

Hydrogen RD&D Collaboration Opportunities: France

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Australian Government

**Department of Climate Change, Energy,
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Executive Summary: France

France is one of the largest players driving hydrogen development and ambitions across Europe. France's planning and implementation of the hydrogen economy is advancing across multiple regions within the country.

The *Hydrogen RD&D Collaboration Opportunities: France* chapter aims to enhance country-to-country engagement by providing an overview of France's hydrogen priorities and ecosystem. This chapter also includes a publication and intellectual property (IP) scan, identifying the key stakeholders in France actively undertaking hydrogen RD&D, both at the early research and commercialisation stages.

France's hydrogen strategy

France's hydrogen strategy is driven by the push to reduce emissions, the potential for hydrogen to decrease the country's reliance on oil and gas imports, the opportunity to build new industries that foster economic development and jobs growth, and the opportunity to bolster France's technological competitiveness on the global stage. France's strategy focuses on developing an electrolysis sector, decarbonising industry, deploying hydrogen produced from renewables for heavy duty mobility, stabilising the energy network, developing multi-sector hydrogen ecosystems in regional areas, and enhancing research, innovation and skills.

France's targets and RD&D priorities

France's targets are to achieve 20-40% hydrogen produced from renewables in the industrial sector and have 20,000-50,000 light-duty fuel cell vehicles, 800-2,000 heavy-duty fuel cell vehicles and 400-1,000 hydrogen refuelling stations before 2030. France is aiming to develop its electrolysis sector, including 6.5GW of generation capacity by 2028. Based on France's National Energy and Climate Plans (NECP), the Fuel Cells and Hydrogen Joint Undertaking (FCH JU) has published a range of hydrogen deployment scenarios for France in 2030, where hydrogen features across all end-uses, totalling a demand of 4,200-19,500 GWh per annum.

To achieve these goals, France is investing in RD&D in the following areas.

Production
Electrolysis: polymer electrolyte membrane, solid oxide
Biological
Photochemical and photocatalytic

Storage and Distribution
Compression and liquefaction: pressurised storage, pipelines, underground storage
Chemical: ammonia, liquid organic hydrogen carriers, hydrides, physisorption

Utilisation
Gas blending: gas separation
Transport: fuel cells, refuelling stations, combustion engines
Electricity generation: fuel cells (polymer electrolyte, solid oxide, reversible, emerging)
Industrial processes

Cross-cutting
Modelling and technoeconomic studies
Characterisation and testing
Recycling and circular economy
Safety, regulation and policy
Skills, education and training

France's domestic hydrogen landscape

The main government bodies leading hydrogen strategy, policy and funding in France are the Ministry of Economy, Finance and Recovery (MEFR), and the Ministry for the Ecological Transition (METS). The two bodies led the development of the 2020 *National strategy for the development of decarbonised and renewable hydrogen in France* and have set key hydrogen targets in the *Multiannual Energy Programming 2019-2028* plan. The MEFR has also committed significant hydrogen funding as part of France's COVID-19 recovery plan.

The French National Research Agency (ANR), which operates under the Ministry for Higher Education, Research and Innovation (MESRI) funds RD&D projects led by public institutions. This includes calls for hydrogen RD&D projects domestically and internationally. The Agency for Ecological Transition (ADEME) also provides public funding for hydrogen RD&D. Public investment banks at the national level (such as Bpifrance and Banque des Territoires) and the EU level (such as the European Investment Bank) also finance hydrogen activities including demonstration projects.

The three main public bodies undertaking hydrogen RD&D are the National Centre for Scientific Research (CNRS), and the Alternative Energies and Atomic Energy Commission (CEA), who lead the Federation of Hydrogen Research (FRH2) encompassing 29 laboratories across France.

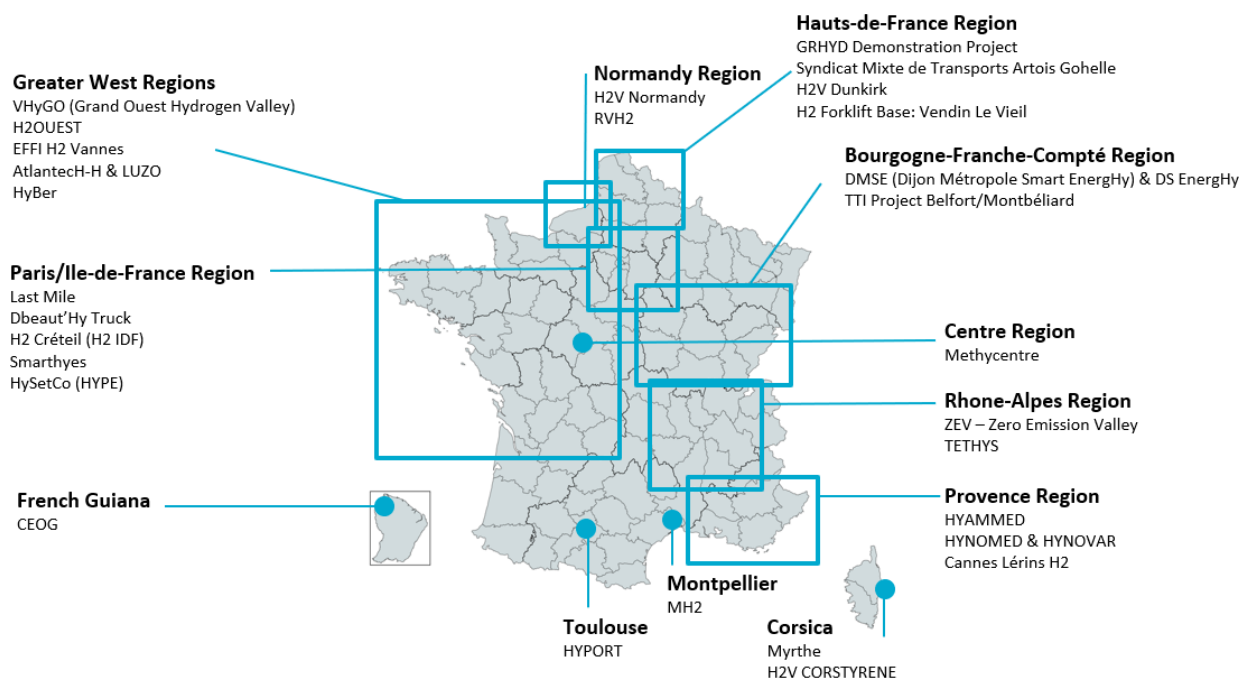
France also has a number of highly active consortia and industry associations, the main one being France Hydrogène (formerly Afhypac) who are actively working on building hydrogen clusters across France (also known as hydrogen valleys, hubs or ecosystems). At the European level, key industry players, government and academia play a strong role in the European Clean Hydrogen Alliance (ECH2A), the Fuel Cells and Hydrogen Joint Undertaking (FCH JU), and Hydrogen Europe.

Figure 1: France's hydrogen RD&D ecosystem



Industry, academia and government are collaborating to bring about hydrogen clusters (also known as valleys, hubs or ecosystems). These are hydrogen value chain demonstrations and pilot projects that cut across sector applications. There are numerous clusters across several regions in France of integrated hydrogen value chain activity:

Figure 2: France's hydrogen clusters



IP and publications scan

Several universities, public research institutions and private companies are highly active in early-stage hydrogen research and late-stage technology commercialisation. This is reflected in hydrogen research publication output and patent output data.

Table 1: Top organisations active in early-stage and late-stage hydrogen RD&D

Rank	Top organisations (Research publication output)	Top organisations (Hydrogen patent output)
1	National Centre for Scientific Research (CNRS)	Air Liquide
2	University of Grenoble Alpes (UGA)	IFP Energies Nouvelles
3	Alternative Energies and Atomic Energy Commission (CEA)	Alternative Energies and Atomic Energy Commission (CEA)
4	University of Paris-Saclay	National Centre for Scientific Research (CNRS)
5	University of Montpellier	Michelin

International collaboration

France has signalled intent to collaborate on hydrogen RD&D across several strategic documents. Key focus areas for collaboration include regulation, qualification and certification with respect to modes of hydrogen production, as well as for technologies in road mobility, aeronautics, maritime and railway applications. France also seeks to enhance hydrogen RD&D collaboration at the European level via researcher collaborations, facilitating industry cooperation, and pooling of European finances to maintain a competitive edge over its strong North American and Asian competitors.

Activity levels for hydrogen and net-zero initiatives is high. While effort has been made to capture major announcements and key information as at 18 August 2022, the content is intended to provide a starting point for informing international engagement, particularly when used in conjunction with other reports in the series, and is non-exhaustive.

1 Country analysis: France

1.1 Introduction

France is one of the largest players driving hydrogen development and ambitions across Europe, alongside Germany. Planning for the hydrogen economy in France can be seen at multiple levels. At the national level, France's hydrogen priorities are driven by the need to reach net zero by 2050, ensuring energy security and achieving economic growth by continuing to be a global technology leader. France has set out an ambitious strategy to develop a large electrolysis sector, to deploy hydrogen across the mobility sector (especially in heavy transport applications), and to utilise hydrogen to stabilise its energy network. In addition to this, several regional areas, and economic sectors have developed their own hydrogen strategies as well. At the supranational level, France is a key contributor to the European Union's (EU) 's hydrogen strategy and research, development and demonstration (RD&D) ¹ programmes.

France's RD&D landscape is comprised of a diverse set of players, including elite schools, universities, public science institutes, large multinationals and SMEs, backed by public research funding agencies, and banks that support innovation and green projects. Hydrogen deployment is highly active, with hydrogen clusters already deployed across many regions, mostly in the mobility sector and some industrial applications. French hydrogen mobility companies with mature commercial technologies (namely in fuel cell vehicles, and hydrogen trains) are scaling-up and expanding across Europe, while companies such as Airbus and local airports are pioneering next generation applications in the aerospace sector. Further RD&D is required to realise France's large scale renewable hydrogen production goals, develop storage and distribution solutions, and for continued cost and efficiency improvements across all hydrogen technologies including mature applications.

The *Hydrogen RD&D Collaboration Opportunities: France* chapter presents an overview of the hydrogen RD&D landscape in France, starting from the national strategy level, down to activity in specific hydrogen technology areas.

1.2 France's hydrogen drivers, strategy and RD&D priorities

1.2.1 France's key drivers

France has identified several drivers for their hydrogen push in the *National strategy for the development of decarbonised and renewable hydrogen in France*.² These drivers are emission reduction, economic growth, energy security and sovereignty, and technological development and independence.

- **Emissions reductions:** France has committed to a net zero emissions goal by 2050 in 2019 with residual gross emissions to be absorbed by carbon sinks. In light of this, hydrogen has been identified as a solution for decarbonising segments of their industrial and transport sectors.
- **Economic growth:** France has identified the potential for hydrogen to build an industrial sector and ecosystem for economic development and job growth.

¹ As defined by the IEA Guide to Reporting Energy RD&D Budget/Expenditure Statistics, 2011

² French Government (2020) National strategy for the development of decarbonised and renewable hydrogen in France. <https://www.bdi.fr/wp-content/uploads/2020/03/PressKitProvisionalDraft-National-strategy-for-the-development-of-decarbonised-and-renewable-hydrogen-in-France.pdf>

- **Energy security:** domestic hydrogen development allows France to reduce their dependence on oil and gas imports.
- **Technology leadership:** hydrogen technology development has been identified as an opportunity to bolster France's global competition.

1.2.2 France's strategic hydrogen industry priorities

France has identified three main priorities in their 2020 *National strategy for the development of decarbonised and renewable hydrogen in France*.³ These priorities were selected based on the main hydrogen markets and to support domestic hydrogen technology development. In this section, these priorities are overlaid by the priorities contained in the earlier *Hydrogen deployment plan for the energy transition*⁴ from 2018.

- **Developing a French electrolysis sector:** A priority in the *National Strategy*⁵, this element has two parts. One is the development of a domestic electrolysis sector, and the second is decarbonisation efforts for industry. For the development of their electrolysis sector, France has allocated EUR 1.5 billion to this action. Claiming to be the most promising process for decarbonising industry, France states that growth in the number of production units and their unit capacity will allow for economies of scale and lower production costs. Their target is 6.5 gigawatts (GW) of electrolyzers installed by 2030. In October 2021, President Macron revealed the EUR 30 billion 'France 2030' Investment Plan which tagged nuclear-powered electrolysis as a core part of France's future energy strategy.⁶
- **Decarbonising industry:** The *National Strategy*⁷ mentions industry decarbonisation under its priorities for research and innovation. France identifies the refining sector for the use of hydrogen for removing sulphur from fuels, in the chemical industry for the production of ammonia and methanol, and in certain sectors such as electronics and food processing which use hydrogen in smaller quantities.
- **Developing the use of decarbonised hydrogen for heavy-duty mobility:** Deploying hydrogen technologies for heavy-duty vehicles is a priority in the *National Strategy*⁸. This includes light commercial vehicles, heavy goods vehicles, buses and regional or inter-regional trains.
- **Developing large-scale regional projects by encouraging pooling of uses:** To accelerate the hydrogen transition for the aforementioned heavy-duty mobility applications, the French strategy puts forth pooling of demand in both the industrial and mobility sectors, at a regional scale, to create strong partnerships between regional authorities and industry. This priority was broader in the 2018

³ French Government (2020) National strategy for the development of decarbonised and renewable hydrogen in France. <https://www.bdi.fr/wp-content/uploads/2020/03/PressKitProvisionalDraft-National-strategy-for-the-development-of-decarbonised-and-renewable-hydrogen-in-France.pdf>

⁴ MTES (2018) Hydrogen deployment plan for the energy transition. (In French) https://www.ecologie.gouv.fr/sites/default/files/Plan_deploiement_hydrogene.pdf

⁵ French Government (2020) National strategy for the development of decarbonised and renewable hydrogen in France. <https://www.bdi.fr/wp-content/uploads/2020/03/PressKitProvisionalDraft-National-strategy-for-the-development-of-decarbonised-and-renewable-hydrogen-in-France.pdf>

⁶ Andrew Lee (2021) Macron hails pink hydrogen from nuclear as 'primary asset' for France, Recharge. Viewed at <https://www.rechargenews.com/energy-transition/macron-hails-pink-hydrogen-from-nuclear-as-primary-asset-for-france/2-1-1086259>

⁷ French Government (2020) National strategy for the development of decarbonised and renewable hydrogen in France. <https://www.bdi.fr/wp-content/uploads/2020/03/PressKitProvisionalDraft-National-strategy-for-the-development-of-decarbonised-and-renewable-hydrogen-in-France.pdf>

⁸ French Government (2020) National strategy for the development of decarbonised and renewable hydrogen in France. <https://www.bdi.fr/wp-content/uploads/2020/03/PressKitProvisionalDraft-National-strategy-for-the-development-of-decarbonised-and-renewable-hydrogen-in-France.pdf>

*Hydrogen Deployment Plan*⁹ but was then focused on heavy-duty mobility under the 2020 *National strategy for the development of decarbonised and renewable hydrogen in France*.¹⁰

- **Supporting research, innovation and skills development to promote the uses of tomorrow:** Here, the strategy emphasises support needed for research and innovation, as well as skills development. The goal is for France to remain at the forefront internationally in hydrogen R&D and to support innovation surrounding hydrogen technology commercialisation. Regarding developing skills, the strategy outlines the need for training on the specific nature of hydrogen and its uses, components and operating procedures. To address this, the strategy prioritises specific support for engineering education and development of new, mainly vocational, courses.
- **Stabilising the energy network:** Although not stated as a key priority in the *National Strategy*¹¹, the 2018 *Hydrogen deployment plan for the energy transition*¹² includes hydrogen as a network stabiliser and energy storage medium as a key pillar in the medium to long-term. The introduction of hydrogen into natural gas networks is identified as an opportunity to reduce the use of imported fossil fuels. In the medium-term, the opportunity mainly lies in hydrogen contributing to the flexibility of electricity systems by providing a means of storage. Over the long-term (2035 and beyond), hydrogen will act as stabilisation for energy networks through hydrogen injection into gas networks.

France's hydrogen targets

France will contribute towards setting and achieving targets for hydrogen set by the EU. France has welcomed the European Commission's package of legislative proposals on climate change, collectively referred to as the 'Fit for 55' package, which was passed in July 2021 as a response to the European Green Deal. The package proposes legislative changes and new policy measures to achieve carbon neutrality by 2050 and to reduce net emissions by at least 55% by 2030, compared to 1990 levels.¹³ The package further sets out various other EU-level targets by addressing sectoral regulations across the EU (see *Section 1.3.4 Other key hydrogen policies, regulation and legislation* for policies impacting EU members, including France). In the context of the European framework, Member States will be required to define their own target levels and policy approaches to achieve these goals.¹⁴

⁹ MTES (2018) Hydrogen deployment plan for the energy transition. (In French) https://www.ecologie.gouv.fr/sites/default/files/Plan_deploiement_hydrogene.pdf

¹⁰ French Government (2020) National strategy for the development of decarbonised and renewable hydrogen in France. <https://www.bdi.fr/wp-content/uploads/2020/03/PressKitProvisionalDraft-National-strategy-for-the-development-of-decarbonised-and-renewable-hydrogen-in-France.pdf>

¹¹ French Government (2020) National strategy for the development of decarbonised and renewable hydrogen in France. <https://www.bdi.fr/wp-content/uploads/2020/03/PressKitProvisionalDraft-National-strategy-for-the-development-of-decarbonised-and-renewable-hydrogen-in-France.pdf>

¹² MTES (2018) Hydrogen deployment plan for the energy transition. (In French) https://www.ecologie.gouv.fr/sites/default/files/Plan_deploiement_hydrogene.pdf

¹³ European Commission (2020) A hydrogen strategy for a climate neutral Europe. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

¹⁴ Herbert Smith Freehills (2021) Legal Briefings: FIT FOR 55 - EU SHIFTS TACTICS FOR PROPOSED ENERGY EFFICIENCY DIRECTIVE. <https://www.herbertsmithfreehills.com/insight/fit-for-55-eu-shifts-tactics-for-proposed-energy-efficiency-directive>

With respect to France's national strategy, France has set several hydrogen related targets. These can be found in several documents including the *National strategy for the development of decarbonised and renewable hydrogen in France*,¹⁵ the *Hydrogen deployment plan for the energy transition*,¹⁶ *The French Green Hydrogen Plan 2020-2030*,¹⁷ and the *Multiannual Energy Programming 2019-2028*.¹⁸ These targets relate to hydrogen production, mobility and economic development and fit into France's broader climate targets, which aims to cut emissions by 6 million tonnes of CO₂ a year by 2030. The targets are summarised in Table 2 below.

Table 2: France's Hydrogen Targets¹⁹

	Present	2023 target	2028 target	2030 target
Generation capacity (electrolysis)	-	-	-	6.5 GW
Industry	95% hydrogen from fossil fuels (2018) ¹	10% green hydrogen used in industrial sector	20-40% green hydrogen used in industrial sector	EU target of 50% renewable fuels of non-biological origin in energy and feedstocks (excluding production of oil products) ²
Hydrogen vehicles	250 hydrogen vehicles (2018) 20 hydrogen refuelling stations (2018)	5,000 hydrogen vehicles 100 hydrogen refueling stations	20,000-50,000 light fuel cell vehicles 800 – 2,000 heavy duty fuel cell vehicles 400 – 1,000 hydrogen refuelling stations	-
Aviation	-	EU target of 2% share of sustainable aviation fuels by 2025 (including hydrogen derived fuels) ²	-	-

¹⁵ French Government (2020) National strategy for the development of decarbonised and renewable hydrogen in France. <https://www.bdi.fr/wp-content/uploads/2020/03/PressKitProvisionalDraft-National-strategy-for-the-development-of-decarbonised-and-renewable-hydrogen-in-France.pdf>

¹⁶ MTES (2018) Hydrogen deployment plan for the energy transition. (In French) https://www.ecologie.gouv.fr/sites/default/files/Plan_deploiement_hydrogene.pdf

¹⁷ French Government, Business France (n.d.) The French Green Hydrogen Plan 2020-2030: Shaping France as one of the most competitive, innovative and decarbonised economies. <https://www.tresor.economie.gouv.fr/Articles/4a1ac560-a021-4358-a466-f5430928a1db/files/7d2fd0e2-8a3d-4ce8-bbb3-94cbd5b9c3d1>

¹⁸ MTES (n.d.) Executive Summary: French Strategy for Energy and climate, Multi Annual Energy Plan 2019-2023 and 2024-2028. <https://www.ecologie.gouv.fr/sites/default/files/PPE-Executive%20summary.pdf>

¹⁹ French Government (2018) Hydrogen Plan: "making our country a world leader in this technology" <https://www.gouvernement.fr/en/hydrogen-plan-making-our-country-a-world-leader-in-this-technology-0>; IHS Markit (2021) EC Fit for 55 offers benefits to hydrogen economy. <https://cleanenergynews.ihsmarkit.com/research-analysis/ec-fit-for-55-offers-benefits-to-hydrogen-economy.html>

An analysis by the EU and the FCH JU calculated the potential opportunity for Hydrogen Energy Technology in the French economy, based on the 2020 *Integrated National Energy & Climate Plan*²⁰ submitted. Results of the scenario analysis undertaken are contained in Table 3 below.

Table 3: Opportunities for hydrogen in France by 2030²¹

	Conservative Scenario	Ambitious Scenario
Hydrogen Production from renewables	Electrolysers 1,150 MW and 4,260 GWh _{H2} /a	Electrolysers 5,290 MW and 19,590 GWh _{H2} /a
Industry	969 GWh/a	5,850 GWh/a
Refineries	770 GWh _{H2} /a	1,330 GWh _{H2} /a
Steel	-	320 kt/a
Olefins	-	82.2 kt/a
Ammonia	-	54.0 kt _N /a
Methanol	-	710 t/a
Aromatics	-	13.7 kt/a
Buildings	578 GWh/a	5,780 GWh/a
Micro-CHP units	26,540 units	115,460 units
Commercial-Scale CHP* installations	30 installations	290 installations
Transport	2,703 GWh/a	7,818 GWh/a
Refueling Stations	635	1,113
Trucks	45,970	91,940
Cars	351,700	703,400
Buses	1,200	2,410
Trains	60	181
Airplanes	202 GWh/a synthetic fuels	1,917 GWh/a synthetic fuels
Power	14 GWh/a (6 GWh/a electricity produced)	137 GWh/a (59 GWh/a electricity produced)

*CHP: Combined Heat and Power

²⁰ European Commission (2020) National Energy and Climate Plans: EU countries' 10-year national energy and climate plans for 2021-2030. https://ec.europa.eu/info/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-energy-and-climate-plans_en

²¹ Trinomics and Ludwig böcklow systemtechnik (2020) France: Opportunities for Hydrogen Energy Technologies Considering the National Energy & Climate Plans. Prepared for the FCH JU, EU. https://www.fch.europa.eu/sites/default/files/file_attach/Brochure%20FCH%20France%20%28ID%209473038%29.pdf

Aside from France's *National strategy for the development of decarbonised and renewable hydrogen in France*,²² the *Hydrogen Deployment Plan*²³, *The French Green Hydrogen Plan 2020-2030*²⁴, and the *Multiannual Energy Programming 2019-2028*,²⁵ hydrogen is also embedded in multiple levels of strategy. This includes high level national science and innovation strategies, sector specific decarbonisation roadmaps, and regional level hydrogen strategies.

National Science and Innovation Strategies:

- *2020 National Research Strategy*:²⁶ Outlines France's research priorities and 'missions' to address society's grand challenges. 'Missions' with a direct link to hydrogen include 'clean, secure and efficient energy' and 'sustainable mobility and urban systems.' The new strategy adds EUR 26 billion to the public research budget over 10 years, EUR 7 billion for the ANR which aims to raise grant success rate to 30% by 2027, EUR 4.5 billion to wastes, and the remainder for blue sky research, technology-transfer projects, equipment, operating expenses.²⁷
- *The SNRE 2016 (National Strategy for Research in Energy)*:²⁸ Sets the strategy for energy transformation, R&D and innovation for territories and industrial networks, developing skills and knowledge for R&D, and creating and streamlined governance system.
- *French National Strategy on Research Infrastructures (2018-2020)*:²⁹ Outlines major RD&D infrastructure that will be undertaken. Many laboratories in France are currently dedicated to the French hydrogen research network (FH2R).

Sector Specific Strategies:

- *Roadmap to Decarbonize the Chemistry Sector (May 2021)*:³⁰ The roadmap targets are reduction of Greenhouse gas (GHG) emissions in the chemistry sector by 26% by 2030 (compared to 2015 levels), production of fossil hydrogen by chemical companies of 300,000 tonnes per year (t/year). The roadmap provides three scenarios for substituting with decarbonised hydrogen by 2030.

²² French Government (2020) National strategy for the development of decarbonised and renewable hydrogen in France. <https://www.bdi.fr/wp-content/uploads/2020/03/PressKitProvisionalDraft-National-strategy-for-the-development-of-decarbonised-and-renewable-hydrogen-in-France.pdf>

²³ MTES (2018) Hydrogen deployment plan for the energy transition. (In French) https://www.ecologie.gouv.fr/sites/default/files/Plan_deploiement_hydrogene.pdf

²⁴ French Government, Business France (n.d.) The French Green Hydrogen Plan 2020-2030: Shaping France as one of the most competitive, innovative and decarbonised economies. <https://www.tresor.economie.gouv.fr/Articles/4a1ac560-a021-4358-a466-f5430928a1db/files/7d2fd0e2-8a3d-4ce8-bbb3-94cbd5b9c3d1>

²⁵ MTES (n.d.) Executive Summary: French Strategy for Energy and climate, Multi Annual Energy Plan 2019-2023 and 2024-2028. <https://www.ecologie.gouv.fr/sites/default/files/PPE-Executive%20summary.pdf>

²⁶ MESRI (2020) National Research Strategy: France Europe 2020 https://cache.media.enseignementsup-recherche.gouv.fr/file/Strategie_Recherche/26/9/strategie_nationale_recherche_397269.pdf

²⁷ Casassus B (2019) France set to get first national strategy for research. Nature. DOI:10.1038/d41586-019-00484-4 <https://www.nature.com/articles/d41586-019-00484-4>; Casassus B (2020) Scientists disappointed by plan to boost France's research prowess. Nature. DOI: 10.1038/d41586-020-02217-4 <https://www.nature.com/articles/d41586-020-02217-4>

²⁸ OECD (2021) SNRE – National Strategy for Energy Research. STIP Compass. <https://stip.oecd.org/stip/policy-initiatives/2019%2Fdata%2FpolicyInitiatives%2F15961>

²⁹ MESRI (2018) French National Strategy on Research Infrastructures 2018 Edition https://cache.media.enseignementsup-recherche.gouv.fr/file/Infrastructures_de_recherche/04/6/Brochure_Infrastructures_2018_UK_1023046.pdf

³⁰ CNI (2021) The decarbonisation of industry: Roadmap for the chemicals sector. https://www.conseil-national-industrie.gouv.fr/files_cni/files/csf/chimie-et-materiaux/feuille_de_route_de_decarbonation_de_la_filiere_chimie.pdf

- *Roadmap to Decarbonise the Mining and Metallurgy Sector (May 2021):*³¹ The roadmap targets are reduction of GHG emissions in the mining and metallurgy sector of 31% by 2030 (compared to 2015 levels). Enabling actions include the use of low-carbon hydrogen for the pre-reduction of iron ore, which could reduce emissions by 45-90 kilotonnes (kt) of CO₂ equivalent a year by 2030.
- *Roadmap for the deployment of sustainable aeronautical biofuels:*³² The roadmap sets a deployment target of 2% by 2025, 5% in 2030, and 50% by 2050 for sustainable aviation fuels.

Regional Strategies:

At least 10 French regions have released their hydrogen strategies and roadmaps at the local level.³³

1.2.3 France's hydrogen RD&D priorities

Table 4 illustrates France's RD&D priorities across the value chain and is broken down by supply chain area. The table outlines sub-technology areas identified by France and the corresponding key RD&D priorities under that area. These priorities are identified by French National Centre for Scientific Research (CNRS) and the French Research Network on Hydrogen Energy (FRH2).³⁴ The key 6 research areas are production, storage, stationary, mobility, training and platform technologies (such as characterisation, modelling and testing). For each area, the network has outlined the key hydrogen R&D priorities. Further insights were drawn from the CNRS presentation at the 'Filling the Gaps' hydrogen workshop at the French Embassy in Australia in September 2021.

Table 4: France's hydrogen RD&D priorities³⁵

Supply chain Area	Sub-technology Areas	France's key RD&D priorities
Production	Electrolysis	<p>Low and high temperature electrolysis (cost reduction, lifetime improvement, and scale-up).</p> <p>Improvement of cell shaping processes, choice of new interconnector materials.</p> <p>Polymer Electrolyte Membrane (PEM) and Alkaline:</p> <p>Catalysts and platinum-free electrodes.</p> <p>Decrease in cell voltage.</p> <p>Solid Oxide Electrolysis (SOE):</p> <p>Improvements in density and lifetime.</p>

³¹ CNI (2021) Decarbonisation of Industry: Roadmap for Mining and Metallurgy Sector. <https://www.conseil-national-industrie.gouv.fr/files_cni/files/csf/mines-metallurgie/decarbonation_feuille_de_route_mines_et_metallurgie.pdf>

³² MESRI, Ministry of Transport, Ministry of Agriculture (2020) French Roadmap for the deployment of sustainable aviation fuels <https://www.ecologie.gouv.fr/sites/default/files/Feuille%20de%20route%20fran%C3%A7aise%20pour%20le%20d%C3%A9ploiement%20des%20bio-carburants%20a%C3%A9ronautiques%20durables.pdf>

³³ IPHE (2020) France <https://www.iphe.net/france>

³⁴ CNRS (n.d.) The French research network on hydrogen energy. <https://frh2.cnrs.fr/>

³⁵ FRH2 (2021) Axe production <https://frh2.cnrs.fr/axe-production/>; FRH2 (2021) Axe stockage <https://frh2.cnrs.fr/axe-stockage/>; FRH2 (2021) Axe mobilité <https://frh2.cnrs.fr/axe-mobilite/>; FRH@ (2021) Axe stationnaire <https://frh2.cnrs.fr/axe-stationnaire/>; FRH2 (2021) Axe formation <https://frh2.cnrs.fr/axe-formation/>; FRH@ (2021) Axe plateformes et moyens d'essais <https://frh2.cnrs.fr/axe-plateformes-et-moyens-dessais/>

Supply chain Area	Sub-technology Areas	France's key RD&D priorities
		<p>Reduction of nickel content through the integration of nanoparticles and development of new architectures (cell design, barrier layers).</p> <p>Proton-conducting SOE:</p> <p>Operating at lower temperatures.</p> <p>Other:</p> <p>Hydrogen purification</p> <p>Catalyst development.</p> <p>Renewable energy coupling with electrolyzers.</p>
	Alternative production methods	<p>Direct photocatalysis.</p> <p>Biological production (catalysts).</p>
Storage and distribution	Gas pipelines	Hydrogen pipelines (embrittlement, needs for retrofitting).
	Solid storage	<p>Though not a high strategic priority in the French strategy, solid storage is research priority at the CNRS and FH2R.</p> <p>Reversible solid storage at room temperature in metal hydrides and complex hydrides, improvements in weight density.</p> <p>Solid storage in porous and hybrid materials.</p> <p>Regenerable hydrides with high mass capacity. Release of hydrogen by thermolysis and hydrolysis. Regeneration processes.</p>
	Compression and liquefaction	<p>Cryogenic hydrogen (thermal insulation, reducing boil-off losses).</p> <p>Electrochemical compression tests in multiphysics usage cycles, over long periods or in accelerated tests.</p>
	Underground storage	<p>Geological storage (salt caverns and water aquifers). This may include geomechanical modelling for stability/safety, flow modelling for economic valuation, and geophysical modelling.</p> <p>Conformability and thermomechanical resistance of hyperbaric reservoirs.</p>
	Hydrogen carriers	Novel ammonia and liquid organic hydrogen carriers (LOHC).
	Storage tanks and storage systems	<p>Modelling of storage tanks and materials.</p> <p>Integrated systems: optimisation of energy efficiency in storage systems coupled with electrolysis fuel cells.</p>
Utilisation	Industrial use	<p>Catalyst development.</p> <p>Energy management systems with power electronics.</p>
	Fuel cells (mobility)	New stack technology with higher operating temperatures (95 °C, 110 °C).

Supply chain Area	Sub-technology Areas	France's key RD&D priorities
		<p>Improved component stability and tolerance to impurities present in air and hydrogen (new supports more resistant to corrosion, membranes with very high dimensional stability).</p> <p>Reduction of quantity of platinum used in fuel cells (<0.1g / kW).</p> <p>New materials: catalysts without critical metals, new polymer electrolytes (cost reduction, lower environmental footprint than Nafion).</p> <p>Optimization of electrical performance and durability (analysis of system lifespan).</p> <p>Energy flow modelling (electrical, thermal, fluidic, etc.).</p> <p>Hybridization with batteries or supercapacitors.</p>
	Fuel cells (stationary)	<p>Integration of novel materials in cells such as protonic ceramic fuel cells (decreasing operating temperatures, improving recyclability).</p> <p>Improvements in design and barrier layers for stability.</p> <p>Improvements and breakthroughs in high temperature gas purification.</p> <p>Material breakthroughs for stability under hydrogen sulphide gas.</p>
	Hydrogen combustion	Hydrogen combustion engines.
Cross-cutting	Modelling and technoeconomic studies	<p>Economic and social analysis.</p> <p>Lifecycle analysis.</p>
	Characterisation and testing	Establishment of platforms and laboratories for characterisation and testing in the areas of materials, modelling, catalysis and performance of cells, storage and systems.
	Recycling and circular economy	<p>Reduce amount of critical raw materials used.</p> <p>Improve recycling processes.</p>
	Safety, regulation and policy	Safety, standards and certification. Regulation policy and incentives.
	Skills, education and training	<p>Identify gaps and analyse needs in light of exponential increase in jobs required across different levels of the hydrogen value chain.</p> <p>Identify actions to be taken, required training and education.</p>

1.3 France's hydrogen RD&D ecosystem

1.3.1 Regulatory bodies and policy ecosystem

Overview of France's STI policy landscape

At the national level, France's science, technology and innovation (STI) system and energy, transport and infrastructure sectors, are governed by several government ministries and administrative bodies. This section describes the overall STI system in France and how it is organised. This aims to provide context for the next section, 'France's Hydrogen RD&D Landscape,' which delves more deeply into the major actors in the hydrogen space.

Government and Funding Agencies: The Ministry of Higher Education, Research and Innovation (MESRI) is responsible for the structure of the higher education and research sectors. Other ministries, such as the Ministry of Economy, Finance and Recovery, and the Ministry for the Ecological Transition are involved in more specific STI policy, for example, hydrogen strategy and planning. At a funding level the National Research Agency (ANR) and Bpi France are the primary funding agencies for RD&D in the research sector and industry respectively.

RD&D strategy implementation in France is conducted by a diverse system of research players ranging from basic science to commercialisation. These include different university systems, different types of non-university research institutions, as well as private companies, and range from fundamental science to industry application, with strong funding support from the state.³⁶ These are often connected through collaborative associations, foundations, and industry clusters.

Research Institutions: In France non-university research institutions have historically received the most funding and played a bigger role in producing R&D outputs.³⁷ There are two types of public R&D institutions in France; public science and technology institutions (EPST) have a greater focus on fundamental R&D, and public industrial and commercial institutions (EPIC) have a greater focus on industrial application. Examples of prominent EPSTs and EPICs are the CNRS and the CEA (two key institutions in the hydrogen landscape). Tertiary institutions are playing an increasing role in France's R&D outputs. There are two types of tertiary institutions in France; Universities are multidisciplinary institutions, and "Grandes Écoles" are elite applied schools in disciplines like engineering. Private companies in France also receive a large portion of public funding for R&D through a system of grants and other financing instruments.

The majority of research in France is conducted in groups called UMRs (Joint Research Units), bringing together experts from several public and private research institutions.³⁸ COMUEs (communities of universities and institutions) and 'Associations' are collaborations between universities, higher education institutions and research organisations often on a regional basis. Further, France has a number of 'Competitiveness Clusters' with a role somewhat similar to that of the Australian Growth Centres.³⁹

³⁶ Powell JJW and Dusal J (2017) Science Production in Germany, France, Belgium, and Luxembourg: Comparing the Contributions of Research Universities and Institutes to Science, Technology, Engineering, Mathematics and Health. Minerva. DOI: 10.1007/s11024-017-9327-z <https://link.springer.com/article/10.1007/s11024-017-9327-z>

³⁷ Powell JJW and Dusal J (2017) Science Production in Germany, France, Belgium, and Luxembourg: Comparing the Contributions of Research Universities and Institutes to Science, Technology, Engineering, Mathematics and Health. Minerva. DOI: 10.1007/s11024-017-9327-z <https://link.springer.com/article/10.1007/s11024-017-9327-z>

³⁸ Embassy of France in Australia (n.d.) Higher Education in France at a Glance. https://02133e50-657d-4c63-a716-f251ccd847c9.filesusr.com/ugd/d0ff8f_9b53e163a0834fdd851b8b79f25404fc.pdf

³⁹ MESRI (2018) French National Strategy on Research Infrastructures 2018 Edition https://cache.media.enseignementsup-recherche.gouv.fr/file/Infrastructures_de_recherche/04/6/Brochure_Infrastructures_2018_UK_1023046.pdf

These clusters bring together private firms, public research bodies and tertiary education institutions to conduct R&D projects and develop synergies in a particular region to realise economic benefits.⁴⁰

R&D infrastructure: there are several avenues to access large labs and specialized equipment; IOs (international organisations) via inter-agency agreements, VLRIs (very large research infrastructures) across France and in Europe and managed through ESFRI (the European Strategy Forum for Research Infrastructure), RIs (Research Infrastructure) through alliances with their operators. Infrastructure ‘projects’ that are under construction are decided through the European ESRI and French *National Strategy on Research Infrastructures*.⁴¹ Examples of dedicated hydrogen laboratories include the FHR2 group, led by the CNRS and CEA.

Supranational bodies: Further to this, actors in France’s hydrogen space are also active at the supranational level, contributing to the EU’s hydrogen strategy, EU hydrogen bodies, and EU hydrogen R&D programmes.

France’s hydrogen RD&D landscape

This section gives a detailed description of the key actors in the French hydrogen landscape Table 5 and Figure 3 below describe each of the players in France’s hydrogen ecosystem in more detail, including their general role in the STI system, and their specific hydrogen initiatives.

Figure 3: Summary of France’s hydrogen policy ecosystem



⁴⁰ MESRI (2018) French National Strategy on Research Infrastructures 2018 Edition https://cache.media.enseignementsup-recherche.gouv.fr/file/Infrastructures_de_recherche/04/6/Brochure_Infrastructures_2018_UK_1023046.pdf

⁴¹ MESRI (2018) French National Strategy on Research Infrastructures 2018 Edition https://cache.media.enseignementsup-recherche.gouv.fr/file/Infrastructures_de_recherche/04/6/Brochure_Infrastructures_2018_UK_1023046.pdf

Table 5: Summary of key public bodies

Body	Role in RD&D ecosystem	Hydrogen initiatives
MESRI <i>Ministry for Higher Education, Research and Innovation</i>	<p>Conducts research policy and implements the <i>National Research Strategy</i>⁴². This ministry is responsible for the governance, structure and strategy of France's science and research system.</p> <p>Funding agencies under this ministry are Bpi France (support for companies), the ANR (National Research Agency), and ADEME (Agency for Ecological Transition).</p>	<p>The most recent <i>National Research Strategy</i>⁴³ includes 'missions' with a direct link to hydrogen including 'Clean, secure and efficient energy' and 'sustainable mobility and urban systems.'⁴⁴</p>
<i>Ministry of Economy, Finance and Recovery</i> <i>(Informally 'Bercy')</i>	<p>This ministry is responsible for economic policy, tax legislation, public procurement, support for new technologies and their dissemination, intellectual property and counterfeiting, and tourism support.⁴⁵</p>	<p>Published France's <i>National strategy for the development of decarbonised and renewable hydrogen in France</i>⁴⁶ jointly with the Ministry for the Ecological Transition.</p> <p>The ministry is also responsible for the COVID-19 recovery plan which includes funding allocated to hydrogen projects.⁴⁷</p>
MTES <i>Ministry for the Ecological Transition</i>	<p>This ministry is responsible for policy in the areas of sustainable development, climate, energy transition and biodiversity.</p>	<p>Published France's <i>National strategy for the development of decarbonised and renewable hydrogen in France</i>⁴⁸ jointly with the Ministry of Economy and Finance.</p> <p>Published the 2018 <i>Hydrogen deployment plan for the energy transition</i>.⁴⁹</p> <p>The ministry is also responsible for the PPE (Multi Annual Energy Plan) outlining the course of action over the next 10 years, and sets out key hydrogen targets.⁵⁰</p>

⁴² MESRI (2020) National Research Strategy: France Europe 2020 https://cache.media.enseignementsup-recherche.gouv.fr/file/Strategie_Recherche/26/9/strategie_nationale_recherche_397269.pdf

⁴³ MESRI (2020) National Research Strategy: France Europe 2020 https://cache.media.enseignementsup-recherche.gouv.fr/file/Strategie_Recherche/26/9/strategie_nationale_recherche_397269.pdf

⁴⁴ MESRI (2020) National Research Strategy: France Europe 2020 https://cache.media.enseignementsup-recherche.gouv.fr/file/Strategie_Recherche/26/9/strategie_nationale_recherche_397269.pdf

⁴⁵ Government (2021) The Ministry of the Economy, Finance and Recovery. <https://www.gouvernement.fr/le-ministere-de-l-economie-des-finances-et-de-la-reliance>; Government (2021) The Investments for the Future Program <https://www.gouvernement.fr/le-programme-d-investissements-d-avenir>

⁴⁶ French Government (2020) National strategy for the development of decarbonised and renewable hydrogen in France. <https://www.bdi.fr/wp-content/uploads/2020/03/PressKitProvisionalDraft-National-strategy-for-the-development-of-decarbonised-and-renewable-hydrogen-in-France.pdf>

⁴⁷ Ministry of Economy, Finance and Recovery (2020) Recovery Plan: Launch of 2 calls for projects for the hydrogen sector. <https://www.economie.gouv.fr/plan-de-reliance/lancement-appels-projets-filiere-hydrogene>

⁴⁸ French Government (2020) National strategy for the development of decarbonised and renewable hydrogen in France. <https://www.bdi.fr/wp-content/uploads/2020/03/PressKitProvisionalDraft-National-strategy-for-the-development-of-decarbonised-and-renewable-hydrogen-in-France.pdf>

⁴⁹ Ministry of Ecological Transition (2018) Hydrogen deployment plan for the energy transition. (In French) https://www.ecologie.gouv.fr/sites/default/files/Plan_deploiement_hydrogene.pdf

⁵⁰ Ministry of Ecological Transition (n.d.) Executive Summary: French Strategy for Energy and climate, Multi Annual Energy Plan 2019-2023 and 2024-2028. <https://www.ecologie.gouv.fr/sites/default/files/PPE-Executive%20summary.pdf>

Body	Role in RD&D ecosystem	Hydrogen initiatives
SGPI <i>General Secretariat for Investment</i>	<p>The SGPI is an administrative body under the French Prime Minister. The SGPI launch the PIA (Investments for the Future Programme). to finance innovation and increase France's growth potential. The SGPI also evaluates the socio-economic impact of public investment of PIA projects.⁵¹</p>	<p>There are several hydrogen R&D related initiatives falling under the PIA programme (see <i>Section 1.4</i> for more on PIA on projects).</p>
National Hydrogen Council	<p>Established in January 2021, following the publication of France's national hydrogen strategy. This body is chaired by the Minister of the Economy, and brings together hydrogen experts across sectors.</p>	<p>The agency's mandate includes decision-making on the implementation of the <i>National Strategy</i> on hydrogen, deployment of funds to support to hydrogen sector, and coordinating collaboration between the government and hydrogen industry stakeholders.</p> <p>Initial plans from the National Hydrogen Council include 3.2 GW of large-scale electrolysis capacity, requiring EUR 8 billion through the European IPCEI program.⁵²</p>
CNI <i>National Industry Council</i>	<p>Operates under the chairmanship of the prime minister and the Minister of Economy, Finance and Recovery, and is made up of representatives from the public sector and industry. The CNI has 18 strategic sector committees (CSFs) dedicated to sectoral issues and solutions.⁵³</p> <p>The task of the CNI is to co-develop industrial policy. Key themes include circular economy, employment and skills, and regulation and simplification.</p>	<p>Produced two roadmaps in May 2021 with respect to industry decarbonisation, which include hydrogen specific targets: The Chemicals industry decarbonisation roadmap, and the Mining and Metallurgy decarbonisation roadmap.⁵⁴</p>
CRE <i>Energy Regulatory Commission</i>	<p>Regulator for the energy and gas markets. This includes regulations in accordance with the "Energy Transition" Law (gas storage regulation, smart grid trials etc.), regulates gas storage under the "Hydrocarbons" Law, implements the "Clean Energy Package", and</p>	<p>The CRE is involved in the approvals for new commercial hydrogen projects, and approves access to the gas grid and hydrogen storage.</p>

⁵¹ Government (2021) General Secretariat for Investment (SGPI) <https://www.gouvernement.fr/secretariat-general-pour-l-investissement-sgpi>

⁵² S&P Global (2021) France launches hydrogen council, 3.2 GW of electrolyser projects see IPCEI funding. <https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/022621-france-launches-hydrogen-council-32-gw-of-electrolyzer-projects-see-ipcei-funding>

⁵³ CNI(2021) The National Industry Council <https://www.conseil-national-industrie.gouv.fr/conseil-national-de-l-industrie>

⁵⁴ CNI (2021) Decarbonisation of Industry: Roadmap for Mining and Metallurgy Sector. https://www.conseil-national-industrie.gouv.fr/files_cni/files/csf/mines-metallurgie/decarbonation_feuille_de_route_mines_et_metallurgie.pdf; National Industry Council (2021) Decarbonisation of Industry: Roadmap for the Chemical Sector https://www.conseil-national-industrie.gouv.fr/files_cni/files/csf/chimie-et-materiaux/feuille_de_route_de_decarbonation_de_la_filiere_chimie.pdf

Body	Role in RD&D ecosystem	Hydrogen initiatives
	implements the French “regulatory sandbox”. ⁵⁵	
ANR <i>National Research Agency</i>	<p>Public institution under MESRI. This agency funds RD&D projects led by public institutions, including joint projects with the private sector and stimulates cooperation between industry and academia.⁵⁶</p> <p>The ANR’s remit also includes funding innovation and technology transfer, implementing programmes of work approved by the Ministry of Research, manage major government investment programmes, and analysing trends and impact of research.⁵⁷</p>	<p>The ANR funds hydrogen RD&D projects led by public research institutions (including joint projects with the private sector). The ANR launched calls for projects under the ‘PEPR – Decarbonised Hydrogen’ in 2021 (see <i>Section 1.4</i> for details on hydrogen projects and programmes).</p> <p>As part of the Japan-EU joint research group (the European Interest Group (EIG) CONCERT-Japan), the ANR has issued a joint international research call for “Sustainable Hydrogen Technology as Affordable and Clean Energy”.⁵⁸</p>
ADEME <i>Agency for Ecological Transition</i>	<p>The ADEME is one of France’s public industrial and commercial institutions (EPIC).</p> <p>The ADEME is a public agency under the Ministry for Ecological transition and the Ministry for Higher Education, Research and Innovation.</p> <p>ADEME’s role is to finance and administer research and innovation, monitor industrial change, provide advisory services, and dissemination of information to the public.</p> <p>ADEME’s five areas of work are waste, land, climate and energy, air and noise, and cross-functional actions (sustainable production and consumption, sustainable cities and territories).⁵⁹</p>	<p>The ADEME support’s France’s PIA programme (Investments for the Future). The ADEME launched two calls for proposals in October 2020; “Hydrogen Territorial Ecosystems” and “Technological bricks and hydrogen demonstrators” (See <i>Section 1.4</i> for project details and budget).⁶⁰</p> <p>The ADEME also provides funding support for a number of hydrogen mobility projects.⁶¹</p> <p>Examples of high profile projects supported by the ADEME include the GRHYD grid injection project in Dunkirk, and the Jupiter 1000 power-to-gas project.</p>
Bpi France <i>Public Investment Bank</i>	France’s national investment bank, and operates under MESRI. This agency funds the private sector, including the financing of R&D and high TRL projects. This bank also	<p>Bpi has financed hydrogen projects by private companies.</p> <p>In 2021 Bpi France also invested USD 100 million in Technip Energies, a LNG, hydrogen</p>

⁵⁵ CRE (2021) Who Are We? <https://www.cre.fr/en/CRE/who-are-we>

⁵⁶ ANR (2021) Missions <https://anr.fr/en/anrs-role-in-research/missions/>

⁵⁷ ANR (2021) Missions <https://anr.fr/en/anrs-role-in-research/missions/>

⁵⁸ ANR (2021) Preliminary announcement on the upcoming international joint research call: “sustainable Hydrogen Technology as Affordable and Clean Energy” https://anr.fr/en/latest-news/read/news/preliminary-announcement-on-the-upcoming-international-joint-research-call-sustainable-hydrogen-te/?tx_news_pi1%5Bcontroller%5D=News&tx_news_pi1%5Baction%5D=detail&cHash=f1e71a0030544934b17bdd5b061b589e

⁵⁹ ADEME (2021) About ADEME. <https://www.ademe.fr/en/about-ademe>

⁶⁰ Watson Farley & Williams (2021) The French Hydrogen Strategy <https://www.wfw.com/articles/the-french-hydrogen-strategy/>

⁶¹ French Government (2020) National strategy for the development of decarbonised and renewable hydrogen in France (Provisional Draft English Version) <https://www.bdi.fr/wp-content/uploads/2020/03/PressKitProvisionalDraft-National-strategy-for-the-development-of-decarbonised-and-renewable-hydrogen-in-France.pdf>

Body	Role in RD&D ecosystem	Hydrogen initiatives
	co-invests in international collaboration projects with country counterparts.	and ethylene company that is growing its portfolio share in hydrogen produced from renewables or from fossil fuel conversion with CCUS, sustainable chemistry and CO ₂ management. ⁶² Bpi France and Banque has jointly launched a Climate Plan from 2020-2024 with Banque des Territoires to fund green transition projects. ⁶³
Banque des Territoires <i>Bank of Territories</i>	The Banque des Territoires provides financing for local and regional actors, for the development of territories across France.	The bank provides financing for the development of commercial hydrogen vehicle fleets and refuelling stations, ⁶⁴ as well as renewable hydrogen projects. ⁶⁵ The Banque des Territoires and Bpi France jointly launched a Climate plan worth close to EUR 40 billion for 2020-2024, to fund green transition projects. ⁶⁶
EIB <i>European Investment Bank</i>	The EIB is the lending arm of the European Union, and the largest provider of climate finance in the world. ⁶⁷	The EIB provides part of the financing for the InvestEU programme for COVID-19 recovery. (See <i>Section 1.3.3 Funding Mechanisms</i> for more details). In July 2021 the EIB signed an agreement with Hydrogen Europe to undertake a number of activities including providing financing advisory support for hydrogen projects and developing EIB financing products for hydrogen produced from renewables. ⁶⁸ In July 2020 the EIB signed an agreement with France Hydrogène to facilitate access to the EIB's financing solutions for hydrogen projects in France. The EIB has engaged in similar agreements with associations and industry in other European countries.

⁶² Businesswire (2021) Bpifrance Strengthens Its Stake in Technip Energies by Investing USD 100 million <https://www.businesswire.com/news/home/20210331005911/en/Bpifrance-Strengthens-Its-Stake-in-Technip-Energies-by-Investing-USD100-Million>

⁶³ Caisse des Dépôts (2020) Banque des Territoires and Bpifrance deploy a Climate Plan worth nearly €40bn <https://www.caissedesdepots.fr/en/news/banque-des-territoires-and-bpifrance-eu40bn-climate-plan>

⁶⁴ Banque des Territoires (2021) Investment in hydrogen mobility <https://www.banquedesterritoires.fr/investissement-pour-la-mobilite-hydrogene>

⁶⁵ Banque des Territoires (2021) Investments in the production of green hydrogen <https://www.banquedesterritoires.fr/investissements-dans-la-production-dhydrogene-vert>

⁶⁶ Caisse des Dépôts (2020) Banque des Territoires and Bpifrance deploy a Climate Plan worth nearly €40bn <https://www.caissedesdepots.fr/en/news/banque-des-territoires-and-bpifrance-eu40bn-climate-plan>

⁶⁷ EIB (2021) Who we are. <https://www.eib.org/en/about/index.htm>

⁶⁸ EIB (2021) EIB signs advisory agreement with Hydrogen Europe <https://www.eib.org/en/press/all/2021-284-eib-signs-advisory-agreement-with-hydrogen-europe>

Body	Role in RD&D ecosystem	Hydrogen initiatives
		Alongside La Banque des Territoires, the EIB has pledged to invest EUR 100 million to create the 'Clean Bus' investment platform which finances energy transition bus fleets. ⁶⁹
CNRS <i>National Centre for Scientific Research</i>	The CNRS is one of France's public science and technology institutions (EPST). The CNRS has a greater focus on fundamental research.	<p>The CNRS is France's primary hydrogen R&D representative in the international sphere.</p> <p>In March 2021 the CNRS launched the FHR2 (Federation of Hydrogen Research) a group of 270 researchers and 28 labs engaged in hydrogen. This is a joint endeavour with the CEA, and includes a 5-year research programme with a budget of EUR 7 billion.</p> <p>The CNRS and CEA are also jointly responsible for leading the decarbonised hydrogen component of the PEPR.⁷⁰</p>
CEA <i>Alternative Energies and Atomic Energy Commission</i>	The CEA is one of France's public industrial and commercial institutions (EPIC). The CEA has a greater focus on development and demonstration for industrial application.	<p>Tasked with jointly implementing the FRH2 (Federation de Recherche Hydrogène) programme with the CNRS.</p> <p>CEA-Liten (Innovation Lab for New Energy Technologies) is the dedicated institute for emerging clean energy technologies including hydrogen production, storage and utilisation.</p> <p>The CEA has had numerous hydrogen and fuel cell programmes since the 1980s, supporting industrial companies in adopting hydrogen energy technologies.⁷¹ Research includes low temperature PEMFC fuel cells, high temperature electrolysis of water vapour (EHT), energy storage (gaseous pressure storage, hydride carriers, liquid storage), and applications in the transport sector.⁷²</p> <p>The CNRS and CEA are jointly responsible for leading the decarbonised hydrogen component of the PEPR.⁷³</p>

⁶⁹ Paris Climate Action (2021) The Bank Banque des territoires and the EIB launch the "Clean Buses" Platform, an innovative investment programme dedicated to the greening of the Territories' bus fleets. Viewed at <https://parisactionclimat.paris.fr/en/bank-banque-des-territoires-and-eib-launch-clean-buses-platform-innovative-investment-programme>

⁷⁰ CNRS (2021) Le CNRS, prêt à tirer parti des opportunités du PIA4. https://www-cnrs-fr.translate.goog/fr/cnrsinfo/le-cnrs-pret-tirer-parti-des-opportunites-du-pia4?_x_tr_sl=fr&_x_tr_tl=en&_x_tr_hl=en-GB&_x_tr_pto=op,sc

⁷¹ CEA (2016) Research Areas: Renewable Energies <https://www.cea.fr/english/Pages/research-areas/renewable-energies.aspx>

⁷² CEA (2021) Hydrogen and Fuel Cells <https://www.cea.fr/Pages/domaines-recherche/energies/energies-renouvelables/recherches-CEA-hydrogene-pile-a-combustible.aspx>

⁷³ CNRS (2021) Le CNRS, prêt à tirer parti des opportunités du PIA4. https://www-cnrs-fr.translate.goog/fr/cnrsinfo/le-cnrs-pret-tirer-parti-des-opportunites-du-pia4?_x_tr_sl=fr&_x_tr_tl=en&_x_tr_hl=en-GB&_x_tr_pto=op,sc

Body	Role in RD&D ecosystem	Hydrogen initiatives
IFPEN <i>IFP Energies Nouvelles</i>	<p>IFP Energies Nouvelles, also known as the French institute of petroleum, is a public research institution and an EPIC institution.</p> <p>The IFP conducts fundamental research for low technology readiness levels, as well as industrial innovation at high technology readiness levels. IFPEN's industry research and innovation programs span the areas of climate, environment and circular economy, renewable energy, sustainable mobility, and responsible oil and gas.⁷⁴</p>	<p>IFPEN is active in hydrogen R&D across the value chain, and in developing the associated industrial sectors.</p> <p>Areas of focus include CO2 capture, resistance of materials in contact with hydrogen, geological storage, storage in porous materials, storage site monitoring, fuel cells for electric vehicles, hydrogen combustion engines, and e-fuels.⁷⁵</p>

1.3.2 Hydrogen consortia

Table 6: Hydrogen consortia

Consortium	Description
France Hydrogène (prev. Afhyopac) <i>Hydrogen France</i>	<p>France Hydrogène is the French association for hydrogen and fuel cells. It brings together different hydrogen stakeholders across the hydrogen value chain including large industry players, SMEs and start-ups supported by labs and research centres, researchers, 'Competitiveness Clusters', and national and local government (See <i>Section 1.4.3</i> for more on hydrogen clusters).⁷⁶ France Hydrogène has 12 regional delegations across France responsible for coordinating the hydrogen sector at the local level between financial, industrial, institutional and community actors.⁷⁷ France Hydrogène is also a member of Hydrogen Europe.</p> <p>Hydrogen France published a white paper on the skills and professions needed for the hydrogen economy.⁷⁸ Hydrogen France also administers the online platform Vig'Hy, an interactive database presenting all the key figures, players and projects for commercial hydrogen deployment in France.⁷⁹</p>
Hydrogen Task Force	Led by Mouvement des Entreprises de France (MEDEF) International and France Hydrogène, the hydrogen task force is a group of private companies implementing France's hydrogen strategy. This group identifies business opportunities, promote French companies overseas with a focus on emerging and developing markets.
Gas for Climate	In 2020, 11 gas infrastructure companies across Europe (including major French gas players GRTgaz and Téréga), published the <i>European Hydrogen Backbone</i> plan to develop 23,000 km

⁷⁴ IFPEN (2021) Fundamental Research <https://www.ifpenergiesnouvelles.com/fundamental-research>; IFP Energies Nouvelles (2021) Innovation and Industry <https://www.ifpenergiesnouvelles.com/innovation-and-industry>

⁷⁵ IFPEN (2021) Our Solutions <https://www.ifpenergiesnouvelles.com/innovation-and-industry/our-expertise/renewable-energies/hydrogen/our-solutions>

⁷⁶ France Hydrogène (2021) Who Are We? <https://afhyopac.org/association/presentation/>

⁷⁷ France Hydrogène (2021) The 12 regional delegations <https://www.france-hydrogene.org/cartographie/>

⁷⁸ France Hydrogène (2021) White paper on the skills and jobs for the hydrogen sector. http://www.afhyopac.org/documents/publications/rapports/France%20Hydrog%C3%A8ne_Livre%20blanc%20Comp%C3%A9tences-m%C3%A9tiers_Final.pdf

⁷⁹ France Hydrogène (2021) Vig'Hy <https://vighy.france-hydrogene.org/>

Consortium	Description
	of hydrogen infrastructure and pipelines by 2040 to support the hydrogen industry. ⁸⁰ This is to be done mainly by repurposing existing pipelines, and includes renewable methane.
ECH2A <i>European Clean Hydrogen Alliance</i>	<p>European level body bringing together industry, national and local public authorities, civil society and other stakeholders such as investors and R&D institutions. The members include several German industry groups such as BASF, BMW, Linde and Diamler.⁸¹</p> <p>The goal of the body is to assist in building a pipeline of investments to scale up the hydrogen value chain across Europe, in order to facilitate and implement the European hydrogen strategy.⁸² The group meets in six roundtables each dedicated to a portion of the hydrogen value chain including production, transmission and distribution, industrial applications, mobility, energy sector and residential applications.⁸³</p>
FCH JU <i>The Fuel Cells and Hydrogen Joint Undertaking</i>	<p>The Fuel Cells and Hydrogen Joint Undertaking (FCH JU) is a public private partnership supporting hydrogen energy and fuel cell technologies across Europe, to accelerate commercialisation and diffusion.</p> <p>The program implements a fuel cell and hydrogen energy technology research and innovation program funded by Horizon 2020 (Europe's largest research and innovation programme). The portfolio of projects includes hydrogen production from renewables, fuel cells for transport applications, minimising use of critical materials, storage and integration into the energy system, and fuel cells for heat and electricity production.⁸⁴ The program also supports cross-cutting activities to support market uptake.⁸⁵</p>
HE <i>Hydrogen Europe</i> & HER <i>Hydrogen Europe Research</i>	<p>Hydrogen Europe is a European body bringing industry players, large companies and SMEs to develop and commercialise hydrogen and fuel cell technology. This association is made up of 300 companies and 30 associations from European nations including France.⁸⁶</p> <p>Hydrogen Europe Research (HER) is the research counterpart of Hydrogen Europe and is made up of 103 universities and RTOs (Research & Technology Organisations) from 25 countries (not limited to European member states), that are active within the European hydrogen and fuel cell sector.⁸⁷ The HER is a partner in the FCH JU.</p>

⁸⁰ Gas For Climate (2020) European Hydrogen Backbone. https://gasforclimate2050.eu/sdm_downloads/european-hydrogen-backbone/

⁸¹ ECHA (n.d.) List of the European Clean Hydrogen Alliance Members
<https://ec.europa.eu/docsroom/documents/42749/attachments/1/translations/en/renditions/native>

⁸² European Commission (2021) European Clean Hydrogen Alliance. Internal Market, Industry, Entrepreneurship and SMEs.
https://ec.europa.eu/growth/industry/policy/european-clean-hydrogen-alliance_en

⁸³ European Commission (2021) Roundtables of the European Clean Hydrogen Alliance. Internal Market, Industry, Entrepreneurship and SMEs.
https://ec.europa.eu/growth/industry/policy/european-clean-hydrogen-alliance/roundtables_en

⁸⁴ FCH JU (2020) Mission & Objectives <https://www.fch.europa.eu/page/mission-objectives>

⁸⁵ FCH JU (2021) Programme & Impact. <https://www.fch.europa.eu/page/programme-impact>

⁸⁶ Hydrogen Europe (2021) About Us. <https://hydrogeneurope.eu/about-us/>; Hydrogen Europe (2021) Hydrogen Europe: Industry
<https://www.hydrogeneurope.eu/about-us/115-2/>

⁸⁷ Hydrogen Europe (2021) Hydrogen Europe Research <https://www.hydrogeneurope.eu/about-us/research/>

1.3.3 Funding mechanisms

Overview of France's hydrogen RD&D public budget allocations

France provides funding for hydrogen RD&D through key government bodies and public investment banks. A summary of key public funding mechanisms are outlined in Table 7.

Table 7: Public funding for hydrogen RD&D

Provider/funding mechanism	Details	International eligibility to participate
Ministry of Economy, Finance and Recovery Public funding (stimulus package)	Hydrogen Specific Funding As part of France's hydrogen strategy, the government plans to invest EUR 7 billion to support the development of decarbonised and renewable hydrogen by 2030. ⁸⁸ In addition to this the French government has launched a EUR 100 billion stimulus plan for COVID-19 recovery until 2022. The primary objectives of the stimulus package are to support the decarbonisation of industry, developing hydrogen mobility, and developing France's research capacity. ⁸⁹ EUR 30 billion has been earmarked for 'ecology and energy transition' projects. This includes EUR 2 billion for renewable hydrogen, and EUR 8.5 billion for low-carbon transport. ⁹⁰	No data
ANR Public funding (direct support)	Hydrogen specific funding The ANR is administering the PIA programme (Investments for the Future programme) to finance projects which include hydrogen-related projects. ⁹¹ More details PIA projects and their respective budgets in <i>Section 1.4</i> . Based on France's hydrogen strategy, the ANR launched a call for expressions of interest for "Hydrogen Applications" in November 2021 under the Priority Research Program and Equipment (PEPR). The 'PEPR – Decarbonised Hydrogen' provides EUR 65 million to support research for new hydrogen technologies. ⁹² See <i>Section 1.4</i> for project details.	Yes, the ANR develops partnerships with other countries to facilitate co-funding research projects. ⁹³

⁸⁸ France refers to renewable hydrogen and decarbonised hydrogen as hydrogen that has been produced from renewables, or from decarbonised electricity (including nuclear electricity). Thresholds for each form of production are currently under discussion. See CMS (2021) Hydrogen Law and Regulation in France. <https://cms.law/en/int/expert-guides/cms-expert-guide-to-hydrogen/france>; Watson Farley & Williams (2021) The French Hydrogen Strategy <https://www.wfw.com/articles/the-french-hydrogen-strategy/>

⁸⁹ Watson Farley & Williams (2021) The French Hydrogen Strategy <https://www.wfw.com/articles/the-french-hydrogen-strategy/>

⁹⁰ Watson Farley & Williams (2021) The French Hydrogen Strategy <https://www.wfw.com/articles/the-french-hydrogen-strategy/>

⁹¹ Watson Farley & Williams (2021) The French Hydrogen Strategy <https://www.wfw.com/articles/the-french-hydrogen-strategy/>; ANR (n.d.) Investments for the Future. <https://anr.fr/en/investments-for-the-future/investments-for-the-future/>

⁹² Watson Farley & Williams (2021) The French Hydrogen Strategy <https://www.wfw.com/articles/the-french-hydrogen-strategy/>

⁹³ ANR (2021) Transnational collaborations. <https://anr.fr/en/anrs-role-in-research/europe-and-international/transnational-collaborations/>

Provider/funding mechanism	Details	International eligibility to participate
ADEME Public funding (direct support)	<p>Hydrogen specific funding</p> <p>The ADEME also provides support to the PIA programme (Investments for the Future programme), discussed above. The ADEME launched two calls for proposals in October 2020; “Hydrogen Territorial Ecosystems” and “Technological bricks and hydrogen demonstrators” (See <i>Section 1.4</i> for project details and budget).⁹⁴</p> <p>Between 2019 and 2020, the ADEME provided EUR 80 million to support 21 hydrogen mobility projects under the ‘Hydrogen Mobility Ecosystems’ funding call.⁹⁵ In 2021, EUR 135 million was provided to renewable hydrogen production and distribution projects under the ‘Hydrogen Territorial Ecosystems’ funding program.⁹⁶</p> <p>The ADEME provides funding for support to industry and research labs primarily for technologies at higher technology readiness levels.⁹⁷</p> <p>The ADEME funds approximately 50 PhD programmes including, but not limited to, hydrogen. This is primarily for low technology readiness levels.⁹⁸</p>	<p>Yes, the ADEME can support doctoral students outside the EU.⁹⁹</p> <p>The ADEME supports French companies developing partnerships and projects internationally.¹⁰⁰</p> <p>The ADEME has developed partnerships in energy with its counterparts worldwide.¹⁰¹</p>
Bpi France Public Investment Bank (under MESRI)	<p>Innovation Funding (includes funding for hydrogen projects)</p> <p>Bpi France finances private companies and is also the innovation agency for entrepreneurs, and operates the “investments for the future” programme on behalf of the ministry.</p>	<p>Potentially.</p> <p>Innovation Development Assistance – Yes, but must partnered with a French SME with less than 2000 people.¹⁰⁴</p> <p>DeepTech Development Assistance – No. Must be a registered entity in France</p>

⁹⁴ Watson Farley & Williams (2021) The French Hydrogen Strategy <https://www.wfw.com/articles/the-french-hydrogen-strategy/>

⁹⁵ French Government (2020) National strategy for the development of decarbonised and renewable hydrogen in France (Provisional Draft English Version) <https://www.bdi.fr/wp-content/uploads/2020/03/PressKitProvisionalDraft-National-strategy-for-the-development-of-decarbonised-and-renewable-hydrogen-in-France.pdf>; FuelCellsWorks (2019) France: 11 Hydrogen Mobility Projects Selected for Public Funding. <https://fuelcellworks.com/news/france-11-hydrogen-mobility-projects-selected-for-public-funding/>; FuelCellWorks (2020) France: ADEME Supports 10 New Hydrogen Mobility Projects FuelCellsWorks (2019) France: 11 Hydrogen Mobility Projects Selected for Public Funding. <https://fuelcellworks.com/news/france-11-hydrogen-mobility-projects-selected-for-public-funding/>

⁹⁶ WFW (2021) The French Hydrogen Strategy [https://www.wfw.com/articles/the-french-hydrogen-strategy/#:~:text=The%20first%20call%20for%20proposals,or%20stationary\)%20on%20the%20other](https://www.wfw.com/articles/the-french-hydrogen-strategy/#:~:text=The%20first%20call%20for%20proposals,or%20stationary)%20on%20the%20other); Consultation with in-country stakeholders.

⁹⁷ Consultation with in-country stakeholders.

⁹⁸ Consultation with in-country stakeholders.

⁹⁹ IRN-FACES (2021) Funding Opportunities <https://faces-irn.cnrs.fr/funding-opportunities/>

¹⁰⁰ ADEME (2021) How ADEME intervenes at the international level. https://www.ademe.fr/sites/default/files/assets/documents/2017-11-2-ademe-plaquette_actions_climat_2017-en_17150_final.pdf

¹⁰¹ ADEME (2021) ADEME Worldwide <https://www.ademe.fr/en/ademe-worldwide>

¹⁰⁴ Bpi France (n.d.) Aid for the development of innovation. <https://www.bpifrance.fr/catalogue-offres/soutien-a-linnovation/aide-pour-le-developpement-de-linnovation>

Provider/funding mechanism	Details	International eligibility to participate
	<p>Bpi funds roughly EUR 1.3 billion of innovation soft loans to roughly 6,000 private companies every year.¹⁰² This includes supporting R&D and supporting capital investments for innovative companies. This is suitable for companies of any size, focused on feasibility study stage.</p> <p>Bpi supports building technology partnerships with international SMEs by funding collaborations between French and international companies (to be co-funded with Bpi's country counterpart funding agency).¹⁰³ These solutions are tailored for SMEs with near-market technologies (within 3 years of development):</p> <ul style="list-style-type: none"> • The "Innovation Development Assistance" (a repayable loan) capped at EUR 3 million • The "DeepTech Development Assistance" (a repayable loan) capped at EUR 2 million • The Eurostars grant programme, capped at EUR 3 million. 	<p>with less than 2000 people.¹⁰⁵</p> <p>Eurostars Grant Program – No. Partnership must be between two Eurostars member countries.¹⁰⁶</p>
<p>Banque des Territoires (Bank of Territories)</p> <p>Public Investment Bank</p>	<p>Green Project Funding (includes funding for hydrogen projects)</p> <p>The bank has jointly launched a Climate Plan with Bpi France worth roughly EUR 40 billion from 2020-2024 to fund green transition projects.¹⁰⁷ The bank provides financing for the development of commercial hydrogen vehicle fleets and refuelling stations,¹⁰⁸ as well as hydrogen production from renewables.¹⁰⁹</p>	No data

¹⁰² Bpi France (2021) Bank for entrepreneurs <https://www.bpifrance.com/bank-for-entrepreneurs>

¹⁰³ Bpi France (2021) International Tech partnerships <https://www.bpifrance.com/bank-for-entrepreneurs/for-non-french-companies/international-tech-partnerships>

¹⁰⁵ Bpi France (n.d.) DeepTech development assistance. <https://www.bpifrance.fr/catalogue-offres/soutien-a-linnovation/aide-au-developpement-deeptech>

¹⁰⁶ Bpi France (n.d.) Eurostars. <https://www.bpifrance.fr/catalogue-offres/soutien-a-linnovation/eurostars>

¹⁰⁷ Caisse des Dépôts (2020) Banque des Territoires and Bpifrance deploy a Climate Plan worth nearly €40bn <https://www.caissedesdepots.fr/en/news/banque-des-territoires-and-bpifrance-eu40bn-climate-plan>

¹⁰⁸ Banque des Territoires (2021) Investments in Hydrogen Mobility <https://www.banquedesterritoires.fr/investissement-pour-la-mobilite-hydrogene>

¹⁰⁹ Banque des Territoires (2021) Investments in Green Hydrogen Production <https://www.banquedesterritoires.fr/investissements-dans-la-production-dhydrogene-vert>

Funding for international RD&D

France has a number of research programmes dedicated to international collaboration. These are summarised in Table 8.

Table 8: International funding for hydrogen RD&D

Provider	Funding mechanism	International eligibility to participate
CNRS	<p>The CNRS provides a suite of international collaboration programs.</p> <p>International Emerging Actions (IEA): focused on exploring new subjects for future partnerships and collaborations. Funding is between EUR 10,000 - 14,000 per project.¹¹⁰</p> <p>International Research Networks (IRN): focused on establishing international researcher networks in particular subject matter. Financing of the research network is between (EUR50,000 – 75,000).¹¹¹</p> <p>International Research Projects (IRP): focused on collaborative R&D projects with overseas research institutes. Funding is between EUR 50,000 - 75,000 over the duration of the project.¹¹²</p> <p>International Research Labs (IRL): focused on localised research collaborations taking place within dedicated facilities. Funding is between (EUR 75,000 – 100,000) per year.¹¹³</p> <p>International Research Centres (IRC): These are multi-project strategic partnerships including joint PhD programs between the CNRS and partner universities.¹¹⁴</p>	Yes.

European Union funding for hydrogen RD&D

French hydrogen RD&D activities are also funded through various EU R&D and innovation framework programmes. The EU Hydrogen Strategy has outlined several European funding mechanisms that it plans to use for the development of a hydrogen economy in Europe.

¹¹⁰ CNRS (2020) International Emerging Actions (IEA) https://international.cnrs.fr/wp-content/uploads/2020/06/ENG_IEA_2020.pdf

¹¹¹ CNRS (2020) International Research Networks (IRN) https://international.cnrs.fr/wp-content/uploads/2020/06/ENG_IRN_2020.pdf

¹¹² CNRS (2020) International Research Projects (IRP) https://international.cnrs.fr/wp-content/uploads/2020/06/ENG_IRP_2020.pdf

¹¹³ CNRS (2019) International Research Laboratory (IRL) https://international.cnrs.fr/wp-content/uploads/2019/06/ENG_IRL_2019.pdf

¹¹⁴ Consultation with in-country stakeholders

Table 9: EU funding mechanisms for hydrogen RD&D

EU funding mechanisms	International eligibility to participate
<p>Horizon Europe:¹¹⁵ This EU program is the largest EU research and innovation program, providing EUR 95.5 billion for the period 2021-2027. Hydrogen projects falling under this program are led by the FCH JU. This program is part of a series of EU funding for RD&D; preceding this program was the Horizon 2020 program which ran from 2014-2020, and the FP7 program which ran from 2002-2013. New elements under the Horizon Europe program include the launch of the European Innovation Council, an open science policy, and 5 new mission areas.</p>	<p>Yes, so long as a bilateral science and technology agreement with the EU is maintained.¹¹⁶</p> <p>Collaboration criteria are likely to be stringent and likely subject to co-contribution.</p>
<p>IPCEI (Important Projects of Common European Interest): Funding in the EU is also allocated to projects that fall under the IPCEI. IPCEI is an instrument enabling funding for research and innovation that meet European strategic interests and that have spillover effects across country borders in the EU. These projects also involve private financing by the beneficiaries of the program funding. Funding is allocated for hydrogen with respect to addressing market failures for large cross-border integrated projects for hydrogen and hydrogen-derived fuels that significantly contribute to achieving climate goals.¹¹⁷ Funding for projects is provided jointly by partner country governments as well as private funding.</p>	<p>Applicants must be members of the European Union.¹¹⁸</p>
<p>InvestEU: This is part of Next Generation EU, a new recovery instrument which supplied increased funding in response of the COVID-19 pandemic, and mobilises more than EUR 372 billion in private and public funds. This fund targets commercially viable projects (demonstration or deployment stage) in areas where there are market failures or investment gaps. Allocation of funds falls into four key windows: sustainable infrastructure; research, innovation and digitisation; SMEs; and social investments and skills. Hydrogen activities will be supported within the sustainable infrastructure window, targeting all areas of the hydrogen value chain.¹¹⁹</p>	<p>Yes, it is possible for international financial institutions to become implementing partners.</p>

¹¹⁵ European Commission (n.d.) Horizon Europe. https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en

¹¹⁶ IRN-FACES (2021) Funding Opportunities <https://faces-irn.cnrs.fr/funding-opportunities/>; European Commission Horizon Europe. https://ec.europa.eu/info/research-and-innovation/strategy/strategy-2020-2024/europe-world/international-cooperation_en#Horizon-Europe

¹¹⁷ European Commission (2020) A hydrogen strategy for a climate neutral Europe. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

¹¹⁸ European Commission (2021) Communication from the Commission: Criteria for the analysis of the compatibility with the internal market of State aid to promote the execution of important projects of common European interest. Document 52021XC1230(02). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.C_.2021.528.01.0010.01.ENG&toc=OJ%3AC%3A2021%3A528%3ATOC

¹¹⁹ European Commission (2021) Invest EU. Internal Market, Industry, Entrepreneurship and SMEs. https://ec.europa.eu/growth/industry/hydrogen/funding-guide/investeu_en

EU funding mechanisms	International eligibility to participate
<p>ERDF (European Regional Development Fund), Cohesion Fund & REACT-EU:¹²⁰ This instrument serves to reduce disparities between EU regions by funding capital-intensive environmental and transport investments through grants. 30-37% of funds under the ERDF are prioritised to support a transition to a climate neutral economy. Programs under this initiative will run their course to 2023, however new programs are currently being drafted for the period 2021-2027. For 2021-2027 the ERDF will comprise EUR 226 billion and the Cohesion fund EUR 48 billion.¹²¹ The REACT-EU provides an additional EUR 50.6 billion stimulus package to the program for 2021 and 2022 to support a green recovery. This funding mechanism supports hydrogen activities in the areas of renewable and low-carbon hydrogen,¹²² technology transfer, public-private partnerships, and pilot projects. Hydrogen project eligibility are assessed on a case-by-case basis.</p>	<p>Applicants must be members of the European Union.¹²³</p> <p>For the Cohesion Fund, access is limited to select EU Member States.¹²⁴</p>
<p>Connecting Europe Facility Energy & Connecting Europe Facility Transport: These mechanisms seek to accelerate investments in transport, energy and digital infrastructure networks. This fund is dedicated to demonstration, studies, and co-financing of energy infrastructure with priority given to cross-border linkages and systems.¹²⁵ This facility has been allocated EUR 30 billion for the period of 2021-2027.¹²⁶ This mechanism can be used to fund hydrogen infrastructure, repurposing gas networks, carbon capture projects and hydrogen refuelling stations.¹²⁷</p>	<p>Applicants must be members of the European Union, however, there may be potential for foreign participants as a third party entity via subcontracts.¹²⁸</p>

¹²⁰ European Commission (2021) European Regional Development Fund, Cohesion fund and REACT-EU. Internal Market, Industry, Entrepreneurship and SMEs. https://ec.europa.eu/growth/industry/hydrogen/funding-guide/european-regional-development-cohesion-fund-react-eu_en

¹²¹ European Commission (2021) Commission welcomes the adoption of €373 billion Cohesion policy legislative package 2021-2027. Newsroom. https://ec.europa.eu/regional_policy/en/newsroom/news/2021/06/25-06-2021-commission-welcomes-the-adoption-of-eur373-billion-cohesion-policy-legislative-package-2021-2027

¹²² The European Union Commission defines low-carbon hydrogen as hydrogen produced from fossil fuels with CCS, and electricity-based hydrogen with significantly reduced full life-cycle GHG emissions compared to existing hydrogen production. The term ‘clean hydrogen’ is used for hydrogen produced from renewables (but not fossil fuels with CCS). Fossil fuels with CCS is defined as ‘blue’ hydrogen. Hydrogen from pyrolysis of natural gas with pure carbon as a side product is defined as ‘turquoise’ hydrogen; European Parliament (2021) EU hydrogen policy: Hydrogen as an energy carrier for a climate-neutral economy [https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/689332/EPRS_BRI\(2021\)689332_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/689332/EPRS_BRI(2021)689332_EN.pdf)

¹²³ European Commission (2020) REGULATION (EU) 2020/2221 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL. Document 32020R2221. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32020R2221&qid=1611824380100>; European Commission (n.d.) European Regional Development Fund. https://ec.europa.eu/regional_policy/en/funding/erdf/

¹²⁴ European Commission (n.d.) Cohesion Fund. https://ec.europa.eu/regional_policy/index.cfm/en/funding/cohesion-fund/

¹²⁵ European Commission (2021) Connecting Europe Facility – Energy. Internal Market, Industry, Entrepreneurship and SMEs. https://ec.europa.eu/growth/industry/hydrogen/funding-guide/connecting-europe-facility-energy_en

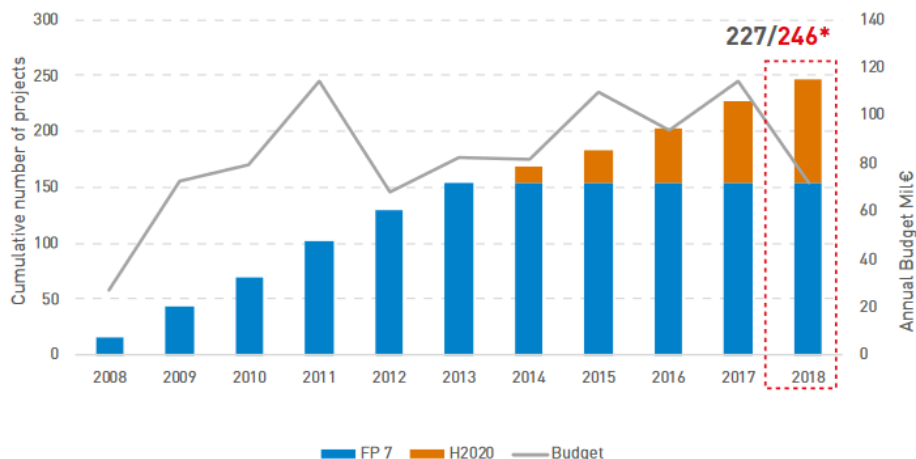
¹²⁶ European Parliament. (2021) €30 billion for infrastructure projects connecting EU regions. News. <https://www.europarl.europa.eu/news/en/press-room/20210701IPR07504/EU30-billion-for-infrastructure-projects-connecting-eu-regions>

¹²⁷ European Commission (2020) A hydrogen strategy for a climate neutral Europe. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

¹²⁸ European Commission (2018) Guidelines on the Eligibility of Costs under the Connecting Europe Facility. https://ec.europa.eu/inea/sites/default/files/wifi4eu/model_grant_agreement/version_for_applicants_and_beneficiaries-final_v01.pdf

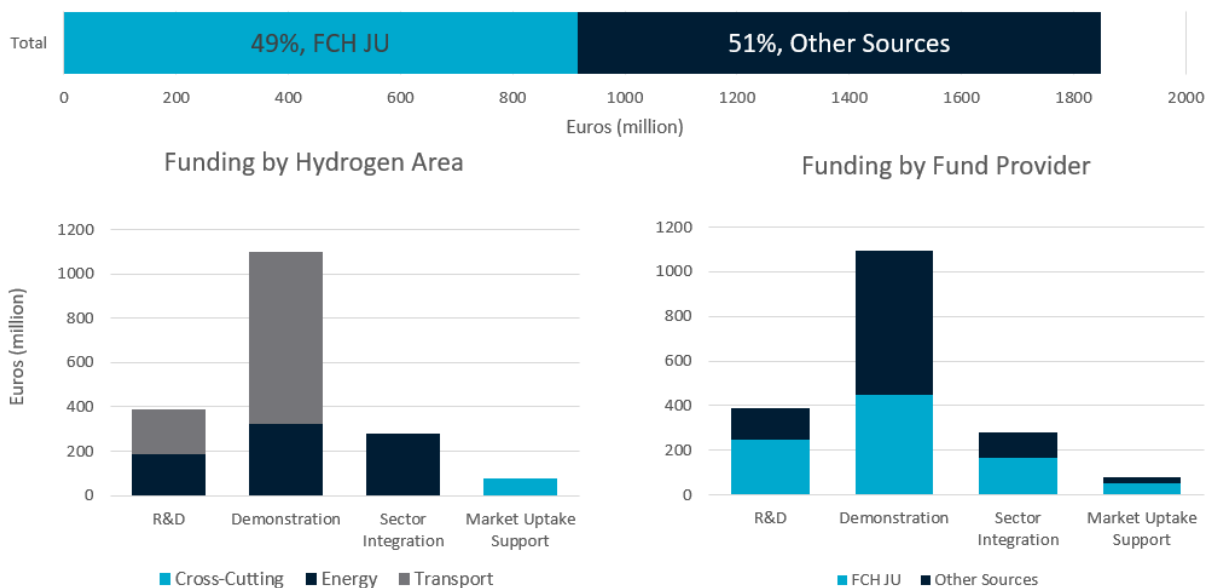
EU funding trends for hydrogen RD&D from 2008 to 2018 are depicted in Figure 4 below. This illustrates the increases in hydrogen RD&D funding each year stemming from two programs, the FP7 and the subsequent Horizon2020. Note that this has now been superseded by a new program, Horizon Europe.

Figure 4: EU trends for Hydrogen RD&D funding (2008-2018)¹²⁹



* Projects included in the Programme Review 2018 covering calls 2008-2017/Projects signed on 1/9/2019.

Figure 5: Hydrogen Funding Breakdown (2008-2018)¹²⁹



EU Hydrogen Funding Compass

The various European Funding mechanisms include grants, subsidies, financing, technical assistance and procurement. The funding available for different RD&D life cycle stages can be found on the EU Hydrogen Public Funding Compass:

https://ec.europa.eu/growth/industry/hydrogen/funding-guide/eu-programmes-funds_en

¹²⁹ Derived from FCH JU (2020) Programme Review Report 2019. European Commission
<https://www.fch.europa.eu/sites/default/files/documents/Programme%20Review%20Report%202019.pdf>

1.3.4 Other key hydrogen policies, regulation and legislation

Outside of governance, strategy and RD&D funding and implementation, other key hydrogen policies in France include:

- The 2019 Energy and Climate Law allows the government to enact ordinances.¹³⁰ In February 2021, the French government published an *Ordinance* on hydrogen, setting out a series of reforms to enable the development of the hydrogen market. These include:¹³¹
 - The introduction hydrogen definitions and categorisations for hydrogen into the French Energy Code such that green or low-carbon hydrogen via electrolysis can be classified as renewable energy and benefit from related support mechanisms.¹³²
 - Provision of guarantees of origin and traceability for renewable or low-carbon hydrogen.¹³³
 - Allowing fuel and natural gas holders to be exempt from obtaining new authorisation to store hydrogen underground for areas covering the mining titles already held, enabling greater uptake of underground hydrogen storage.¹³⁴
 - Licensing requirements for transportation of hydrogen in the gas grid.¹³⁵
 - Calls for tenders for renewable energy projects under the new ordinance including hydrogen will be launched in 2022 by the Ministry of Energy and the regulator.¹³⁶
- The right for hydrogen producers to access the gas grid (beyond experimental projects) was introduced into law in November 2019, however the conditions have not yet been set and are yet to be approved by the Energy Regulation Commission (CRE).¹³⁷
- The mining code was reformed to allow government to issue ordinances with respect to underground storage of hydrogen, and extending underground storage permits for substances such as hydrogen.¹³⁸

Key policies at the EU level:

- In 2019 the FCH JU laid out the *Hydrogen Roadmap Europe*¹³⁹ and in 2020 the European Commission has laid out a European *Hydrogen Strategy*.¹⁴⁰ As a large economic player in the region France is a contributor to the drafting and the achievement of these strategies.
- All member states publish Integrated National Energy and Climate Plans (NEPCs), modelled on Germany's Energy Concept, outlining plans to cut carbon and GHG emissions by 2030 and 2050.

¹³⁰ An ordinance a legal instrument used in France, whereby the Council of Ministers issues an order in areas of the law that are normally reserved for enactment by the Parliament.

¹³¹ Watson Farley & Williams (2021) The French Hydrogen Strategy <https://www.wfw.com/articles/the-french-hydrogen-strategy/>

¹³² Watson Farley & Williams (2021) The French Hydrogen Strategy <https://www.wfw.com/articles/the-french-hydrogen-strategy/>

¹³³ Watson Farley & Williams (2021) The French Hydrogen Strategy <https://www.wfw.com/articles/the-french-hydrogen-strategy/>

¹³⁴ Watson Farley & Williams (2021) The French Hydrogen Strategy <https://www.wfw.com/articles/the-french-hydrogen-strategy/>

¹³⁵ Herbert Smith Hills (2021) Recent developments in the French hydrogen sector: the draft hydrogen ordinance <https://hsfnotes.com/energy/2021/02/12/recent-developments-in-the-french-hydrogen-sector-the-draft-hydrogen-ordinance/>

¹³⁶ Watson Farley & Williams (2021) The French Hydrogen Strategy <https://www.wfw.com/articles/the-french-hydrogen-strategy/>; https://hsfnotes.com/energy/2021/02/12/recent-developments-in-the-french-hydrogen-sector-the-draft-hydrogen-ordinance/#_ftn2

¹³⁷ Watson Farley & Williams (2021) The French Hydrogen Strategy <https://www.wfw.com/articles/the-french-hydrogen-strategy/>

¹³⁸ IPHE (2021) France <https://www.iphe.net/france>

¹³⁹ FCH JU (2019) Hydrogen Roadmap Europe https://www.fch.europa.eu/sites/default/files/Hydrogen%20Roadmap%20Europe_Report.pdf

¹⁴⁰ European Commission (2020) A hydrogen strategy for a climate-neutral Europe https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

- The European Union will develop and introduce a comprehensive terminology and European-wide criteria for the certification of renewable and low-carbon hydrogen (by June 2021).
- The European Union will endeavour to develop a pilot scheme for a 'Carbon Contracts for Difference' programme, to support the production of low-carbon and circular steel, and basic chemicals.
- France signed a manifesto with 22 countries to develop a IPCEI (Important Projects of Common European Interest) in 2021 with a budget of EUR 1.5 billion. This will include R&D for electrolyzers (and electrolyser gigafactories), industrialisation of components, fuel cells and other technologies.

Under the 'Fit for 55' package, 13 new legislations and legislative amendments have been proposed. Whilst not yet in place, below are a number of hydrogen-related adjustments that are being considered under the initiative.¹⁴¹

- Revision of the Energy Tax Directive (ETD) to disincentivise the use of fossil fuels by lowering rates for hydrogen and renewable products while simultaneously setting higher rates for fossil fuels. Other revisions of the ETD include revising tax reductions and exemptions that lower the taxation of non-renewables.
- The revised Renewable Energy Directive (RED II) may see an increased target from 32% to 40% of final consumption energy coming from renewable energy sources. Sectoral targets for renewable energy sources are also being considered in areas of heating/cooling, transport and industry. Some of these targets may be coupled with binding legislation.
- Implementing the 'ReFuelEU Aviation' Initiative that introduces targets for the use of sustainable aviation fuel and synthetic aviation fuels from 2035-2050. This may potentially be achieved via an EU-established blending mandate with all aircraft leaving EU airports required to refuel using green jet fuels. Sub-mandates for e-fuels, such as electrolysis produced hydrogen, is also under consideration.
- Implementing the 'FuelEU Maritime' Initiative which introduces GHG intensity and reduction requirements to increase demand of renewable and low-carbon fuels in the maritime transport sector.
- The Energy Efficiency Directive (EED) currently sets out that the EU meet 32.5% energy efficiency improvements by 2030. The recast proposes a target of 36-39% by 2030.
- Revising Regulation (EU) 2019/631 (the current CO₂ emission standard for cars and vans). Drafts of the regulation update require a 60-90% cut in emissions from new vehicles by 2030 with penalties for not reaching this target.
- The conversion of the Alternative Fuels Infrastructure Directive into a formal regulation. With reference to hydrogen, this would introduce mandatory deployment targets for electric charging stations and hydrogen refuelling infrastructure for Member States. The revision also seeks to tackle the lack of transparency on pricing and facilitate cross-border payments when recharging e-vehicles.
- Additional regulations on the establishment of a framework to facilitate sustainable investments.

¹⁴¹ European Commission (2021) Proposal for a COUNCIL DIRECTIVE: Restructuring the Union framework for the taxation of energy products and electricity, EUR-Lex Access to European Union Law. <https://eur-lex.europa.eu/legal-content/EN-CS/TXT/?from=pl&uri=CELEX%3A52021PC0563>

1.4 France's domestic hydrogen RD&D projects

1.4.1 Major domestic hydrogen RD&D projects

Projects led by government bodies

As part of the French Hydrogen Strategy and the COVID-19 recovery plan, the French government and public research agencies have issued a number of calls for proposals for hydrogen-related RD&D projects (Table 10). In addition to these targeted hydrogen projects there are also a number calls for more general but related projects around decarbonisation of industry.

Table 10: Calls for Project Proposals¹⁴²

Call for Proposal	Description	Budget/ Call Dates
IPCEI project on hydrogen (Important Projects of Common European Interest)	Support R&D and industrialisation of electrolyzers, and deploy hydrogen applications in industry. Examples include electrolyser gigafactories, and the industrialisation of other technology 'bricks' (e.g. fuel cells, tanks, materials). Strategic focus on technologies that integrate into the European hydrogen value chain. Aligns with France's priority to decarbonise industry by establishing a French electrolysis sector.	France to contribute EUR 1.5 billion Discussions began September 2020. Notification of IPCEI project by end of 2021.
Briques technologiques et démonstrateurs (Technological bricks and demonstrators)	Develop and improve technologies in components and systems linked to production and transportation of hydrogen, and its utilisation in mobility and energy sectors. Support for demonstration projects integrating strong value creation at the national and sector levels. Aligns with France's priority to develop heavy mobility using decarbonised hydrogen.	EUR 350 million until 2023 Call dates: October 2020-December 2022
Hubs territoriaux d'hydrogène / Écosystèmes territoriaux hydrogène (Territorial Hydrogen Hubs/Territorial hydrogen ecosystems)	Decarbonize industry (creating an electrolysis sector), develop heavy mobility using carbon free hydrogen, and support research, innovation and skills development. Focus on territorial projects deployed by consortia, in partnerships between communities and manufacturers. The goal is to promote economies of scale at the territorial level.	EUR 275 million until 2023 Call dates: have closed: October 2020 – September 2021

¹⁴² MESRI (2021) Appels à projets <https://www.economie.gouv.fr/plan-de-relance/appels-projets>; MESRI (2020) Presentation of the national strategy for the development of carbon-free hydrogen in France <https://www.economie.gouv.fr/presentation-strategie-nationale-developpement-hydrogene-decarbone-france>

Call for Proposal	Description	Budget/ Call Dates
	Aligns with France's priority to develop heavy mobility using decarbonised hydrogen.	
Programme Prioritaire de Recherche et l'équipement (PEPR) - hydrogène décarboné ¹⁴³ (Priority Research Programme and Equipment – Decarbonised Hydrogen)	Upstream R&D to develop next generation hydrogen technologies, including fuel cells, tanks, materials and electrolyzers. EUR 30 million of the EUR 65 million budget will be allocated towards upskilling trade and research professionals. The PEPR was established under the PIA4 by combining two precursor programs that existed under the former PIA3: the Programme Prioritaire de Recherche (PPR) and the 'Structuring equipment for research program'. The CNRS and CEA are responsible for leading the Hydrogen PEPR, while funding and overarching responsibility for the more general PEPR program falls to the ANR. ¹⁴⁴ Aligns with France's priority to support research, innovation and skills development to promote novel technologies.	EUR 65 million PIA allocation Call dates: 2021-2022
Development of a French sector for sustainable aeronautical fuels	RD&D support for development of sustainable aviation fuels.	EUR 200 million PIA allocation Calls 1 st wave: October 2021 Calls 2 nd wave: April 2022

To stay up to date with calls for project proposals, these are posted on the following online resource:

Ministry of Economy, Finance and Recovery – Calls for Proposals

- <https://www.economie.gouv.fr/plan-de-relance/appels-projets>

In addition to the table above, the PIA programme will also mobilise financial support mechanisms to finance companies requiring support for technology innovation, industrialisation, or to launch their first commercial projects in energy infrastructure.¹⁴⁵

¹⁴³ ANR (2021) PEPR Decarbonized Hydrogen – Call for projects – 2021. <https://anr.fr/fr/detail/call/pepr-hydrogene-decarbhone-appel-a-projets-2021/>

¹⁴⁴ CNRS (2021) Le CNRS, prêt à tirer parti des opportunités du PIA4. <https://www.cnrs.fr/fr/cnrsinfo/le-cnrs-pret-tirer-parti-des-opportunites-du-pia4>; MESRI (2021) Call for programs "Priority programs and equipment for exploratory research". <https://www.enseignementsup-recherche.gouv.fr/fr/appel-programmes-programmes-et-equipements-prioritaires-de-recherche-exploratoires-47130#:~:text=Les%20porteurs%20de%20projets%20devront,seront%20annonc%C3%A9s%20courant%20septembre%202021.>

¹⁴⁵ MESRI (2020) Presentation of the national strategy for the development of carbon-free hydrogen in France <https://www.economie.gouv.fr/presentation-strategie-nationale-developpement-hydrogene-decarbhone-france>

Further, in 2022 there will also be calls for tenders within the support mechanism for production of carbon-free hydrogen.¹⁴⁶

RD&D Projects of note led by France's research sector include:

- FRH2 (Fédération de Recherche Hydrogène) is a 5-year project launched in March 2021, combining 300 researchers from 28 laboratories, and the CEA.¹⁴⁷ Objectives are the hydrogen production from renewables, storage, development of efficient and durable fuel cells.
- HyCube – Hybrid Hydride and Pressure Storage of Hydrogen (project supported by the ANR, and led by the CEA. The project aim is to develop a mature technology solution that combines and hybridizes pressurised transport and hydride storage technology, for application in heavy off-road vehicles.¹⁴⁸
- The CEA and Sylfen developed the rSOC solution and Smart Energy Hub, a hybrid energy storage and co-generation system combining reversible SOFC/SOE and batteries with smart energy management, enabling buildings to use 100% clean and local energy supply.¹⁴⁹
- As at 2020, the ADEME had supported close to 20 major hydrogen demonstration projects spanning hydrogen production, storage and utilisation in the mobility, industrial, and electricity sectors, as part of the PIA programme (Investments for the Future Programme).¹⁵⁰
- The ADEME completed a number of studies on hydrogen, including an LCA study on light hydrogen mobility in partnership with Sphera and Gincko 21, and a study on the decarbonisation potential of hydrogen trains.¹⁵¹
- TETHYS project (Energy transition, territories, hydrogen and society), is a cross-cutting social sciences project launched by the ANR. This project is a collaboration between actors in the territories, and is a societal, multidisciplinary and comparative analysis of the hydrogen energy vector in three French territories.¹⁵² This collaborative research project will be undertaken by the University of Caen, University of Nantes (Polytechnic School), and University of Burgundy.

At the European level, several projects under Horizon 2020 are underway or completed. The subsequent round of projects will be under the new Horizon Europe program, but are yet to be announced. The following resource provides up to date information on specific hydrogen RD&D projects occurring in Europe.

Horizon 2020 / FCH JU (Horizon Europe projects yet to be announced):

- Projects: <https://www.fch.europa.eu/fchju-projects/h2020>
- Calls for Tenders: <https://www.fch.europa.eu/page/procurements>

¹⁴⁶ MESRI (2020) Presentation of the national strategy for the development of carbon-free hydrogen in France <https://www.economie.gouv.fr/presentation-strategie-nationale-developpement-hydrogene-decarbone-france>

¹⁴⁷ Chemistry World (2021) France steps up hydrogen research with €7 billion investment <https://www.chemistryworld.com/news/france-steps-up-hydrogen-research-with-7-billion-investment/4013490.article>; CNRS (2021) H2 The French Research Network on Hydrogen Energy <https://frh2.cnrs.fr/>

¹⁴⁸ ANR (2021) Hybrid Hydride and Pressure Storage of Hydrogen – HyCube <https://anr.fr/Project-ANR-12-EITE-0003>

¹⁴⁹ IPHE (2021) France <https://www.iphe.net/france>; CEA (2019) The Smart Energy Hub developed by the CEA and Sylfen, EARTO innovation of the year <https://www.cea.fr/english/Pages/News/smart-energy-hub-earto2019-sylfen.aspx>

¹⁵⁰ ADEME (2020) 2020 Programme d'investissements d'avenir. Available at <https://bibliothèque.ademe.fr/recherche-et-innovation/4024-bilan-de-la-thematique-hydrogene-et-power-to-gas-du-programme-d-investissements-d-avenir-pia-9791029716324.html>

¹⁵¹ IPHE (2021) France <https://www.iphe.net/france>

¹⁵² ANR (2021) Energy transition, territories, hydrogen and society - TETHYS <https://anr.fr/Project-ANR-17-CE05-0026>

Projects by consortia

Industry collaborations and public-private-research consortia are typically involved in later stage demonstration projects. The following key projects are recently completed or ongoing hydrogen demonstrations:

Sector	Projects
Aviation	<ul style="list-style-type: none"> H2 HUB AIRPORT is a project launched by the Ile-de-France region, Paris Airport (ADP), Airbus, Air France-KLM and Choose Paris Region Agency in February 2021. The group issued a joint call for expressions of interests for exploring hydrogen opportunities at airports, and 11 winning projects have been selected and the first on-site experiments will commence from 2023.¹⁵³ This is intended to make possible the Airbus hydrogen aircraft planned for 2035. The Occitanie region and Toulouse Métropole will create a hydrogen ‘technocampus’ to undertake research and clean hydrogen pilot projects at Francal Airport, Toulouse. This will be done with the Aerospace Valley (Toulouse’s aeronautics cluster) and will involve the research sector and industry players such as the CNRS, the University of Toulouse, ONERA, research labs, Safran and Airbus.¹⁵⁴ Airbus is also developing hydrogen aircraft concepts to be selected by 2025.¹⁵⁵
Gas Networks & Residential	<ul style="list-style-type: none"> Project Jupiter 1000 was the first power-to-gas demonstration in France led by GRTgaz, injecting hydrogen into the natural gas network. This was done in partnership with CNR (wind and solar), RTE (power network), McPhy (electrolysis), Leroux & Lotz (CO₂ capture and storage), Khimod Alcen and the CEA (methanation), and Teréga (grid injection). The GRHYD demonstration led by ENGIE is trialling a number of hydrogen related applications in Dunkirk Urban Community. The project was launched in 2014 at demonstration phase is to end in 2021.¹⁵⁶ <ul style="list-style-type: none"> The injection of hydrogen into natural gas distribution networks of newly constructed neighbourhood, Le Petit Village in Cappelle-la-Grande district. The hydrogen will be produced using wind power. Hythane, a new gas combining hydrogen and natural gas (variable hydrogen content below 20%) for heating and hot water residential applications for 200 homes. Hythane will also be used for natural gas refuelling station (NGV) for buses in Dunkirk Urban Community. This will fuel a fleet of 50 buses, starting with a 6% hydrogen content, to be ramped up to 20% over time.
Mobility	<ul style="list-style-type: none"> The HYPE project is set to demonstrate the first fleet of hydrogen taxis in the Paris region, and has raised 80 million to do so. The project is led by HysetCo and Hype, and the financial backers are RGREEN INVEST, Mirova, RAISE Impact and Eiffel Investment Group.¹⁵⁷

¹⁵³ Watson Farley & Williams (2021) The French Hydrogen Strategy <https://www.wfw.com/articles/the-french-hydrogen-strategy/>; https://www.airfranceklm.com/sites/default/files/pr_-_results_call_for_expressions_of_interest_for_hydrogen_branch_for_airports.pdf

¹⁵⁴ Invest in Toulouse (2020) Aeronautics / Energy-efficient planes: A technocampus dedicated to hydrogen. <https://www.invest-in-toulouse.com/aeronautics-energy-technocampus-dedicated-hydrogen>

¹⁵⁵ Airbus (2021) ZEROe. <https://www.airbus.com/innovation/zero-emission/hydrogen/zeroe.html>

¹⁵⁶ ENGIE (2021) The GRHYD demonstration project. <https://www.engie.com/en/businesses/gas/hydrogen/power-to-gas/the-grhyd-demonstration-project>

¹⁵⁷ Air Liquide (2021) Hydrogen mobility pioneer, Hype, is entering a new phase with HysetCo’s acquisition of major taxi firm Slota <https://energies.airliquide.com/hydrogen-mobility-pioneer-hype-entering-new-phase-hysetcos-acquisition-major-taxi-firm-slota>

Sector	Projects
	<ul style="list-style-type: none"> Safra and Symbio have developed the design of the first French Hydrogen buses. The first of these buses has been deployed, and the companies are set to demonstrate the manufacture and deployment an additional 1,500 hydrogen buses by the end of 2021.¹⁵⁸ The RATP, the Paris public transport company announced a 2-month test of its first hydrogen bus in 2020 as part of an evaluation of several low-carbon technology options. The bus was provided by Solaris and hydrogen supplied by Air Liquide.¹⁵⁹ In 2020, Faurecia, a French automotive equipment manufacturer, launched a global centre of excellence dedicated to hydrogen storage tanks in Bavans, France. At this facility, engineers will develop storage systems for cars, trucks, trains or other vehicles equipped with hydrogen engines. The company plans to manufacture tanks at scale from 2023 and is aiming to equip 200,000 vehicles over the next 10 years.¹⁶⁰ ENGIE and ArianeGroup have signed a cooperation agreement to develop and optimise hydrogen liquefaction technology, and application in heavy-duty and long-distance transport.¹⁶¹

The hydrogen demonstration space in France is very large and constantly evolving. Demonstration projects led by industry and consortia are numerous. A repertoire of these can be found on the following resource:

International Partnership for Hydrogen and Fuel Cells in the Economy: France

- <https://www.iphe.net/france>

1.4.2 Major domestic commercial hydrogen projects

The scope of this report is on research, development and demonstration (RD&D) projects. For information on commercial hydrogen projects, see *HyResource*, an online knowledge sharing platform across the hydrogen community led by CSIRO, Future Fuels CRC, NERA and the Australian Hydrogen Council.

HyResource provides a directory of publicly available databases and information sources on international projects:

- <https://research.csiro.au/hyresource/projects/international/>

Additionally, the French online platform *Vig'Hy* provides an interactive database tracking deployment figures, actors, and commercial hydrogen projects in France:

- <https://vighy.france-hydrogene.org/>

¹⁵⁸ Fuelcellworks (2021) Safra and Symbio are Partnering to Manufacture 1,500 Hydrogen Buses. <https://fuelcellworks.com/news/safra-and-symbio-are-partnering-to-manufacture-1500-hydrogen-buses-2/>

¹⁵⁹ RATP (2020) RATP Group trials a Solaris hydrogen bus with Air Liquide. <https://www.ratp.fr/en/groupe-ratp/newsroom/bus/ratp-group-trials-a-solaris-hydrogen-bus-air-liquide>

¹⁶⁰ Beck C (2021) Faurecia relies on the Pays de Montbéliard for its hydrogen tanks. France Bleu <https://www.francebleu.fr/infos/economie-social/faurecia-mise-sur-le-pays-de-montbeliard-pour-ses-reservoirs-a-hydrogene-1601998875>

¹⁶¹ ArianeGroup (2020) ENGIE and ArianeGroup Team up to develop renewable liquid hydrogen. <https://www.ariane.group/en/news/engie-and-arianegroup-team-up-to-develop-renewable-liquid-hydrogen/>

1.4.3 France's hydrogen RD&D clusters

There are 29 laboratories across France dedicated to hydrogen research. This is a group called the FHR2 (French Research Network on Hydrogen Energy) led by the CNRS and the CEA. This group follows a decentralised approach, rather than a cluster approach, with each laboratory distributed across France and each specialising in a different area. Their locations and primary contacts can be found on the following resource:

FRH2 French Research Network on Hydrogen Energy - Laboratories

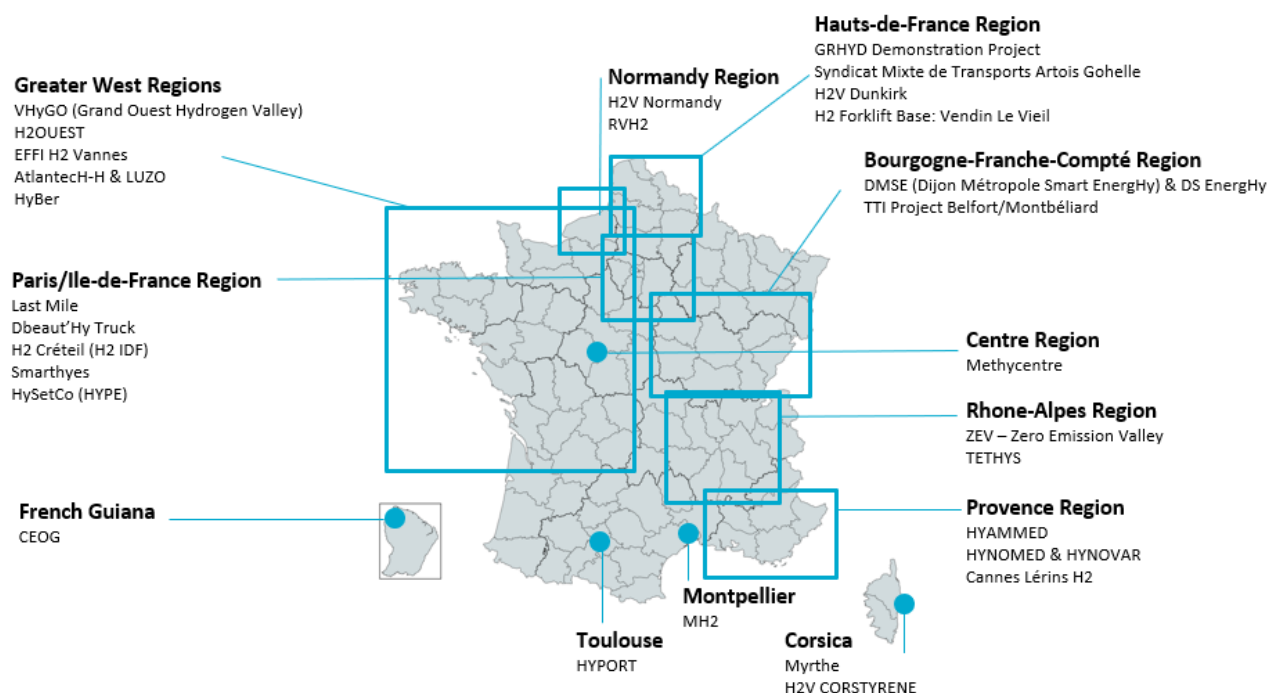
- <https://frh2.cnrs.fr/les-laboratoires/>

France has a large number of hydrogen clusters (also known as hubs, valley or ecosystems) where various industry, research and government bodies partner to build integrated hydrogen production, storage and utilisation projects. Individual cluster projects have now expanded into regional clusters, with a view to eventually achieve an integrated hydrogen economy across France and Europe. New projects are likely to feed into pre-existing hydrogen clusters which are already in place across many parts of France.

Several projects and clusters have emerged from the ADEME's call for "Territorial Hydrogen Ecosystems", and "H2 Mobility Ecosystems". This programme of funding stems from France's hydrogen strategy, which focuses on the development of domestic hydrogen production to integrate into regional clusters, and to reduce France's reliance on hydrogen imports.¹⁶²

¹⁶² Herbert Smith Freehills (2021) Recent developments in the French hydrogen sector: the draft hydrogen ordinance. Viewed at <https://hsfnotes.com/energy/2021/02/12/recent-developments-in-the-french-hydrogen-sector-the-draft-hydrogen-ordinance/>

Figure 6: France's hydrogen clusters¹⁶³



Project (Location)	Value Chain Coverage	Organisations
Greater West Region		
VhyGO ¹⁶⁴ (Brest, Saint-Nazaire, Dieppe)	Electrolysis (renewables) Distribution (Refuelling stations) Mobility applications (buses)	Lhyfe, ADEME (only provides subsidies for projects)
H2Ouest ¹⁶⁵ (La Roche-sur-Yon, Le Mans)	Electrolysis (renewable) Distribution (Refuelling stations)	Lhyfe, Vendée Hydrogen (SyDEV), ACO
EFFIH2 Vannes ¹⁶⁶ (Vannes)	Distribution Station Mobility applications Industrial use	ENGIE Cofely H2 France, Morbihan Energies, Région Bretagne, Banque des Territoires

¹⁶³ Adapted from: Mission Innovation and FCH JU (2021) Hydrogen Valleys. https://www.h2v.eu/hydrogen-valleys?populate=&field_ch_1_q_10_value=FR#cat_118; Vig'hy (2021) Hydrogen Observatory (In French) <https://vighy.france-hydrogene.org/cartographie-des-projets-et-stations/>; FuelCellsWorks (2021) In France, the VHyGO Project (Grand ouest Hydrogen Valley) Will Deploy Green Hydrogen in Three Different Regions. <https://fuelcellsworld.com/news/in-france-the-vhygo-project-grand-ouest-hydrogen-valley-will-deploy-green-hydrogen-in-three-different-regions/>; FuelCellsWorks (2019) 11 Hydrogen Mobility Projects Selected for Public Funding <https://fuelcellsworld.com/news/france-11-hydrogen-mobility-projects-selected-for-public-funding/>; FuelCellsWorks (2020) France: ADEME Supports 10 New Hydrogen Mobility Projects <https://fuelcellsworld.com/news/france-ademe-supports-10-new-hydrogen-mobility-projects/>

¹⁶⁴ Vig'hy (2021) VHyGO Dieppe (In French) <https://vighy.france-hydrogene.org/projets/vhygo-dieppe/>; FuelCellsWorks (2021) In France, the VHyGO Project (Grand Ouest Hydrogen Valley) Will Deploy Green Hydrogen in Three Different Regions <https://fuelcellsworld.com/news/in-france-the-vhygo-project-grand-ouest-hydrogen-valley-will-deploy-green-hydrogen-in-three-different-regions/>

¹⁶⁵ FuelCellsWorks (2021) LHYFE: The H2Ouest Green Hydrogen Project Selected by ADEME. <https://fuelcellsworld.com/news/europe/lhyfe-the-h2ouest-green-hydrogen-project-selected-by-ademe/>

¹⁶⁶ Vig'Hy (2021) EFFI H2 Vannes (In French) <https://vighy.france-hydrogene.org/projets/effi-h2-vannes/>

Project (location)	Value Chain Coverage	Organisations
AtlantechH-H and LUZO ¹⁶⁷ (La Rochelle)	Electrolysis (renewable) Buildings (heat/power) Mobility applications	AtlantechH-H, La Rochelle CDA, EIGSI (La Rochelle School of Engineers)
HyBer ¹⁶⁸ (Indre Department)	Electrolysis (renewable) Mobility applications	Departmental Energy Syndicate of Indre, the Department of Indre, Chateauroux Metropole, Issoudun Community of Communes, BERHY
Paris and Ile-de-France Region		
HySetCo (HYPE) ¹⁶⁹	Distribution (refuelling stations) Mobility applications (taxis)	Air Liquide, IDEX, STEP (Paris Electric Taxi Company), Toyota, Total
Last Mile ¹⁷⁰ and DBeaut'Hy Truck ¹⁷¹ (Paris, Marseille, Lyon, Bordeaux, Europe)	Compact electrolysis (renewable) and distribution stations Vehicle fleets	Last Mile: Ataway, European Union, JCDecaux, Galeries Lafayette and others. DBeaut'HyTruck: E-Néo
H2IDF/H2 Créteil ¹⁷²	Electrolysis (energy from waste) Mobility applications	SIPPEREC, SIPEnR, Suez SA, ADEME (only provides subsidies for projects), Ile-de-France region
Smarthyes ¹⁷³	rSOC (high temperature reversible electrolysis) Buildings (energy storage)	ENGIE, Sylfen, CEA

¹⁶⁷ EIGSI (2021) LUZO project: Zero-Carbon Urban Logistics <https://www.eigsi.fr/engineering-school-france-research/luzo-project-zero-carbon-urban-logistics/?lang=en>

¹⁶⁸ Vig'Hy (2021) HyBer (In French) <https://vighy.france-hydrogene.org/projets/hydrogene-en-berry-hyber-chateauroux/>

¹⁶⁹ Vig'Hy (2021) HySetCo (In French) <https://vighy.france-hydrogene.org/projets/hysetco/>; FuelCellsWorks (2021) Hype, a Pioneer in Hydrogen Mobility, Takes a New step with the Acquisition by HysetCo of Slota, a major Taxi Player; Bloomberg (2021) Toyota-backed Paris Venture Targets 10,000 Hydrogen Taxis by 2024. <https://www.bloomberg.com/news/articles/2021-01-19/toyota-backed-paris-venture-targets-10-000-hydrogen-cars-by-2024>; Electrive (2021) Total joins HysetCo's fuel cell joint venture in Paris. <https://www.electrive.com/2021/05/28/total-joins-hysetcos-fuel-cell-joint-venture-in-paris/>

¹⁷⁰ Akuo Energy SAS (2020) European Hydrogen Week Presentation https://www.fch.europa.eu/sites/default/files/4.%20Gabriel%20Delmer_Last%20Mile.pdf; Vig'hy (2021) Last Mile (In French) <https://vighy.france-hydrogene.org/projets/last-mile-idf/>; FuelCellsWorks (2018) "Last Mile Project": Ataway and its Partners will Deploy 33 hydrogen Refuelling Stations in France <https://fuelcellworks.com/news/last-mile-project-ataway-and-its-partners-will-deploy-33-hydrogen-refuelling/>; H2Bulletin (2021) France's Ataway unveils hydrogen refuelling network plan. <https://www.h2bulletin.com/frances-ataway-unveils-hydrogen-refuelling-network-plan/>; Vig'hy (2021) Last Mile (In French) <https://vighy.france-hydrogene.org/projets/last-mile-idf/>; FuelCellsWorks (2018) "Last Mile Project": Ataway and its Partners will Deploy 33 hydrogen Refuelling Stations in France <https://fuelcellworks.com/news/last-mile-project-ataway-and-its-partners-will-deploy-33-hydrogen-refuelling/>

¹⁷¹ Vig'Hy (2021) DBeaut'Hy Truck

¹⁷² Adeeb (2021) Suez forms JV to produce green hydrogen at French energy-from-waste plant. S&P Global <https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/suez-forms-jv-to-produce-green-hydrogen-at-french-energy-from-waste-plant-62456794>; Suez (2021) Environmental innovation: SUEZ and SIPPEREC join forces to develop 1st green hydrogen production solution on an Energy-from-Waste plant in France: a local and carbon-free energy solution that benefits air quality and climate. <https://www.suez.com/en/news/press-releases/environmental-innovation-suez-and-sipperec-join-forces--to-develop-the-1st-green-hydrogen-production-solution-on-an-energy-from-waste-plant-in-france>

¹⁷³ Hody S and Nechache A (2019) Test and evaluation of a hybrid storage solution for buildings, based on a reversible high-temperature electrolyzer. ECS Transactions. DOI: 10.1149/09101.2485ecst; Vig'Hy (2021) Smarthyes (In French) <https://vighy.france-hydrogene.org/projets/smarthyes/>

Project (location)	Value Chain Coverage	Organisations
Normandy Region		
RVH2 (Rouen Valley H2) ¹⁷⁴	Electrolysis (renewable) Mobility (public transport, utility vehicles, light vehicles)	Valorem-DMSI, Rouen Normandie Métropole
H2V Normandy ¹⁷⁵ (Port-Jérôme)	Electrolysis (renewable) Distribution (gas network) Distribution Station Industry application (manufacturing)	H2V Industry, RTE, General Electric, Caux Seine agglo, HydrogenPro, Bureau Veritas
Hauts-de-France¹⁷⁶		
GRHYD	Distribution (gas network) Distribution (refuelling stations) Electrolysis (renewable)	ENGIE, Communauté Urbaine de Dunkerque
Syndicat Mixte de Transports Artois Gohelle	Vehicle fleet (6 hydrogen buses) Distribution (refuelling station) Electrolysis (renewable)	SAFRAN, ENGIE, McPhy
H2V Dunkirk	Electrolysis (renewable) Industry application (manufacturing)	H2V Industry, HydrogenPro
H2 Forklift Base: Vendin Le Vieil	Distribution (forklift refuelling station) Vehicle fleet (137 hydrogen trucks)	Carrefour, Air Liquide
Bourgogne-Franche-Comté¹⁷⁷		
DMSE (Dijon Métropole Smart EnergyHy) & DS EnergyHy ¹⁷⁸	Electrolysis (energy from waste and renewables) Mobility applications (bus, garbage truck, light vehicles)	Dijon Métropole, Rougeot Energie, Storengy (ENGIE)
Belfort/Montbéliard TTI (Transformation of an Industrial Territory) Project ¹⁷⁹	EUR 16 million programme, to develop industry 4.0, hydrogen economy, and develop workforce skills, across the local industrial sector.	Local agglomerations, universities, innovative SMES and industry groups. Support by the PIA programme

¹⁷⁴ Vig'Hy (2021) RHV2 (In French) <https://vighy.france-hydrogene.org/projets/rvh2/>

¹⁷⁵ Vig'hy (2021) H2V Industry (In French) <https://vighy.france-hydrogene.org/annuaire-des-acteurs/h2v-industry/>; Vig'hy (2021) H2V Normandie (In French) <https://vighy.france-hydrogene.org/projets/h2v-normandie/>

¹⁷⁶ Nord France Invest (2020) The Hydrogen Sector in Hauts-de-France. <https://www.nordfranceinvest.com/hydrogen-in-hauts-de-france/>

¹⁷⁷ AER (2021) Hydrogen Sector (In French) <https://aer-bfc.com/la-bourgogne-franche-comte/filieres/hydrogene/>

¹⁷⁸ McPhy (2020) Development of the hydrogen infrastructure of the metropolis of Dijon <https://mcphy.com/en/achievements/hydrogen-mobility-en/dijon-metropole-smart-energy-dmse/?cn-reloaded=1>

¹⁷⁹ Vig'Hy (2021) Project "Transformation d'un Territoire Industriel" (TTI) Belfort/Montbéliard (In French) <https://vighy.france-hydrogene.org/projets/projet-transformation-dun-territoire-industriel-tti-belfort/>

Project (location)	Value Chain Coverage	Organisations
	25% of jobs in this area are in the energy and transport sectors, primarily at PSA, Alstom, General Electric and Faurecia.	
Auvergne-Rhône-Alpes Region ¹⁸⁰		
ZEV (Zero Emissions Valley) ¹⁸¹	Electrolysis (renewable) Distribution (refuelling stations) Mobility applications	Hympulsion Consortium (Auvergne-Rhône-Alpes, Michelin, ENGIE, Banque des Territoires, and Crédit Agricole)
Provence Region		
HyAMMED ¹⁸² (Fos-sur-Mer)	Existing regional hydrogen infrastructure Mobility (heavy vehicle applications)	Air Liquide, Capenergies.
HYNOMED ¹⁸³ & HYNOMED ¹⁸⁴ (Toulon)	Electrolysis (renewable) Refuelling station Sea Transport (maritime hydrogen shuttle)	HYNOMED Consortium (CCI du Var, ENGIE, Circuit Paul Ricard, Bateliers de la Côte d'Azur, HySeas)
Cannes Lérins H2 & HoverTaxi ¹⁸⁵	Electrolysis (renewable) Sea transport applications Mobility (buses, hydrogen garbage trucks) Aerial application (drone/helicopter taxi) Industrial applications	Hynamics (EDF Group)
Occitanie Region ¹⁸⁶		
MH2 (Montpellier Horizon Hydrogen) ¹⁸⁷	Distribution (refuelling stations) Mobility applications (buses)	Hynamics (EDF Group), Montpellier Métropole, TaM

¹⁸⁰ FuelCellsWorks (2020) France: ADEME Supports 10 New Hydrogen Mobility Projects <https://fuelcellsworld.com/news/france-ademe-supports-10-new-hydrogen-mobility-projects/>; Hyvolution (2018) HyWay: results of 3 years' hydrogen-fuelled fleet deployment in Auvergne-Rhône-Alpes <https://fuelcellsworld.com/news/france-ademe-supports-10-new-hydrogen-mobility-projects/>

¹⁸¹ Vig'Hy (2021) Zero Emission Valley (ZEV) (In French) <https://vighy.france-hydrogene.org/projets/zero-emission-valley-zev/>

¹⁸² Vig'hy (2021) HyAMMED <https://vighy.france-hydrogene.org/projets/hyammed-hydrogene-a-aix-marseille-pour-une-mobilite-ecologique-et-durable/>

¹⁸³ Vig'Hy (2021) HYNOMED <https://vighy.france-hydrogene.org/projets/hynomed/>

¹⁸⁴ ENGIE, CCI Var and Banque des Territoires (2020) A great start for Hynomed SAS, a new player in the Var for the development of green hydrogen. Press Release. https://www.engie-solutions.com/sites/default/files/assets/2020-10/2020.10.21%20CP%20Hynomed_EN.pdf

¹⁸⁵ Vig'Hy (2021) Cannes Lérins H2 <https://vighy.france-hydrogene.org/projets/cannes-lerins-h2/>; TechSnooper (2020) The Cannes Lérins agglomeration is launching its 'Cannes Lérins H2' project for a 'zero carbon' mobility plan <https://techsnooper.io/agglomeration-cannes-lerins-lance-son-projet-cannes-lerins-h2-pour-un-plan-de-mobilite-zero-carbone/>

¹⁸⁶ FuelCellsWorks (2021) France: Occitanie Mobilizes for the Emergence of the Hydrogen Sector <https://fuelcellsworld.com/news/france-occitanie-mobilizes-for-the-emergence-of-the-hydrogen-sector/>

¹⁸⁷ FuelCellsWorks (2021) France: Occitanie Mobilizes for the Emergence of the Hydrogen Sector <https://fuelcellsworld.com/news/france-occitanie-mobilizes-for-the-emergence-of-the-hydrogen-sector/>

1.5 International collaboration and joint RD&D projects

1.5.1 Overview of France's approach to international collaboration

France's strategic documents highlight the importance of international collaboration with respect to decarbonisation and the regulatory space. However, France's documents indicate some selectivity with respect to strategic collaborations in technology RD&D in order to maintain a competitive edge against its strongest competitors:

- **Regulation, qualification and certification:** France's 2018 *Hydrogen Deployment Plan for the Energy Transition* highlights the importance of collaborating on international regulations relating to hydrogen development. In particular, it mentions ensuring that environmental impact is included in international regulations, differentiating between modes of hydrogen production (i.e. green, blue and grey hydrogen). It also mentions France's intent to inform and support the creation of an international qualification and certification centre for high pressure H₂ components for road mobility, aeronautics, maritime, river and railway applications.¹⁹³
- **Selective collaborations on hydrogen technology RD&D:** France's *Multiannual Energy Programming 2019-2028*¹⁹⁴ plan recognises the importance of global mobilisation of players involved in low-carbon research and innovation. France sees the expansion of research and activities in the energy field as crucial for technology development.¹⁹⁵ This document announces plans to work with the International Energy Agency to carry out work in integrating renewable energies into the electricity system. However, France's 2020 *National Strategy for the Development of Carbon-Free Hydrogen in France*¹⁹⁶ indicates some selectivity with respect to hydrogen technology RD&D activities. The strategy states that France seeks to maintain a long-term competitive advantage ahead of its North American and Asian competitors by enhancing collaboration at the European level via supporting researcher collaborations, facilitating industry cooperation and pooling of European finances.¹⁹⁷ The 2018 *Hydrogen Deployment Plan for the Energy Transition* makes particular mention to cooperate with Germany on industrial applications, mobility, and hydrogen production given respective country strengths and existing market ties.¹⁹⁸

France has several general avenues for engaging in international collaboration on RD&D:

- Early career researchers can collaborate via a 'Cotutelle' (an agreement between partner institutions for PhD student exchanges and joint PhDs. Further, PhD candidates may have opportunities to

¹⁹³ MTES (2018) Hydrogen deployment plan for the energy transition. (In French)
https://www.ecologie.gouv.fr/sites/default/files/Plan_deploiement_hydrogene.pdf

¹⁹⁴ MTES (n.d.) Executive Summary: French Strategy for Energy and climate, Multi Annual Energy Plan 2019-2023 and 2024-2028.
<https://www.ecologie.gouv.fr/sites/default/files/PPE-Executive%20summary.pdf>

¹⁹⁵ MTES (2018) French Strategy for Energy and Climate, Multi Annual Energy Plan 2019-2023 and 2024-2028.
https://www.ecologie.gouv.fr/sites/default/files/O-PPE%20English%20Version%20With%20Annex_0.pdf

¹⁹⁶ French Government (2020) National strategy for the development of decarbonised and renewable hydrogen in France. <https://www.bdi.fr/wp-content/uploads/2020/03/PressKitProvisionalDraft-National-strategy-for-the-development-of-decarbonised-and-renewable-hydrogen-in-France.pdf>

¹⁹⁷ French Government (2020) National strategy for the development of decarbonised and renewable hydrogen in France. <https://www.bdi.fr/wp-content/uploads/2020/03/PressKitProvisionalDraft-National-strategy-for-the-development-of-decarbonised-and-renewable-hydrogen-in-France.pdf>

¹⁹⁸ MTES (2018) Hydrogen deployment plan for the energy transition. (In French)
https://www.ecologie.gouv.fr/sites/default/files/Plan_deploiement_hydrogene.pdf

perform research within industry in France under the CIFRE programme.¹⁹⁹ France and Australia have an existing ‘Cotutelle’ arrangement between them.

- The ANR has several RD&D collaboration instruments, including:
 - PRCI (International collaborative research projects) – bilateral partnerships that are generic in nature, and underpinned by agreements between the ANR and counterpart country agencies.²⁰⁰
 - Specific calls for research collaborations through European and international channels, such as Horizon Europe.
 - The ANR has also launched the MRSEI 2021 (Setting up European or International Scientific Networks) allowing French researchers to participate overseas.²⁰¹
- Countries can leverage established bilateral and multilateral RD&D networks they are a part of. For example, as part of the Japan-EU joint research group (the European Interest Group (EIG) CONCERT-Japan), the ANR has issued a joint international research call for “Sustainable Hydrogen Technology as Affordable and Clean Energy”.²⁰²

1.5.2 France’s bilateral hydrogen relationships

France has several formalised relationships with other countries related to hydrogen. Major relationships are detailed in the table below.

Table 11: Bilateral relationships with other countries

Country	Relationship	Description
US	Joint Statement	In May 2021, the French Ministry for Ecological Transition and the US Department of Energy issued a joint statement outlining their intent to enhance cooperation and collaboration between the two countries on RD&D on clean energy technologies (including hydrogen), breakthrough innovations and policies to achieve net-zero emissions by 2050. ²⁰³
Germany	Partnership	Germany and France are the leaders of the EU’s push for hydrogen strategy, both committing several billions of euros in their national strategies and presenting their hydrogen proposals to the European Commission as IPCEI projects. They are currently discussing plans for a Franco-German collaboration in the development of hydrogen technologies. Whether or not nuclear power can be used to produce

¹⁹⁹ Embassy of France in Australia (n.d.) Higher Education in France at a Glance https://au.ambafrance.org/IMG/pdf/french_factsheets_all_161222_final_1__version_mai_2017.pdf?11327/1abe9ea90fa565c9c074786c6326d3b57ef37d25

²⁰⁰ ANR (2021) Generic call for projects - AAPG 2021 https://anr.fr/fr/detail/call/appel-a-projets-generique-2021/?tx_anrprojects_request%5Baction%5D=show&cHash=16674fce7ebadc3329d8e0c319f14624

²⁰¹ ANR (2021) Call of proposals: “Setting up European or/and International Scientific Networks” – MRSEI 2021. <https://anr.fr/en/call-for-proposals-details/call/call-of-proposals-setting-up-european-orand-international-scientific-networks-mrsei-2021/>

²⁰² ANR (2021) Preliminary announcement on the upcoming international joint research call: “Sustainable Hydrogen Technology as Affordable and Clean Energy”. News. https://anr.fr/en/latest-news/read/news/preliminary-announcement-on-the-upcoming-international-joint-research-call-sustainable-hydrogen-te/?tx_news_pi1%5Bcontroller%5D=News&tx_news_pi1%5Baction%5D=detail&cHash=f1e71a0030544934b17bdd5b061b589e

²⁰³ DOE (2021) Joint Statement of the United States and France Energy Ministers on Energy Technology and Policy Resolve <https://www.energy.gov/articles/joint-statement-united-states-and-france-energy-ministers-energy-technology-and-policy>

Country	Relationship	Description
		<p>‘clean’ hydrogen is a matter under negotiation, France being a big proponent of nuclear energy, and Germany set to phase out nuclear.²⁰⁴</p> <p>McPhy has preselected Belfort, France as the location for an electrolyser gigafactory, an IPCEI supported project which will create direct jobs across France, Germany and Italy.²⁰⁵</p>
Australia		<p>Although no formal relationships have been established explicitly between France and Australia, outreach has begun at various levels.</p> <p>In 2020, NERA (National Energy Resources of Australia) provided an overview of Australian and Queensland hydrogen industry opportunities to French businesses as part of MEDEF International (the French Business Confederation representing the private sector overseas) and Trade and Investment Queensland.²⁰⁶</p> <p>In 2021 the FACCI (French-Australian Chamber of Commerce) hosted its first Energy & Resources event in WA dedicated to Hydrogen.²⁰⁷</p> <p>In 2021, Russian Deputy Prime Minister announced that Russia will set up a working group with partners from Germany, France and Australia on hydrogen production.²⁰⁸</p>
India	MoU	In 2021, the Indian and French governments signed a Memorandum of Understanding for joint research and development projects on renewable energy, covering solar, wind, hydrogen and biomass energy. ²⁰⁹
UAE	MoU	In 2021 the Emirates Nuclear Energy Corporation (Enec) signed an MoU with France’s EDF (nuclear electric power generation company) for research and development in nuclear energy and the potential to collaborate in the production of hydrogen from nuclear power. ²¹⁰
Japan	MoC	In 2019, METI (Japan) and France’s Ministry for the Ecological Transition signed a Memorandum of Cooperation to advance cooperation on, among other things, sharing expertise of hydrogen and promoting international cooperation on R&D of hydrogen technologies. ²¹¹

²⁰⁴ Euractiv (2021) Franco-German team-up to drive hydrogen production forward. Euractive. <https://www.euractiv.com/section/energy/news/franco-german-team-up-aims-to-drive-hydrogen-production-forward/>; McPhy

²⁰⁵ McPhy (2021) McPhy Gigafactory. Press Releases <https://mcphy.com/en/press-releases/mcphy-gigafactory/>

²⁰⁶ NERA (2020) Australia and France connect to discuss global trade and investment opportunities through hydrogen. <https://www.nera.org.au/News/Hydrogen-discussions>

²⁰⁷ FACCI (2021) WA | Hydrogen, Fuel of the Future – Australia & France capabilities <https://www.facci.com.au/news/n/news/wa-hybrid-hydrogen-fuel-of-the-future-australia-france-capabilities.html>

²⁰⁸ Reuters (2021) Russia to set up working group on hydrogen with Germany, France and Australia. <https://www.reuters.com/business/energy/russia-set-up-working-group-hydrogen-with-germany-france-australia-2021-06-04/>

²⁰⁹ Gupta U (2021) Cabinet approves India, France MoU on renewable energy. PV Magazine <https://www.pv-magazine-india.com/2021/03/03/cabinet-approves-india-france-mou-on-renewable-energy/>

²¹⁰ Informa (2021) UAE signs nuclear MoU with France’s EDF. Energy & Utilities <https://energy-utilities.com/uae-signs-nuclear-mou-with-france-s-edf-news113052.html>

²¹¹ METI (2019) METI and the Ministry for Ecological and Inclusive Transition of France Exchanged. News Releases https://www.meti.go.jp/english/press/2019/0626_006.html

Country	Relationship	Description
China	MoU	In 2019, Chinese company, Sinopec and French company, Air Liquide signed an MoU for hydrogen fuel development in China. ²¹²

1.5.3 France's joint international RD&D projects

France has a number of international R&D collaboration pathways with small to moderate pools of financing. This bottom-up approach has proven to be successful model for building international research communities in a systematic manner, and for paving the way towards larger collaborations and access to larger project funding, for example, ANR supported projects and European Horizon Europe funding.

- **The CNRS international collaboration toolkit:** Summarised in Figure 7, the CNRS provides a suite of international collaboration programs, spanning from exploration of new projects, through to the establishment of labs and research centres. This toolkit provides a framework by which to enhance collaboration.

Figure 7: CNRS international collaboration toolkit

Programme	International Emerging Actions (IEA)	International Research Networks (IRN)	International Research Projects (IRP)	International Research Laboratories (IRL)	International Research Centres (IRC)
Duration	2 years	5 years	5 years	5 years	n.a.
Type	Research Projects	Multi-team scientific coordination networks	Lab-to-lab collaborative research projects	Joint research laboratories	Multi-project strategic partnerships (joint PhD programmes)
Purpose	Capacity building for future collaborations	Strengthening collaboration	Strengthening collaboration	Inter-institutional contracting between CNRS and research institutes/universities	Framework agreements and bilateral steering
Pathway	Calls for proposals	Endorsements, letters of support	Endorsements, letters of support		
Approach	Bottom-up	Bottom-up	Bottom-up	Strategy Driven	Strategy Driven

France engages in RD&D collaboration extensively across the European Union through the Horizon2020 programme, IPCEI projects, and FCH JU platform see below for links to extensive lists of current and future projects.

FCH JU Projects:

- <https://www.fch.europa.eu/fchju-projects>

Horizon 2020 Hydrogen-related Projects (Horizon Europe Projects yet to be announced):

- <https://www.fch.europa.eu/fchju-projects/h2020>

IPCEI hydrogen projects:

- <https://www.hydrogen4climateaction.eu/projects>

Funding for these EU-level projects are discussed in *Section 1.3.3 Funding Mechanisms*.

²¹² Reuters (2010) Sinopec, French Air Liquide in MOU for hydrogen fuel development in China <https://www.reuters.com/article/china-france-hydrogen-sinopec/sinopec-french-air-liquide-in-mou-for-hydrogen-fuel-development-in-china-idUSL3N27M32G>

Additional international RD&D projects between France and other countries are listed below:

Country	Projects
South Africa	French energy company, ENGIE, has announced a collaboration with South Africa's department of Science and Innovation, National Energy Development Institution, Anglo American and Bambiliy energy, to perform a feasibility study for a 'Hydrogen Valley' on the Bushveld Complex and around Johannesburg, Mogalakwena and Kwazulu Natal. ²¹³
Germany	<p>In 2021, Elogen, a French company leading in PEM electrolysis, was selected by EON to provide electrolyzers to the SmartQuart project which aims to transform the energy sector in three German cities. The partnership includes a provision for the R&D development of a hydrogen purification unit.²¹⁴</p> <p>The MOSAHYC (Moselle Sarre Hydrogen Conversion) demonstration project will be carried out by French and German transmission network operators, GRTgaz and German Creos Deutschland. This project will convert two existing pipelines into a 70km hydrogen pipeline to connect several cities in France, Germany and Luxembourg in the creation of a cross-border 'hydrogen valley'.²¹⁵</p> <p>French company, Alstom successfully demonstrated the world's first two hydrogen trains in 2018 and 2020 in Germany. 41 of these have been sold in Germany and will become a regular service from 2022. Alstom's Coradia iLint hydrogen train has been tested successfully in Netherlands and Austria, and 6 trains will be supplied to Italy, and are currently being proposed for Poland.²¹⁶</p>
Canada	In February 2021, HPQ Silicon Resources INC in Canada is working with French Apollon on the development of efficient silicon powders for hydrogen production. HPQ, Appollon and Pragma have signed an MoU to study the commercial potential of TREKHY®, a small portable hydrogen power generator developed by Pragma and Apollon. ²¹⁷ Earlier in January Pragma and Apollon provided its TREKHY® fuel cell system and Gennao H2 hydrogen reactors to the Japanese civil aid services. ²¹⁸
Denmark	Lhyfe (French clean hydrogen producer and supplier) has partnered with the GreenLab consortium and joined the GreenHyScale project for hydrogen production via electrolysis at the GreenLab Skive site. GreenLab is the world's first green industrial park, and one of the first official and regulatory energy test zones, located in Denmark. The GreenHyScale project demonstrates onshore and offshore green electrolysis using a novel alkaline electrolyser developed by Green Hydrogen Systems. ²¹⁹
Australia	Eneos Japan and France's Neoen have signed an MoU and are planning a pre-feasibility study for a CO2-free hydrogen supply chain in South Australia at the end of 2021. This would transport clean hydrogen produced from renewables in South Australia in the form of MCH to Japan, followed by

²¹³ IPHE (2021) France. <https://www.iphe.net/france>

²¹⁴ Elogen (2021) Elogen is selected to equip the SmartQuart project led by E.ON in Germany. News. <https://elogenh2.com/en/category/news/>

²¹⁵ FuelCellsWorks (2021) GRTgaz SA and Creos Deutschland GmbH Sign Collaboration Agreement on Hydrogen. <https://fuelcellsworks.com/news/grtgaz-sa-and-creos-deutschland-gmbh-sign-collaboration-agreement-on-hydrogen/>

²¹⁶ Alstom (2021) Coradia iLint: Alstom presents the world's first hydrogen passenger train in Poland. Press releases and news. <https://www.alstom.com/press-releases-news/2021/6/coradia-ilint-alstom-presents-worlds-first-hydrogen-passenger-train>

²¹⁷ HPQ-Silicon Resources (2021) HPQ Receives its First Mini-Generator Set Based on Clean Hydrogen Produced by Simply Combining Water and a Powder Bag. <https://www.globenewswire.com/fr/news-release/2021/02/25/2182387/0/en/HPQ-Receives-its-First-Mini-Generator-Set-Based-on-Clean-Hydrogen-Produced-by-Simply-Combining-Water-and-a-Powder-Bag.html>

²¹⁸ IPHE (2021) France. <https://www.iphe.net/france>

²¹⁹ FuelCellsWorks (2021) Lhyfe Announces its First Projects for Hydrogen Production From Renewables in Denmark. <https://fuelcellsworks.com/news/lhyfe-announces-its-first-projects-for-hydrogen-production-from-renewables-in-denmark/>

Country	Projects
	<p>dehydrogenation at ENEOS refineries in Japan for use in industry. Toluene would then be returned to Australia to repeat the process.</p> <p>The French Embassy hosted a workshop in September 2021, the French-Australian Hydrogen workshop “Filling the gaps” between French and Australian stakeholders in the hydrogen sector to discuss research and development, adaptation, implementation, and the respective French and Australian hydrogen ecosystems and practices. The workshop seeks to promote collaborations between French and Australian academia and industry.</p> <p>The Australian Government and ARENA have confirmed funding for ENGIE, a French multinational energy company, for two projects:</p> <ul style="list-style-type: none"> • Hydrogen Park Murray Valley: A project in Wodonga, Victoria, comprising a 10MW electrolyser, is set to produce hydrogen from renewables from mid-2023, and will enable the blending of 10% renewable hydrogen into the gas network.²²⁰ • Yara Pilbara: A renewable hydrogen plant will be built within Yara Pilbara’s existing ammonia plant to deliver green ammonia for use in power generation, shipping, fertiliser and mining explosives.²²¹ <p>France’s Total Eren (French renewable energy company) will partner with Perth’s Province Resources to develop plans for a 8GW hydrogen facility in WA.²²²</p>
Scotland	<p>The European Marine Energy Centre (EMEC) and its partners have produced a report outlining recommendations for the Scottish government on research collaborations between French and Scottish organisations in offshore wind and hydrogen supply chains. This will be done in partnership with French engineering firm INNOSSEA and London-based Renewables Consulting Group (RCG).²²³</p>

1.6 Data insights: France’s hydrogen RD&D activity

The following section provides data-driven insights on France’s RD&D activity in hydrogen technologies. Research publication data, patent data, and commercial project data has been used to understand hydrogen related activity. While limitations exist with such an approach, these data sources do provide an opportunity to consider activity across the innovation spectrum from basic research to demonstration. It also aims to help identify technology areas that have received significant focus in each country and key organisations to support international collaboration efforts.

The data for this section was sourced from CSIRO’s publications team, CSIRO’s IP team, IP Australia, and the IEA’s hydrogen projects database.

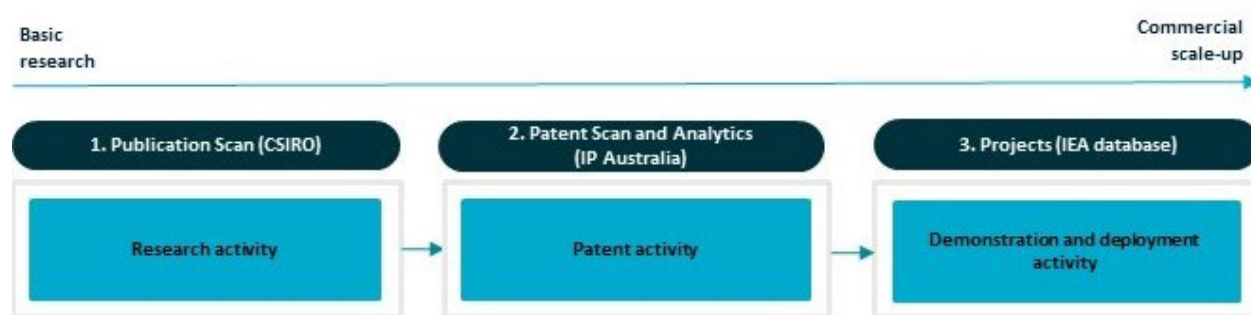
²²⁰ FACCI (2021) Australian Government confirms funding for ENGIE’s hydrogen projects in VIC and WA <https://www.facci.com.au/news/n/news/australian-government-confirms-funding-for-engies-hydrogen-projects-in-vic-and-wa.html>

²²¹ FACCI (2021) Australian Government confirms funding for ENGIE’s hydrogen projects in VIC and WA <https://www.facci.com.au/news/n/news/australian-government-confirms-funding-for-engies-hydrogen-projects-in-vic-and-wa.html>

²²² Mazengarb M (2021) French giant Total Eren signs on to massive 8GW green hydrogen project in WA. Renew Economy <https://reneweconomy.com.au/french-giant-total-eren-signs-on-to-massive-8gw-green-hydrogen-project-in-wa/>

²²³ EMEC (2021) Press Release: EMEC to Explore Franco-Scottish Wind/Hydrogen Collaboration. Media Centre. <http://www.emec.org.uk/press-release-emec-to-explore-franco-scottish-windhydrogen-collaboration/>

Figure 8: Hydrogen innovation activity data



1.6.1 Research publication data

Research publications in hydrogen are an indicator of basic and applied research activity. CSIRO's publications team has conducted a research publication scan to identify French organisations conducting research across the hydrogen value chain. The publications search approach was developed in 2019 to support the report *Hydrogen Research, Development and Demonstration: Priorities and opportunities for Australia*. This search approach was applied in 2021 to provide an updated dataset for this report. The details of the search approach can be found in the *National Hydrogen Research, Development and Demonstration (RD&D): Technical Repository*.²²⁴

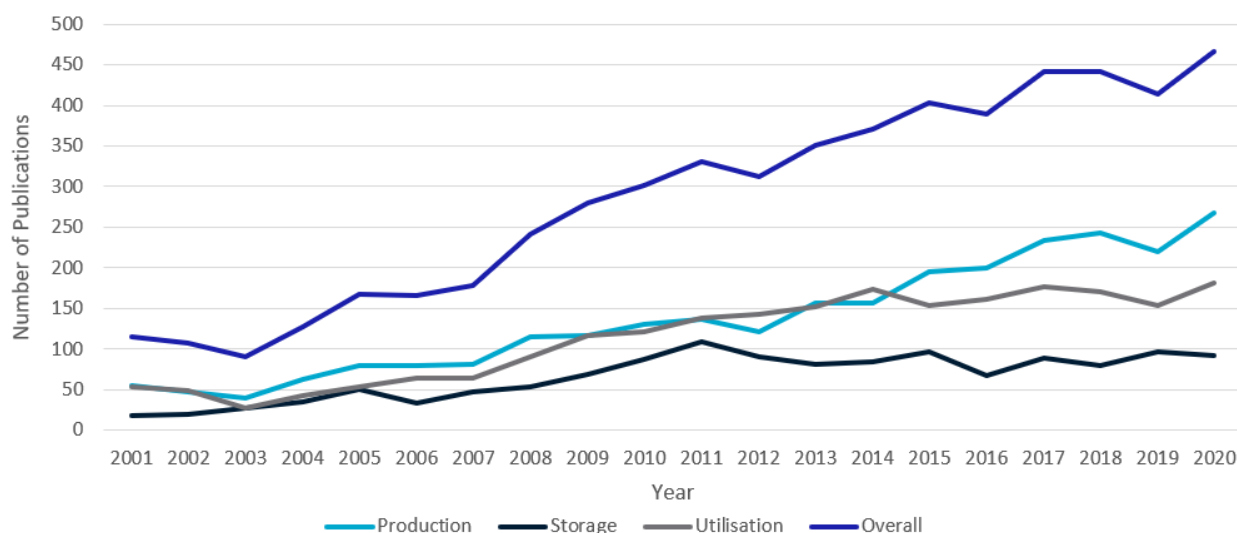
Figure 9 shows French institutions ranked in terms of publication output across hydrogen production, storage and distribution, and utilisation from 2016-2020. Figure 10 shows France's country-wide research publication output trends across the hydrogen value chain.

Figure 9: Top institutions by publication output (2016-2020)

Rank	Production	Storage and Distribution	Utilisation	Overall
	11 th Global Rank	7 th Global Rank	8 th Global Rank	8 th Global Rank
1 st	Centre National de la Recherche Scientifique (CNRS)	Centre National de la Recherche Scientifique (CNRS)	Centre National de la Recherche Scientifique (CNRS)	Centre National de la Recherche Scientifique (CNRS)
2 nd	Universite Paris Saclay	Universite Grenoble Alpes (UGA)	Universite Grenoble Alpes (UGA)	Universite Grenoble Alpes (UGA)
3 rd	CEA	Universite Paris-Est-Creteil-Val-de-Marne (UPEC)	Universite Bourgogne Franche-Comte (ComUE)	CEA
4 th	Sorbonne Universite	Universite de Montpellier	Universite de Montpellier	Universite Paris Saclay
5 th	Universite Grenoble Alpes (UGA)	Universite Paris Saclay	Universite de Technologie de Belfort-Montbéliard (UTBM)	Universite de Montpellier

²²⁴ CSIRO (2019) National Hydrogen Research, Development and Demonstration (RD&D): Technical Repository. Available at <https://www.csiro.au/en/work-with-us/services/consultancy-strategic-advice-services/csiro-futures/futures-reports/hydrogen-research>

Figure 10: France's hydrogen-related research publication output (2001-2020)



1.6.2 Patent data

Patent activity in hydrogen is an indicator of applied R&D and innovation occurring across the value chain. This section draws on two different patent analytics approaches. CSIRO developed a search approach in 2019 to support the *Hydrogen Research, Development and Demonstration: Priorities and opportunities for Australia* report. CSIRO applied this approach to provide a patent landscape across the hydrogen value chain for each country. The details of the search approach and any limitations can be found in the *National Hydrogen Research, Development and Demonstration (RD&D): Technical Repository*.²²⁵ The second approach, performed by IP Australia, builds on the hydrogen technology taxonomy developed in CSIRO's 2019 report to provide information on specific hydrogen technologies that sit within production, storage and utilisation. The full data visualisations, details of the search approach and any limitations can be found at *Patent analytics of hydrogen technologies: an interactive visualisation*.²²⁶

It should be noted that analysis of patent data is not necessarily representative of patent impact. As such, this data should be viewed holistically with the other data presented in this section, particularly project deployment.

Patent landscape of hydrogen value chain

Performed by the CSIRO, this patent landscape analyses patent family²²⁷ filings across the hydrogen value chain. Figure 11 outlines patent filings over time across the areas of hydrogen production, storage/distribution and utilisation. Figure 12 shows the jurisdictions in which French patent applicants are filing patents, outside of France. This provides an indication of which global markets, or manufacturing/commercialisation destinations are of interest to French patent applicants or inventors.

²²⁵ CSIRO (2019) National Hydrogen Research, Development and Demonstration (RD&D): Technical Repository. Available at <https://www.csiro.au/en/work-with-us/services/consultancy-strategic-advice-services/csiro-futures/futures-reports/hydrogen-research>

²²⁶ IP Australia (2021) Patent Analytics on Hydrogen Technology, Australian Government. Available at <https://www.ipaustralia.gov.au/tools-resources/publications-reports/patent-analytics-hydrogen-technology>

²²⁷ Applications with the same priority, but filed in different jurisdictions, are known as patent families. Patent families enable us to analyse inventive activity regardless of the number of countries in which protection is sought. Patent families are used in analytics to represent a single invention.

Note that patent databases have a delay of roughly 18 months, therefore 2020 and 2021 have been omitted from the graphs below. Some patent filings may also be counted twice as the categories of production, storage and utilisation may not be mutually exclusive in all instances and some could relate to multiple areas of the hydrogen value chain.

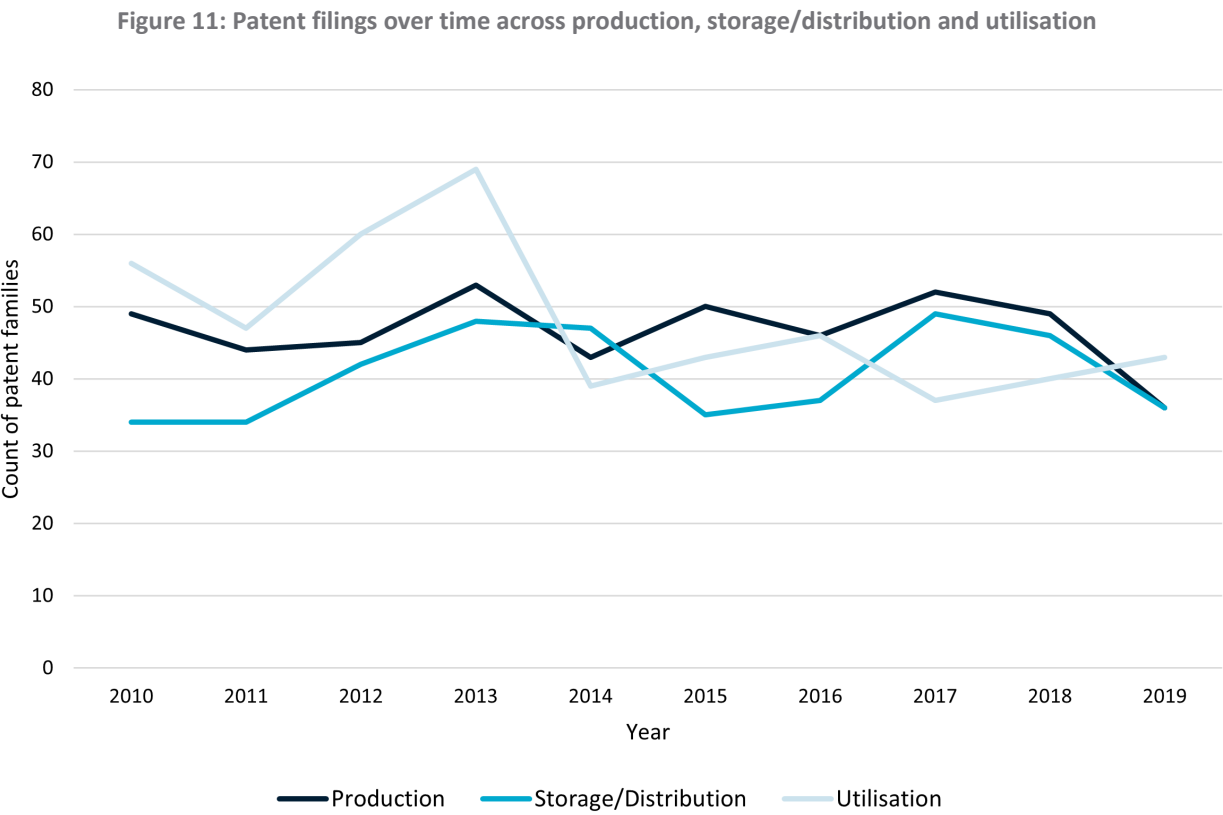
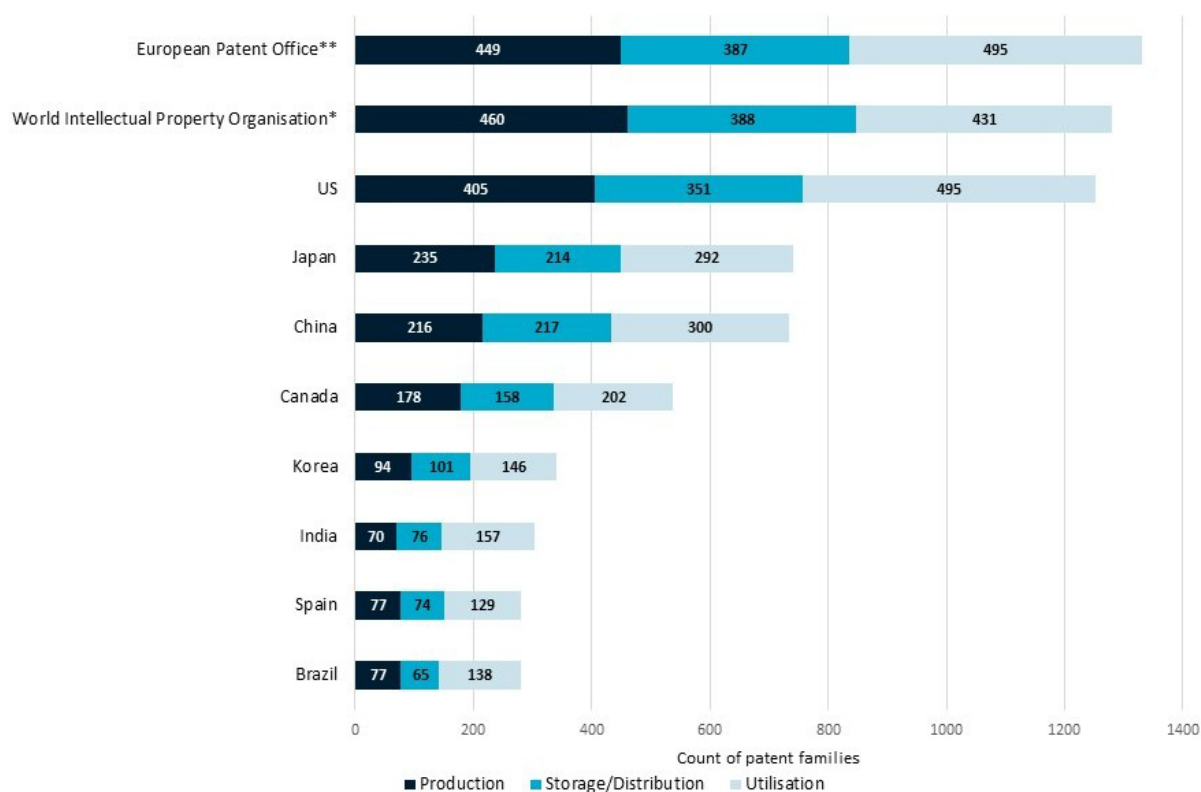


Figure 12: Location of patents filings by French patent applicants



* The World Intellectual Property Organisation (WIPO) is an international organisation that promotes the protection of intellectual property and supervises administrative cooperation amongst the intellectual unions regarding protection of intellectual property. Patents filed in the WIPO enable applicants to obtain protection for their inventions in up to 153 of the parties to the Patent Cooperation Treaty.

** The European Patent Office enables investors, researchers and companies to obtain protection for their inventions in up to 44 countries, including all 27 EU member states.

Patent analytics of specific hydrogen technologies

Data extracted from IP Australia's interactive visualisation provides an in-depth analysis of specific hydrogen technology developments. Figure 13 shows the number of patent families filed since 2010 for specific technology areas by French applicants.

Table 12 shows the number of patent families filed by French applicants since 2010 by sub-technology area, expressed as a percentage of total global patent family filings. Table 12 also shows the top organisations in France filing patents in each technology area. It should be noted that the majority of fuel cell technologies are categorised under the 'electricity generation' category.

Figure 13: France's patent family output by sub-technology area (2010-2020)

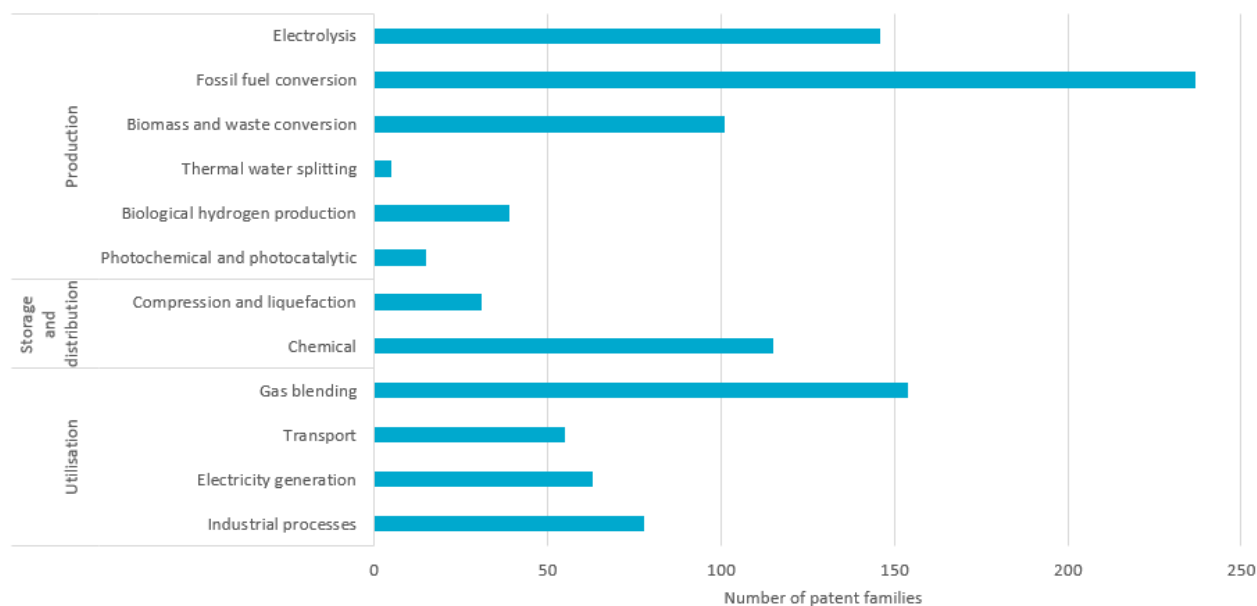


Table 12: France's IP output (number of patent families filed by French applicants) by sub-technology area from 2010-2020

Technology area		IP output (% of global)	Leading companies	Leading non-profits and universities
Production	Electrolysis	1.8%	Electricité De France, Air Liquide, Areva, ENGIE, Airbus Defence & Space	Commissariat A L'Energie Atomique Et Aux Energies Alternatives, Ifp Energies Nouvelles, CNRS, INSERM
	Fossil fuel conversion	3.8%	Air Liquide, Total Raffinage, Technip France, IFP Energies Nouvelles	IFP Energies Nouvelles, Commissariat A L'Energie Atomique Et Aux Energies Alternatives, CNRS, Université Des Sciences Et Technologies De Lille, Université Pierre Et Marie Curie
	Biomass and waste conversion	3.4%	Air Liquide, Total Raffinage, IFP Energies Nouvelles	IFP Energies Nouvelles, Commissariat A L'Energie Atomique Et Aux Energies Alternatives, CNRS, Ecole Polytechnique
	Biological	1.6%	Total, Air Liquide, Roquette Frères, L'Oréal	CNRS, INSERM, IFP Energies Nouvelles, INRA, Institut De Recherche Pour Le Développement (IRD)
	Photochemical and photocatalytic	0.8%	Société De Technologie Michelin, Electricité De France, Michelin	CNRS, Université De Montpellier, Université Louis Pasteur, Université Joseph Fourier
	Thermal water splitting	0.7%	STMicroelectronics, Air Liquide	IFP Energies Nouvelles

Technology area		IP output (% of global)	Leading companies	Leading non-profits and universities
Storage and distribution	Compression and liquefaction	4.3%	Air Liquide, Zodiac Aerotechnics, Areva Stockage D'énergie	CEA
	Chemical storage	4.6%	Air Liquide, McPhy Energy, L'Oréal, Coldway	CEA, CNRS, IFP Energies Nouvelles, Université Joseph Fourier, Université De Versailles Saint-Quentin-En-Yvelines
Utilisation	Gas blending	10.8%	Air Liquide, Technip France, Arkema, EREIE	CEA, IFPEN, Université Grenoble Alpes, Conservatoire National Des Arts Et Metiers
	Transport	2.2%	Peugeot Citroën, Airbus, Michelin	CEA, IFPEN, Université De Poitiers, CNRS, Conservatoire National Des Arts Et Métiers
	Electricity generation	1.5%	Société Nationale D'étude Et De Construction De Moteurs D'aviation (SNECMA), Total, Safran Power Units, Michelin, Renault	CEA, IFPEN, CNRS, National Polytechnical Institute of Toulouse (INPT), Ecole Nationale Supérieure des Techniques Industrielles Et Des Mines
	Industrial processes	1.8%	Air Liquide	IFPEN, CEA, CNRS, Université Des Sciences Et Technologies De Lille, Université De Lille

IP Australia patent analytics on hydrogen technology

IP Australia has developed an interactive visualisation tool to provide hydrogen insights to researchers, academics, business and policy sectors. For more hydrogen IP statistics including key destination markets, origin profiles, applicant profiles, collaborations and specific patent searches, refer to IP Australia's Hydrogen Patent Landscape tool:

- <https://www.ipaustralia.gov.au/tools-resources/publications-reports/patent-analytics-hydrogen-technology>

1.6.3 Project data

Data from the IEA Hydrogen Projects Database (as at October 2021)²²⁸ provides insight on clean hydrogen technology value chains deployed at pilot and commercial scale across France. Note that the following limitations should be taken into account:

- The database does not indicate whether the technologies used are indigenous or purchased from an overseas provider. While many countries often deploy their own technologies at scale, many countries purchase technologies from overseas to deploy locally. As such the database indicates deployment activity, but not necessarily the ability to translate indigenous R&D into commercial scale-up.
- This dataset counts only low-carbon hydrogen projects and their associated value chains. As such hydrogen production projects from gas, coal and oil without CCS are not included. Similarly, utilisation projects not related to a clean hydrogen project source are not included.
- The dataset reflects only projects occurring domestically, and therefore does not count projects undertaken by French companies outside of France. As such, the table may understate France's activity, particularly its contribution to international supply chain development. This data should therefore be considered holistically with the rest of this report.
- Any limitations stated in the data collection methodology, definitions and assumptions should be taken into account (see IEA Hydrogen Projects Database for details).

For the purposes of this report, the dataset has been filtered to include only projects from 2010 through to projects expected to be operational by 2030 as this timespan best reflect current activities. Projects without a specified date have been excluded from the table below. Further, only projects that are at feasibility study stage, final investment decision, demonstration, and operational are included. Projects at the 'concept' stage are not included. It should be noted that the majority of projects listed span production, storage and multiple end-uses, and as such can be counted in more than one technology category.

Table 13: France's domestic clean hydrogen project data

Technology	Sub-technology		Domestic project count	% of global
Production	Electrolysis	PEM	7	3.8
		Alkaline	9	7.8
		SOE	3	11.1
		Other or unspecified	14	5.7
	Fossil fuel conversion	Coal gasification with CCS	-	-
		Natural gas with CCS	1	2.8
		Oil with CCS	-	-
		Methane pyrolysis	-	-


²²⁸ IEA (2021) Hydrogen Projects Database. Available at <https://www.iea.org/data-and-statistics/data-product/hydrogen-projects-database>

Technology	Sub-technology		Domestic project count	% of global
	Biomass and waste conversion		1	6.7
	Photochemical and photocatalytic		-	-
	Biological production		-	-
	Thermal water splitting		-	-
Storage and distribution	Compression and liquefaction		28	5.5
	Chemical carriers	Ammonia	-	-
		Methane	3	5.8
		Methanol	-	-
		Synfuels	-	-
Utilisation	Gas blending		9	6.7
	Transport		23	9.7
	Electricity generation		4	3.0
	Industrial processes	Refining	-	-
		Ammonia	-	-
		Methane	-	-
		Iron and steel	-	-
		Biofuels	-	-
		Synfuel	1	4.3
		Other industry	5	3.7

IEA Hydrogen Projects Database

The latest version of the IEA Hydrogen Projects Database can be found at:

- <https://www.iea.org/data-and-statistics/data-product/hydrogen-projects-database>



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