electrolyzer manufacturers' successful navigation of the necessary technological learning curve.

— **This approach will probably result in plans being made to expand hydrogen production capacity beyond the initial single industrial client model (including e-fuels) so that this production capacity can be used to cater to more decentralized local applications, especially in the field of transportation.** This production capacity pooling approach will enable different groups of users to avail themselves of hydrogen at a competitive price (economies of scale and reduced logistics costs), contributing to the success of the Hydrogen Strategy and saving money.

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▪ **Providing electrolyzers with competitively priced, decarbonized electricity, with long-term clarity on costs,** a key factor in Final Investment Decisions (FID). In the first instance, this will involve continuing the work the French Government is currently carrying out on the reform of the EU electricity market to prepare for the post-ARENH (Regulated Access to Incumbent Nuclear Electricity) environment. Speeding up the development of Power Purchase Agreements (PPAs) will be crucial. Most importantly, this will involve working with the hydrogen sector drawing up a strategy whereby PPAs are used to encourage producers of renewable electricity to sell to producers of hydrogen to take advantage of the exceptions granted to countries with a very low-carbon electricity mix (France, Sweden, Finland) on the rules governing the production of renewable hydrogen (right to use existing renewable energy installations and for these installations to have received state aid), and to turn this into a competitive advantage. Lastly, it would seem important to look at the role electrolyzers could play in balancing the electricity grid, along with the system of payments (demand-response) which would have to be developed as a result.

▪ Taking account of land-use planning as it relates to semi-centralized applications and production capacities, making appropriate matches between energy supply and demand at national level and being aware of the constraints and opportunities specific to each local area should enable the National Hydrogen Strategy to evolve beyond its single focus on electrolyzers connected to the electrical grid. This could make hydrogen into a driver for the expansion of renewable energy sources in the shape of two avenues of exploration:

— **Planning the development of hydrogen production capacity by means of pyrogasification or biomass thermolysis.** These production methods offer a cost-competitive solution to relatively decentralized hydrogen needs (especially transportation), 'filling in the blanks on the map' in areas that are unable to benefit from the economies of scale of the semi-centralized electrolysis model. They are also extremely valuable in that they can reduce pressure on the grid and create significant synergies for other sectors concerned with decarbonization and reducing their reliance on external inputs, both agricultural and industrial (e.g. the pulp and paper industry).

— Some wind and solar farm projects have been greenlit but are currently stalled due to grid connection issues (delays and/or excessive costs). It's expected that this grid connection bottleneck will quickly get a lot worse over the next few years up to 2030: **directly connecting renewable energy installations to electrolyzers, which will cater to relatively decentralized applications (especially road transportation), means that these energy resources can be used after all.** Above and beyond reviving projects that were 'abandoned' despite being 'shovel-ready', planning ahead at local level with a view to tapping into renewable energy resources in this way, in partnership with RTE (France's electricity transmission network operator) and France Hydrogène, would both focus renewable energy developers' attention on new areas, increasing the number of projects coming on stream and reduce pressure on the electricity transmission network operator.

3 - Infrastructure

▪ **Without further delay, begin a detailed process of planning and implementing hydrogen transportation, distribution and storage infrastructure projects**, partnering with the operators of the relevant hydrogen infrastructure, RTE and France Hydrogène. This in-depth work is made possible by the twin-track planning approach focusing on applications at local level and different methods of decarbonized hydrogen production. Hydrogen transportation infrastructure requires substantial investment over the long-term. As a result, it needs to be planned well in advance – in other words, during the current decade – and should run alongside the roll-out of the hydrogen sector already underway.

▪ Planning this infrastructure is closely linked to **getting ready to compete on a global hydrogen and hydrogen derivatives market**. The challenge is to quickly get domestic projects up and running before imports of hydrogen or hydrogen derivatives begin. This French-based hydrogen industry 'core' will in time boost France's negotiating hand internationally and position French businesses on these value chains. This preparatory work should involve the industry as a whole to maximize the value thus created:

— Based upon these infrastructure projects, develop an export strategy for industrial manufacturing companies – not just large components manufacturers but also the network of small and medium-sized businesses and industries in France which will have gained plenty of experience in this field.

— Ensure ports and ship owners position themselves in such a way that the international trade in hydrogen derivatives becomes a driver for economic diversification.

4 - Industrial and technological sovereignty

▪ **Create connections between the National Strategy, the France Mer 2030 plan and the maritime decarbonization road-map:** Hydrogen should be a key driver for bringing the shipbuilding industry back to France (retrofitting ships, high-power fuel cells etc), and port activity (increasing bunkering operations in France).

▪ **Strengthen our industrial sovereignty in the hydrogen value chain over the long term:**

— Continue efforts in R&D&I to be in the vanguard of disruptive technologies and reduce our dependence on critical raw materials and per- and polyfluoroalkyl substances (PFAS), for example, through the extension of an existing PEPR[11] or the creation of a dedicated initiative.

— Organize and develop expertise in the key technologies supply chain in partnership with the relevant industries and the OFREMI.

— Adapt, add to and devise training provision in the hydrogen field, taking account of the hydrogen sector's research and recommendations

The goals of the French Hydrogen Strategy for 2030 are still relevant. Adapting certain approaches, especially in relation to planning, coordination between different stakeholders and related funding mechanisms is needed to ensure these targets are achieved as efficiently as possible, whilst preparing for the next decade.

| *11 - Priority Research Programme and Infrastructure*

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