Technology Collaboration Programme
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ANNUAL REPORT

2025

FUEL CELLS AND ELECTROLYZERS COLLABORATION PROGRAMME

The Technology Collaboration Programme on Fuel Cells and Electrolyzers (FCE TCP), is a programme of Research, Development and Demonstration on Fuel Cell and Electrolyzer technologies organized under the auspices of the International Energy Agency (IEA). The TCP is functionally and legally autonomous. Views, findings, and publications of the FCE TCP do not necessarily represent the views or policies of the IEA Secretariat or its individual member countries.

This Annual Report was prepared by the National Members, Task Managers and the Secretariat of the Executive Committee, who also acted as editor.

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Chair's welcome

As Chair of the Fuel Cells and Electrolyzers Technology Collaboration Programme (FCE TCP), organized under the auspices of the International Energy Agency (IEA), I am delighted to welcome you to our Annual Report for 2025.

This past year has represented an important transition for our Programme. While building on the long-standing legacy of the Technology Collaboration Programme on Advanced Fuel Cells, the evolution towards the Fuel Cells and Electrolyzers Technology Collaboration Programme reflects the broader scope and strategic relevance of electrochemical conversion technologies in today's energy landscape. Fuel cells and electrolyzers are increasingly recognized as complementary pillars of clean energy systems, enabling renewable hydrogen production, efficient energy conversion, sector coupling, industrial decarbonization, and resilient energy supply.

Throughout 2025, global interest in hydrogen technologies has remained strong, even within a complex context marked by geopolitical uncertainty, cost pressures, infrastructure challenges and slower-than-expected market uptake in some sectors. At the same time, these challenges have made international collaboration even more important. Research, innovation, demonstration and knowledge sharing continue to be essential to reduce costs, improve performance and durability, support scale-up, and accelerate the market readiness of fuel cell and electrolyzer systems.

During the year, we have seen continued progress across a wide range of applications. Fuel cell technologies are advancing in stationary power, premium power, transport, heavy-duty mobility, maritime applications and clean heat and power solutions. Electrolyzer technologies are gaining increasing attention as a key enabler for renewable hydrogen production, energy storage and industrial decarbonization. High-temperature electrolysis, system integration, modelling, safety, performance benchmarking and technology validation remain central topics for the international R&D community.

Within the FCE TCP, our Tasks and collaborative activities have continued to provide a valuable platform for experts from member countries, research institutions, industry and policymakers. Our work supports the exchange of non-proprietary information, the identification of technology gaps, the development of shared knowledge, and the creation of international networks able to accompany the evolution of these technologies from research to deployment.

In 2025, we further strengthened our activities on fuel cells, electrolyzers, system analysis, modelling, stationary and transport applications, and emerging areas such as maritime applications and integrated hydrogen systems. These activities confirm the capacity of the FCE TCP to adapt to changing technological and policy priorities, while maintaining a strong scientific and collaborative foundation.

The achievements described in this Annual Report are the result of the dedication, expertise and commitment of all participants involved in the Programme. I would like to sincerely thank the Task Managers, national representatives, sponsors, researchers, industry experts, policymakers and the Secretariat for their continuous contribution.

Their work is essential to ensure that the FCE TCP remains a relevant and trusted international platform for cooperation on fuel cells and electrolyzers.

Looking ahead, our mission is to continue fostering international collaboration, supporting research and innovation, promoting technology validation, and contributing to the broader understanding and deployment of electrochemical conversion technologies. The energy transition requires not only ambitious targets, but also reliable technologies, robust data, shared expertise and strong cooperation across countries and sectors.

We invite companies, research institutions, public authorities and other stakeholders from IEA members and non-member countries to join our activities and contribute to this global effort.

For more information, please visit our website at www.ieafuelcell.com or contact us directly at secretariat@ieafuelcell.com.

Together, through shared vision, scientific excellence and persistent international cooperation, we will continue to advance fuel cells and electrolyzers and support the realization of a sustainable, secure and low-carbon energy future.

Viviana Cigolotti

Chair, Fuel Cells and Electrolyzers Technology Collaboration Programme (FCE TCP)

Dr. Viviana Cigolotti
Head of Division Technologies and Vectors for Decarbonization: Storage, Hydrogen, Mobility, CCUS, and End Uses - Department of Energy Technologies and Renewable Sources
ENEA - Italian National Agency for New Technologies, Energy and Sustainable Economic Development

Chair of the FCE TCP

Introduction

The Technology Collaboration Programme on Fuel Cells and Electrolyzers aims to contribute to research, development, and demonstration (RD&D) of fuel cell and electrolyzer technologies. FCE TCP is uniquely positioned to provide an overview of the status of fuel cell technology and deployment in its member countries, as well as the opportunities and barriers they face. Our focus is to work together to improve and advance technology. This annual report includes detailed country-specific overviews from FCE TCP member states, along with summaries of the ongoing tasks and activities conducted under the programme.

The International Energy Agency

The IEA is at the heart of the global energy dialogue, providing authoritative analysis, data, policy advice and practical solutions to help countries provide secure and sustainable energy for all.

The IEA is an intergovernmental organization established in 1974 to help coordinate a collective response to major oil supply disruptions. While oil security remains a key aspect of its work, the IEA has evolved and expanded significantly since its inception.

Taking a multi-fuel, multi-technology approach, the IEA advocates policies that enhance the reliability, affordability, and sustainability of energy. It examines the full range of issues, including renewable energy, oil, gas and coal supply and demand, energy efficiency, clean energy technologies, electricity systems and markets, access to energy, demand management, and more.

Since 2015, the IEA has opened its doors to major emerging countries to expand their global impact, and deepen cooperation in energy security, data and statistics, energy policy analysis, and the growing use of clean energy technologies.

The Technology Collaboration Programme

The Technology Collaboration Programme (TCP) is a multilateral mechanism established by the International Energy Agency (IEA) with the belief that the future of energy security and sustainability begins with global cooperation. The programme is made up of thousands of experts from government, academia, and industry in 55 countries dedicated to advancing collaborative research and application of specific energy technologies.

Currently, 38 individual Technology Collaborations are working across multiple technology or sector categories: energy efficiency end-use technologies (buildings, transportation, industry, and electricity), renewable energy and hydrogen, fossil energy, fusion energy, and cross-cutting issues. These Technology Collaborations are a vital, member-driven part of the IEA family, but they are functionally and legally autonomous from the IEA Secretariat. The breadth of analytical expertise in the Technology Collaboration Programmes is a unique asset in the global transition to a cleaner energy future.

The FCE TCP aims to advance knowledge through a coordinated exchange of information on international research and technology development, and to conduct systems analysis. The programme focuses primarily on electrolysis, molten carbonate fuel cells (MCFCs), solid oxide fuel cells (SOFCs), and their applications in stationary power generation, portable power, and transportation. An important aspect of the programme is the exchange of information through task-focused meetings, workshops, and reports.

Executive Committee Report

Activities

In 2025, two Executive Committee (ExCo) meetings were held:

MEETINGS	DATE AND PLACE
72nd ExCo	April 29-30, 2025, in Storrs, USA
73rd ExCo	November 04-05, 2025, in Paris, France

The 72nd ExCo meeting took place in April 2025 in Storrs, USA, hosted by the University of Connecticut. Key discussions included comprehensive country and task updates, as well as the successful launch of the new AFC TCP website. During the meeting, the formal closure of Task 36 on System Analysis was decided, and the committee approved a new subtask under Task 34 focusing on the Sustainability Assessment of Fuel Cell Electric Vehicles. Initial preparations were also established for a potential new task concerning fuel cell applications in the maritime sector, beginning with a kick-off workshop.

The 73rd ExCo meeting was held in November 2025 in Paris, France, hosted by CEA. A major strategic outcome of this meeting was the decision to initiate a formal name change of the programme to „Fuel Cells and Electrolyzers" TCP, aiming to better reflect the growing relevance of electrolyzer technologies within its scope. The committee also reviewed the Secretariat's strategic work plan for 2026, agreeing on new prolongation activities and a revised membership fee structure to sustain future operations. Additionally, the meeting featured exchanges with several related IEA TCPs—including AMF, EV, and ETSAP—to foster closer cross-programme collaboration and strategic alignment

Membership

In 2025, the FCE TCP encompassed 14 participating countries and three organizational members (sponsors).

There were a few changes in the number of ExCo-Representatives in 2025. The current list of ExCo representatives is presented on the website of the FCE TCP: https://ieafuelcell.com/about/#members.

Financing and Procedures

Within the framework of the FCE TCP Implementing Agreement representatives of member countries join specific tasks to exchange best practices, news on technology advancements and to discuss strategies, policy changes and funding programmes. The only cost-shared activity is the Common Fund, which provides funding for the operations of the Secretariat which are carried out on behalf of the Executive Committee. The funding arrangements were introduced in 2011. A country´s level of GDP determines the membership fee.
Since 2015, two types of membership have been offered:

- Contracting Parties: The national government of a country can join the Technology Collaboration Programme on Advanced Fuel Cells as a Contracting Party.
- Sponsors: Research organizations, industry, and business partners may join the Technology Collaboration Programme on Advanced Fuel Cells as Sponsors.

National Overviews

AUSTRIA

ExCo Representatives

Dr. Günter Simader,
Austrian Energy Agency
Arno Gattinger, BMK

REGULATORY FRAMEWORKS & POLICY LANDSCAPE

Austria maintains its hydrogen strategy commitments with targets: 1 GW electrolysis by 2030, replacing 80% fossil hydrogen in industry, supported by the Federal Hydrogen Promotion Act (WFöG) and Gas Industry Act reforms. International cooperation includes IPCEI projects, SoutH2 Corridor agreements, and SET-Plan participation.

Austria maintains a strong commitment to hydrogen, anchored in its 2022 National Hydrogen Strategy, which defines a pathway toward industrial decarbonization, renewable hydrogen deployment, and international cooperation. The strategy targets 1 GW of electrolysis capacity by 2030 and the substitution of 80% of fossil-based hydrogen in industry by 2030. These targets frame Austria's transition toward climate neutrality by 2040.

In 2025, the federal government reaffirmed hydrogen as a strategic pillar for industrial competitiveness, energy security, and innovation. Legislative actions included strengthening the Federal Hydrogen Promotion Act (WFöG) and modernizing the Gas Industry Act to introduce a dedicated hydrogen market design. These legal frameworks provide clarity for investment, infrastructure planning, certification, and integration with European mechanisms.

The WFöG mobilizes € 820 million until 2026 for renewable hydrogen production, of which €400 million is channeled through the European Hydrogen Bank's 'Auctions-as-a-Service' platform. Awarded projects represent 171 MW of new electrolysis capacity, including OMV's UpHyLarge (140 MW), Energie Steiermark's Hydrogen Hub Bergla, VERBUND's Mellach project, and a biomass-to-methanol project in Hallein. These projects support scaling domestic production and reducing reliance on fossil-derived hydrogen.

Austria strengthened international cooperation via participation in IPCEI Hy2Tech and Hy2Use, boosting contributions to EU-wide hydrogen value chains. National stakeholders such as AVL, Bosch, Plastic Omnium, VERBUND, Borealis, and Christof Industries contribute across mobility technologies, industrial applications, and infrastructure readiness.

Austria is an active member of the SET-Plan's Hydrogen Implementation Working Group, supporting alignment of national and EU funding and the implementation of the Strategic Research and Innovation Agenda (SRIA) for hydrogen. Austria's involvement underscores its commitment to driving large-scale hydrogen valleys, cross-border innovation, and coordinated European deployment.

Support Programmes & Funding

Programme Name	Focus	Budget	Period	Details
WFöG	Production	€ 820 M	2024 - 2026	Hydrogen auctions

EBIN	Mobility	€ 250 M	2022 - 2026	Zero-emission buses
ENIN	Mobility	€ 365 M	2022 - 2026	Commercial vehicles

Hydrogen Status & Key Figures

As of April 2025, Austria hosts 32.2 MW of operational electrolysis capacity according to Hydrogen Partnership Austria (March 2026). This includes several small and medium scale electrolyzers operated by industry and utilities, as well as the 10 MW UpHy electrolyzer at OMV's Schwechat refinery.

Large-scale electrolysis capacity expansion is underway. OMV's major 140 MW electrolyzer in Bruck an der Leitha is planned for operation in 2027, positioning Austria among Europe's leading hydrogen producers. Additional projects by VERBUND and Energie Steiermark contribute to a rapidly growing pipeline, expected to more than triple national renewable hydrogen output within the next years.

Austria's hydrogen import strategy is built around the SoutH2 Corridor, a 3,300 km dedicated hydrogen pipeline connecting North Africa, Italy, Austria, and Germany. The corridor will transport up to 4 million tons of renewable hydrogen annually — covering around 40 % of the EU's REPowerEU target for hydrogen imports. Austria formally joined the initiative through a political declaration in January 2025.

The SoutH$_2$ Corridor and its associated Austrian infrastructure components — the H_2 Backbone WAG + Penta-West and the TAG H_2 Readiness project — were reaffirmed as Projects of Common Interest (PCI) by the European Commission in December 2025. PCI designation provides accelerated permitting procedures, harmonized technical assessments, and access to funding through the Connecting Europe Facility (CEF).

Hydrogen in Austria is primarily used in industrial processes such as refining, chemicals and metallurgy, and demand is expected to rise markedly in the coming years. The National Infrastructure Plan projects hydrogen demand to reach around 5 TWh by 2030 and to increase further toward 2040, driven by decarbonization needs in energy-intensive sectors and a growing requirement for imports.

Austria is strengthening its hydrogen storage and system-integration capabilities across both pilot- and large-scale environments. RAG Austria is advancing underground hydrogen storage concepts that enable long-duration, high-volume testing, while the Hydrogen Test Center at TU Graz provides a controlled environment for system validation and component testing. The facility operates with an electrolysis capacity of up to 2.5 MW, enabling hydrogen production rates of around 50 kg per hour and on-site storage of approximately 190 kg.

Hydrogen Infrastructure Status

Type	Operational	Under Construction & Planned	2030 Target	Notes
Electrolysis	32,25 MW	Ca. 500 MW	1 GW	PEM/AEL mix

Projects & Demonstration Initiatives

Austria's hydrogen project landscape accelerated significantly during 2024–2025, driven by strong governmental support, WFöG funding, and major industrial investment. Notable projects include OMV UpHyLarge (140 MW), regional Hydrogen Hubs, and cross-sector demonstration initiatives.

The OMV UpHyLarge project will supply the Schwechat refinery with up to 23,000 t of renewable hydrogen per year, avoiding around 150,000 t of CO_2 and representing Austria's largest planned hydrogen production facility. In Styria, the Hydrogen Hub Bergla project will provide renewable hydrogen to regional industrial users, including Wolfram Bergbau, supporting a regionally integrated hydrogen ecosystem. In Hallein, VERBUND and AustroCel are developing a 20 MW project that will produce roughly 2,600 t of green hydrogen annually for synthesis with biogenic CO_2 into climate-neutral e-methanol.

HI2 Valley represents Austria's largest multi-regional hydrogen valley, spanning Styria, Upper Austria, and Carinthia. It includes 17 projects, over 10,000 t/year of hydrogen production, 101 MW of electrolyzer capacity, up to € 600 million investment, and the potential to reduce 200.000 t CO_2e by 2030.

Austria's mobility pilots include Vienna's new hydrogen-electric bus fleet, consisting of ten Rampini Hydron minibuses deployed on city-center routes 2A and 3A, each offering a minimum range of 250 km. [hywest.at], [energieins...ut-linz.at]

In Tyrol, the HyWest programme is establishing a regional green hydrogen economy that integrates hydrogen production, storage, distribution and mobility applications. Within this framework, supermarket operator MPREIS operates Austria's first regularly deployed hydrogen truck, which has been in service since early 2023 for regional logistics. [rag-austria.at]

Together, these initiatives demonstrate the operational validation of hydrogen technologies across urban public transport (Vienna) and logistics applications (Tyrol). **Fuel cells:** Funding increased tenfold to € 15.4 million after a low point in 2022.

Hydrogen Valleys

Valley	Location	Sectors	Demand 2030	Status	Investment
HI2 Valley	AT (3 regions)	Industry/Mobility	>10 kt	Advanced	€ 580 M
HyWest	Tyrol	Mobility/Commerce	~ 0,5 kt	Early	€ 9.2 M

Industry Landscape & Commercial Ecosystem

Austria's hydrogen sector features a strong industrial base spanning electrolyzer developers, component manufacturers, and energy producer such as OMV and VERBUND. OMV leads hydrogen production capacity expansion (10 MW + 140 MW), while VERBUND leads renewable hydrogen integration in the industrial sector.

Fuel cell and mobility innovation is driven by AVL, Bosch Austria, and Plastic Omnium, all of which participate in Hy2Tech. Hydrogen-intensive industries such as voestalpine, RHI Magnesita and Borealis engage in hydrogen-based production processes under IPCEI Hy2Use and the HI2 Valley framework.

System integrators such as Gas Connect Austria and TAG GmbH lead hydrogen backbone conversion projects essential for the SoutH2 Corridor. RAG Austria enables strategic underground hydrogen storage, providing seasonal balancing and regional integration for future hydrogen markets.

Company	Technology	Type	Scale	Stage	Application	Notes
OMV	PEM Electrolysis	Producer	10 -140 MW	Operational/ Construction	Industry	Refinery H2
AVL	PEMFC & SOEC	Systems	kW-MW range	R&D/ Commercial	Mobility/ Industry	IPCEI Hy2Tech

Outlook, Challenges & Next Steps

Austria's hydrogen trajectory for 2026 is shaped by continued efforts to expand renewable hydrogen production and consolidate the national hydrogen ecosystem. The WFöG hydrogen auctions, which mobilize € 820 million between 2024 and 2026, remain central to scaling domestic electrolysis capacity and supporting progress toward the national goals of 1 GW by 2030 and the broader objective of climate neutrality by 2040. Austria is also preparing for deeper integration into emerging European hydrogen corridors, including the SouthH_2 Corridor, supported by updates to the Gas Industry Act (GWG), expected by mid-2026. These measures aim to create a clearer market framework and ensure connectivity with cross-border hydrogen infrastructure.

Public R&D funding trends reinforce this strategic direction. In 2024, Austria reached a record level of € 60.4 million in hydrogen RD&D expenditure, with 85% financed by federal ministries, while funding for fuel cell technologies declined to € 4.8 million, reflecting a focused prioritization of renewable hydrogen production and system integration.

Several challenges continue to shape Austria's hydrogen landscape. Renewable hydrogen still requires substantial cost support, and certification and regulatory frameworks aligned with EU requirements are still evolving. Early hydrogen regions face infrastructure limitations, including restricted refueling capacity, storage options, and limited pipeline readiness. Moreover, securing reliable long-term industrial offtake remains essential to enable large-scale private investment and accelerate the commercial deployment of hydrogen technologies.

At the same time, Austria holds strong strategic advantages. Its central location in Europe, substantial renewable energy potential, established industrial base, and active participation in IPCEI projects and hydrogen valley initiatives position the country to advance as a regional hydrogen hub. Continued engagement in cross-border infrastructure projects, such as the SouthH_2 Corridor and future hydrogen backbone connections, will further enhance Austria's long-term competitiveness and energy security within the evolving European hydrogen economy.

CANADA

ExCo Representatives

Amir Hanifi Yazdi, NRCan
Brad Richard, NRCan

Regulatory Frameworks & Policy Landscape

National Hydrogen Strategy & Climate Targets

- The Hydrogen Strategy for Canada was published in December 2020, and the first Hydrogen Strategy Progress Report was released in May 2024. [1][2]
- Canada's hydrogen strategy positions Canada as a producer, user and exporter of low-carbon hydrogen and associated technologies. [1][2]
- Canada's legislated 2030 greenhouse gas target is 40–45% below 2005 levels, and the long-term legislated target is net-zero emissions by 2050. [3][4]
- Hydrogen is positioned as a complement to electrification, particularly for heavy industry, heavy-duty and long-distance transport, clean fuels and exports. [1][2]

Programme	Focus area	Budget / volume	Implementation period	Key details
Clean Hydrogen Investment Tax Credit (CHITC)	Production / clean hydrogen equipment	Refundable tax credit of 15%–40% depending on expected carbon intensity	Eligible property acquired from March 28, 2023, to Dec. 31, 2034	Administered by CRA and NRCan; the rate depends on lifecycle carbon intensity and labor requirements. [5][6] Budget 2025 indicated that methane pyrolysis would become an eligible pathway under the Clean Hydrogen Investment Tax Credit. [7]

Programme	Focus area	Budget / volume	Implementation period	Key details
Clean Fuels Fund	Production / studies / enabling codes and standards	$1.5B[1] originally; retooled and extended to March 31, 2030	2021–2030	Supports new or expanded clean-fuel production capacity, studies, and codes and standards work. [8]
Strategic Innovation Fund / Net Zero Accelerator (example)	Large projects / production / industrial decarbonization	Project-specific	Project-specific	A federal contribution of $300M was announced for the Air Products Alberta hydrogen project. [9]
Canada Infrastructure Bank – Charging and Hydrogen Refueling Infrastructure Initiative (CHRI)	Infrastructure / refueling / corridors	Minimum $500M initiative; HTEC financing announced at $337M	Active	Supports large-scale private-sector charging and hydrogen refueling infrastructure; HTEC financing supports production, liquefaction and refueling infrastructure in British Columbia and Alberta. [10][11][12]
Zero Emission Vehicle Infrastructure Program (ZEVIP)	Infrastructure / public and fleet refueling	NA	Available until 2027	Supports EV charging and hydrogen refueling infrastructure across Canada. [13]
Incentives for Medium- and Heavy-Duty Zero-Emission Vehicles (iMHZEV)	Mobility / demand creation	Up to $200,000 per eligible vehicle	Launched July 2022; current end date March 31, 2026	Apply to eligible medium- and heavy-duty ZEVs, including fuel-cell electric vehicles. [14][15]

Energy Innovation Program – On-road Transportation Decarbonization	RD&D / mobility / enabling infrastructure	Up to $1.5M per R&D project; up to $5M per demonstration project	2023 call; projects begin from 2024	Funds RD&D and demonstration projects for low- and zero-emission on-road MHDVs and related infrastructure solutions, including hydrogen fuel-cell technologies.

Selected Provincial Hydrogen Strategies / Roadmaps (The info here is voluntarily added by Canada)

Jurisdiction	Official strategy / roadmap	Year	Key details
British Columbia	B.C. Hydrogen Strategy	2021	The executive summary identifies 63 actions across short-, medium- and long-term horizons. [16][17]
Alberta	Alberta Hydrogen Roadmap	2021	Provincial roadmap outlining Alberta's approach to hydrogen use and production. [18]
Ontario	Ontario's Low-Carbon Hydrogen Strategy	2022	Ontario identifies eight concrete and immediate actions in support of a low-carbon hydrogen economy. [19][20]
Québec	Québec Green Hydrogen and Bioenergy Strategy	2022	Provincial strategy for the production, distribution and use of green hydrogen and bioenergy. [21]
New Brunswick	New Brunswick Hydrogen Roadmap	2024	Provincial roadmap was released in January 2024 as a five-year plan with 13 actions. [22]
Nova Scotia	Green Hydrogen Action Plan	2023	The Action Plan sets out seven goals and 23 actions for sector development. [23]

Newfoundland and Labrador	Hydrogen Development Action Plan	2024	Provincial action plan focused on green hydrogen development, exports, regulation and innovation. [24]

International Cooperation & Frameworks

- EU memberships / frameworks: NA. Canada is not an EU Member State. The strongest Europe-related linkage in the reviewed sources is the Canada–Germany Hydrogen Alliance and associated bilateral market arrangements. [25][26]
- Twelve international hydrogen-related agreements had been concluded by May 2024, including agreements involving Germany, the Netherlands, the United States, South Korea and Japan. [2]

Hydrogen Status & Key Figures

Energy System Overview

Metric	Value	Unit	Year	Source / note
Total energy supply	12,210	PJ	2023	Energy Fact Book 2025–2026, Section 1. [27]
Renewable share of total energy supply	16.5	%	2023	Energy Fact Book 2025–2026, Section 1. [27]
Hydrogen production / demand proxy	Around 4.0	Mt H2/year	2024–2025 context	Hydrogen production is concentrated on refining, chemicals and steel. [28]
Deployed low-carbon H2 production capacity	3,450	tons H2/year	2024	Hydrogen Strategy for Canada: Progress Report. [2]
Projects announced / under consideration or development	About 80	projects	2024	Hydrogen Strategy for Canada: Progress Report. [2]
Potential investment represented by announced projects	Over 100	CAD billions	2024	Hydrogen Strategy for Canada: Progress Report. [2]
Light-duty fuel-cell electric vehicles in operation	334	vehicles	as of Oct. 1, 2025	Transport Canada ZEV Council Dashboard. [29]
Medium- and heavy-duty fuel-	8	vehicles	as of Oct. 1, 2025	Transport Canada ZEV Council Dashboard. [29]

Metric	Value	Unit	Year	Source / note
cell electric vehicles in operation				

Hydrogen Infrastructure Status

Infrastructure type	Operational	Under construction / deployment	Planned / announced	2030 target	Notes
Low-carbon hydrogen production capacity	3,450 tons H2/year of deployed low-carbon hydrogen production capacity. [2]	Multiple projects were under construction or in deployment in 2024–2025, including HTEC-linked assets and the Air Products Alberta project. [12][30][31]	Approximately 80 low-carbon hydrogen production projects announced or under development. [2]	NA	Public reporting remains project- and tonne-H2-per-year-oriented rather than MW-consolidated.
Hydrogen refueling stations	NA	Commercial and project-specific station deployment continued in 2024–2025, including Ontario's first commercial heavy-duty station and the Air Products Edmonton corridor buildout. [30][32]	HTEC's H2 Gateway includes up to 20 stations in British Columbia and Alberta. [12]	NA	HTEC's official station-status page confirms operating stations in British Columbia. [33]
Storage / liquefaction / distribution	Project-specific compressed, liquid and industrial	HTEC's North Vancouver liquefier (15 t/day) and associated	Further storage, distribution and dispensing are	NA	The current landscape remains project-specific rather

	distribution assets are in operation. [30][31][34]	storage and distribution systems are under buildout. [12][31]	embedded in H2 Gateway, the Air Products Alberta corridor and rail-fueling projects. [12][30][35]		than a nationally integrated merchant storage network.

Key Technologies & R%D Focus Areas

Technology area	Development stage	Key activities / projects	Lead organizations	Funding	Notes
PEM electrolysis	Canada's PEM ecosystem spans stack development and testing, manufacturing/assembly, and multi-megawatt project deployment. AVL Fuel Cell Canada publicly identifies PEM electrolyzer stack development and testing as part of its Burnaby activities, while Accelera by Cummins operates PEM electrolyzer manufacturing/assembly capability in Mississauga	Key activities include: (1) AVL Fuel Cell Canada's PEM electrolyzer stack development, prototyping, and testing services in British Columbia; (2) Air Liquide's 20 MW PEM electrolyzer in Bécancour, Québec, which entered operation in late 2020 / early 2021 and produces over 3,000 tons per year of hydrogen; (3) Atura Power's Niagara Hydrogen Centre in Ontario, a 20 MW PEM project using an electrolyzer manufactured	AVL Fuel Cell Canada; Accelera by Cummins (including its Mississauga/Hydrogenics PEM manufacturing base); Air Liquide; Atura Power; Varennes Carbon Recycling / Enerkem; Hy2gen Canada / Plug Power. [36][37][38][39][40]	Varennes Carbon Recycling received a $277 million Canada Infrastructure Bank loan, and project materials also describe VCR as supported by the Canadian and Québec governments. Air Liquide separately announced a >€140 million (>C$200 million) low-carbon gas platform investment in Bécancour connected to its existing 20 MW PEM electrolyzer. In no specific public funding amount was	Canada's PEM electrolysis activity combines a strong Canadian technology legacy through Hydrogenics/Cummins/Accelera in Mississauga, engineering and stack-development capability at AVL Fuel Cell Canada, and several large projects in Québec and Ontario ranging from 20 MW operating scale to 90 MW under development and 275 MW FEED-stage planning. [36][37][38][39][40]

Technology area	Development stage	Key activities / projects	Lead organizations	Funding	Notes
	and supplies large PEM systems into Canadian projects. [36][37]	in Mississauga and anticipated to reach commercial operation in the second half of 2026; (4) Varennes Carbon Recycling (VCR) in Québec, which selected a 90 MW PEM electrolyzer system from Accelera by Cummins for waste-to-fuels and circular chemicals production, with Enerkem now describing commissioning in 2026; and (5) Hy2gen Canada's Courant project in Baie-Comeau, for which Plug Power announced a 275 MW PEM FEED contract in April 2026. [36][37][38][39][40]		identified for AVL Fuel Cell Canada's PEM development work, Atura's electrolyzer procurement, or Plug Power's FEED work for Courant. [37][38][40][41]	
Alkaline electrolysis	Canada's alkaline electrolysis activity is led primarily by Next Hydrogen	Key activities include: (1) Next Hydrogen's NH-X Series advanced alkaline	Next Hydrogen; Hydrogen Optimized. [42][43]	Next Hydrogen received a $2 million repayable FedDev Ontario	Next Hydrogen positions its technology as a new generation of alkaline electrolysis

Technology area	Development stage	Key activities / projects	Lead organizations	Funding	Notes
	and Hydrogen Optimized, with Next Hydrogen advancing advanced / pressurized alkaline systems designed for renewable load-following and Hydrogen Optimized commercializing its RuggedCell® unipolar alkaline platform for large-scale projects. [42][43]	electrolyzers, including pressurized alkaline systems with integrated gas-liquid separation and dynamic response designed for direct connection to renewables; (2) continued scale-up of Next Hydrogen's commercial product line, including the NH150 0.75 MW module, which the company reported had been operating since August 2025 at a Toronto-area distribution center using fuel-cell-powered forklifts; (3) Next Hydrogen's third-generation alkaline electrolyzer supply for a renewable ammonia production research		investment in August 2024 to increase production of next-generation electrolyzer modules, and earlier public reporting indicated $5.1 million from SDTC to support development of its next-generation electrolysis systems. Hydrogen Optimized received an over $3.5 million repayable FedDev Ontario contribution toward an $11 million manufacturing expansion project in Owen Sound, with additional private investment and support from the Government of Ontario. [43][44]	combining the lower-cost characteristics of alkaline systems with improved dynamic response for renewables integration, while Hydrogen Optimized emphasizes durability, zero stack replacement over project life, and very large-scale industrial modules based on proven unipolar alkaline architecture. [42][43]

Technology area	Development stage	Key activities / projects	Lead organizations	Funding	Notes
		project announced in August 2024; and (4) Hydrogen Optimized's RuggedCell® manufacturing expansion in Owen Sound to support large industrial alkaline electrolyzer deployment. [42][43][44]			
AEM electrolysis	Canada's AEM ecosystem spans component and membrane development, stack/system development, and early deployment. Cipher Neutron is advancing pilot-scale AEM stacks, Ionomr is commercializing AEM membranes/ionomers, DCL is developing electrocatalyst-coated components, dynaCERT is involved	Key activities include: (1) Cipher Neutron's development of AEM electrolyzer stacks and the announced 0.5 MW / two 250 kW stacks for Simon Fraser University's Hydrogen Hub; (2) Ionomr's development of Aemion® / Aemion+® membranes and collaborations with Sunfire and Cipher Neutron/dynaCERT on industrial-scale and 250 kW AEM development; (3) DCL's work	Cipher Neutron; Ionomr Innovations; dynaCERT; DCL International; Carlsun Energy Solutions. [45][46][47][48][49]	Ionomr reported NRC IRAP advisory services and funding for its AEM collaboration with Sunfire, but no amount was disclosed; Carlsun's Port Elgin AEM project received $1,891,400 from Ontario's Hydrogen Innovation Fund, with a reported total project cost of $4,212,800; no specific public funding amount was identified for	Cipher Neutron is the clearest Canadian stack/system developer, Ionomr is a critical membrane/materials enabler, DCL contributes electrode/catalyst component capability, dynaCERT supports commercialization through partnership, and Carlsun provides an early Canadian deployment/integration case. [45][46][47][48][49]

Technology area	Development stage	Key activities / projects	Lead organizations	Funding	Notes
	through co-development /commercialization support, and Carlsun is demonstrating AEM deployment in Ontario. [45][46][47][48][49]	on AEM electrocatalysts, catalyst-coated membranes (CCMs), and catalyst-coated substrates (CCSs); and (4) Carlsun's 500 kW AEM hydrogen production, compression and storage facility in Port Elgin linked to Ontario's first publicly accessible hydrogen fueling station. [45][46][47][48][49]		Cipher Neutron's SFU AEM stack project, DCL's AEM component work, or dynaCERT's AEM collaboration activities. [45][47][48][49]	
SOEC / high-temperature electrolysis	SeeO2 Energy is advancing a solid oxide electrolyzer / reversible solid oxide platform in Alberta, while Canadian Nuclear Laboratories (CNL) and partners are advancing projects using FuelCell Energy's solid oxide electrolysis technology	Key activities include: (1) a pilot in Alberta, supported through the Emissions Reduction Alberta (ERA) Advanced Materials Challenge and aimed at low-carbon hydrogen and syngas production; (2) CNL-led e-fuels projects announced in August 2024, where FuelCell	SeeO2 Energy; Canadian Nuclear Laboratories (CNL); FuelCell Energy; Expander Energy; Nuclear Promise X; St. Marys Cement; World Energy GH2 / Bloom Energy. [50][51]	CNL and partners announced \$4.9 million from NRCan's Clean Fuels Fund (CFF) and Energy Innovation Program (EIP) for two synthetic-fuels projects involving solid oxide electrolysis / HTSE. SeeO2 Energy separately reported support through	In Canada, SOEC/high-temperature electrolysis is best described as an emerging niche focused on integration with industrial heat, e-fuels, and carbon utilization rather than broad commercial deployment. SeeO2 Energy represents the clearest Canadian company directly

Technology area	Development stage	Key activities / projects	Lead organizations	Funding	Notes
	for synthetic fuels. Canada also appears in large project planning through World Energy GH2's Nujio'qonik project in Newfoundland and Labrador, which includes SOEC alongside PEM electrolysis. [50][51]	Energy, Expander Energy, Nuclear Promise X, and St. Marys Cement are using solid oxide electrolysis / high-temperature steam electrolysis (HTSE) to evaluate synthetic diesel and sustainable aviation fuel pathways; and (3) World Energy GH2's Nujio'qonik project, where Bloom Energy SOEC technology is planned to be used in combination with PEM electrolysis for green hydrogen and ammonia production in Newfoundland and Labrador. [50][51]		ERA's Advanced Materials Challenge, funded by Alberta's TIER fund, and public reporting linked that award to approximately $250,000 for development of its solid oxide system. No specific public funding amount was identified for the SOEC portion of the Nujio'qonik project. [50][51]	advancing solid oxide electrolyzer technology, while CNL/FuelCell Energy projects show application of SOEC/HTSE in synthetic fuel pathways. The Nujio'qonik project indicates that Canada is also being used as a development site for larger SOEC-linked export-oriented hydrogen/ammonia concepts. [50][51]
PEM fuel cells (light-duty vehicles)	Commercial niche	Light-duty FCEVs remain niche and are concentrated where	Ballard; HTEC. [33][52]	NA	Transport Canada reports 334 light-duty FCEVs in operation as of

Technology area	Development stage	Key activities / projects	Lead organizations	Funding	Notes
		refueling exists. [29][33]			Oct. 1, 2025. [29]
PEM fuel cells (heavy-duty)	Demonstration / early commercial	Visible projects include HTEC H2 Gateway, the CPKC hydrogen locomotive program, Walmart Canada's hydrogen semi-truck deployment and transit demonstrations. [12][35][53][54][55]	HTEC; Ballard; CPKC; transit agencies; fleet partners. [12][35][52][53][54][55]	Mixed public/private project support	8 heavy-duty mobility units in operation as of Oct. 1, 2025 [29].
Hydrogen storage / distribution / liquefaction	Pilot / early commercial	Compressed gaseous storage, liquefaction and distribution are advancing through HTEC, Air Products and rail-fueling projects. [12][30][34][35]	HTEC; Air Products; CPKC / partners. [12][30][34][35]	Project-specific	Important enabling segment for corridors and clusters.
Codes, standards and test infrastructure	Implementation phase	The Canadian Hydrogen Codes and Standards Roadmap was published in early 2025. [56]	NRCan; Standards Council of Canada; AVL Fuel Cell Canada. [36][56]	NA	Twenty-two codes and standards had been developed by 2024. [57]

Projects & Demonstration Initiatives

Major Demonstration & Commercial Projects (selection, 2024–2025j

Project	Status	Scale / capacity	Primary application	Lead partners	Timeline	Funding	Expected outcomes
HTEC H2 Gateway	Construction / phased deployment	100 fuel-cell electric trucks; up to 20 stations; 3 new production facilities; 15 t/day liquefaction asset	Mobility / infrastructure / production	HTEC; Province of BC; Canada Infrastructure Bank; fleet / OEM partners	2024 onward	Approx. $900M total program value; CIB financing announced at $337M. [12]	Support development of a western Canadian heavy-duty hydrogen ecosystem and help reduce transport emissions. [12]
HTEC North Vancouver by-product hydrogen liquefier	Under construction / federal support announced 2025	15 t/day liquefaction of industrial by-product hydrogen	Production / distribution	HTEC; ISED Strategic Innovation Fund	Announced March 2025	$49M federal investment in support of a $472M project. [31]	Lower-cost liquid hydrogen supply for HTEC's western network. [31]
Air Products Alberta hydrogen complex and corridor stations	Under construction / corridor buildout	Large low-carbon hydrogen production and liquefaction facility plus corridor refueling stations	Production / infrastructure / mobility	Air Products; federal and provincial partners	2022–2025+	$300M federal support announced for the Alberta project; corridor stations announced separately. [9][30]	Contribute to development of the Edmonton–Calgary hydrogen corridor and support industrial and mobility use. [9][30][34]

Project	Status	Scale / capacity	Primary application	Lead partners	Timeline	Funding	Expected outcomes
UBC Smart Hydrogen Energy District (SHED)	Operational research facility launched June 2024	$23M integrated micro-grid with hydrogen fueling capability	R&D / infrastructure / integrated energy systems	UBC; public and private partners	Launched June 2024	$23M. [58]	Demonstrates integrated hydro / solar / hydrogen energy systems and supports research, testing and training. [58]
CPKC Hydrogen Locomotive Program	Operational pilot / demonstration	North America's first hydrogen-powered freight-locomotive program; early Ballard modules totaled 1.2 MW	Rail mobility / decarbonization	CPKC; Ballard; fueling partners	2020 onward	NA	Tests a retrofit pathway for zero-emission freight rail and builds operational knowledge. [35]
Winnipeg Transit transition to zero-emission buses	Initial ZEB deliveries in 2025	16 initial ZEBs in 2025 within a broader 90-bus program; includes fuel-cell battery-electric buses	Transit mobility	City of Winnipeg / Winnipeg Transit; New Flyer; governments	2023–2026	$280.3M through the Investing in Canada Infrastructure Program for the broader program. [53][54]	Cold-climate testing and operational learning for fuel-cell and battery-electric transit. [53][54]
Walmart Canada	Operational	One Nikola	Freight mobility	Walmart Canada;	Announced	NA	First major retailer in

Project	Status	Scale / capacity	Primary application	Lead partners	Timeline	Funding	Expected outcomes
hydrogen fuel-cell semi-truck deployment	demonstration	hydrogen fuel-cell Class 8 tractor in Ontario		Nikola; ITD Industries	June 2024		Canada to introduce a hydrogen fuel-cell electric semi-truck. [55]
Elemental Addressing the Market Gap: A Cost Optimized, High Performance 63.5 Tone Hydrogen Electric Truck	Advanced development and integrated system testing	Prototype-scale system	Zero-emission / electrified heavy-duty vehicle systems	BMS, Bendix	Announced July 2025 [59]	$1.5M [60]	- Validated integrated HEV powertrain system - Progress toward regulatory compliance (CMVSS) - Reduced technical risk for commercialization
Hydra pre-demonstration of H_2 Co-Combustion System for Trucks with Extended Controls and Diesel Displacement	Prototype development and early validation	Pilot-scale retrofit system	Hydrogen-diesel dual-fuel retrofit for heavy-duty trucks	NRC-IRAP, Excel Transportation, Taylor Driving School	Announced November 2025 [61]	$1.35M [62]	- Demonstration of diesel signal interception and control - Development of hydrogen dual-fuel controller - Potential pathway to retrofit decarbonization solution for existing fleets - Reduced emissions from legacy diesel vehicles

Hydrogen Valleys / Regional Clusters

Valley / initiative	Location	Primary focus sectors	Projected H2 demand by 2030	Status	Investment
Edmonton-region hydrogen hub	Edmonton / Alberta Industrial Heartland	Production, heavy-duty mobility, industry, power and corridors	NA	Formed / active ecosystem	NA as a single hub total; multiple project-level investments are active. [2][9][30]
H2 Gateway / BC hydrogen hubs	Burnaby–North Vancouver–Nanaimo–Prince George plus BC/AB corridor	Production, trucking, refueling, distribution	NA	Under construction / phased deployment	Approx. $900M project value. [12]
Southern Ontario hydrogen mobility corridor activity	Greater Toronto Area and related freight corridors	Heavy-duty trucking, refueling, fleet deployment	NA	Early commercial / corridor formation	NA as a single corridor total; station and fleet announcements exist. [32][55]

Industry Landscape & Commercial Ecosystem

Selected Industry Players Verified in Reviewed Public Sources

Company / organization	Technology / product focus	Type	Capacity / scale	Development stage	Applications	Notes
Next Hydrogen	Advanced alkaline water electrolyzers (NH-X Series)	System / electrolyzer manufacturer	NH-X 500 Series: 500 Nm³/h nominal H2 production, 0.2–2.4 MW system range	Pilot to commercial scaling	Industrial and transportation-oriented green hydrogen production	Product page and FedDev Ontario support were both reviewed. [42][44]
AVL Fuel Cell Canada	PEM fuel-cell and electrolyze	Engineering / stack	Company highlights 9 fuel-cell	R&D / pilot / customer	Mobility and industrial	Directly supported by the

Company / organization	Technology / product focus	Type	Capacity / scale	Development stage	Applications	Notes
	r stack development / testing	development	testbeds and stack development / prototyping capability	development	energy applications	company page. [36]
Ballard Power Systems	PEM fuel-cell stacks and modules	Stack / system manufacturer	Company states it has produced over 1 GW of PEM fuel-cell products	Commercial	Bus, truck, rail, marine, stationary	Long-standing Canadian fuel-cell company with an established operating track record. [52]
HTEC	Hydrogen production, liquefaction, refueling and ecosystem integration	Infrastructure developer / owner-operator	Existing BC retail network plus H2 Gateway expansion	Commercial / scale-up	Mobility and hydrogen supply	One example of Canadian hydrogen infrastructure scale-up activity reflected in the reviewed sources. [12][31][33]
Air Products Canada	Large-scale low-carbon hydrogen production, liquefaction and station network	Producer / infrastructure developer	Alberta net-zero hydrogen energy complex plus corridor stations	Under construction / scale-up	Industrial supply, mobility, power	Major private-sector project developer in western Canada. [30][34]

Outlook, Challenges and Next Steps

Selected Areas of Ongoing Activity

- Federal measures currently in place include the Clean Hydrogen ITC, the retooled Clean Fuels Fund, and follow-up work related to the 2025 Codes and Standards Roadmap. [5][8][56]
- Several large-scale projects are expected to continue progressing, including H2 Gateway, Air Products' Alberta buildout, CPKC rail testing, and Winnipeg's next transit-delivery phases. [12][30][35][53][54]
- Canada–Germany hydrogen corridor arrangements remain one example of ongoing international cooperation relevant to export readiness. [25][26]
- The iMHZEV Program is currently scheduled to end on March 31, 2026, unless it is renewed or replaced. [15]

Key Challenges to H2 Deployment

- Project economics, offtake certainty, and investor confidence remain commonly identified challenges. Key areas of focus include production-project economics and investor certainty. [2][63]
- Infrastructure remains geographically concentrated. Public retail hydrogen refueling is concentrated in British Columbia, with project-specific assets elsewhere. [32][33]
- Hydrogen codes, standards and internationally aligned certification frameworks continue to evolve. Additional harmonization, including carbon-intensity metrics, will help improve reporting comparability and support sector growth.[2][56]

Selected Strengths and Areas of Opportunity

- Canada combines multiple hydrogen production pathways, including renewable-electricity-based electrolysis and natural-gas-plus-CCUS pathways. [1][2][28][34]
- Canada retains an established fuel-cell and hydrogen engineering base, including Ballard, AVL Fuel Cell Canada, and UBC-linked research. [36][52][58]
- Visible early-use cases include heavy-duty trucking, rail, transit, industrial feedstock and export-oriented clean-fuel value chains. [1][2][28][35][53][54][55]
- The Canada–Germany corridor is one example of export-oriented cooperation with a major partner market. [25][26]
- Regional hub development in Alberta, British Columbia and Southern Ontario supports localized supply–demand matching. [2][12][30][32]

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REGULATORY FRAMEWORKS & POLICY LANDSCAPE

National Hydrogen Strategy & Climate Targets

- **Strategy Publication Date:** March 2022
- **Primary Objectives:** *The Medium- and Long-Term Plan for the Development of Hydrogen Energy Industry (2021-2035)* emphasizes the importance of hydrogen in achieving carbon neutrality and aims to create a robust hydrogen energy industry that supports the country's energy transformation goals. By 2025, the number of fuel cell vehicles will be about 50,000, and a batch of hydrogen refueling stations will be deployed and constructed. The hydrogen production from renewable energy reaches 100,000 to 200,000 tons per year, becoming an important component of new hydrogen consumption and achieving a reduction of carbon dioxide emissions by 1-2 million tons per year.
- **Key Climate Goals by 2030/2040/2050:** By 2030, a relatively complete hydrogen energy industry technology innovation system, clean energy hydrogen production and supply system will be formed, the industrial layout will be reasonable and orderly, renewable energy hydrogen production will be widely applied, and strong support will be provided for achieving the carbon peak target. By 2035, establish a hydrogen energy industry system and build a diverse hydrogen energy application ecosystem covering transportation, energy storage, industry, and other fields. The proportion of renewable energy hydrogen production in terminal energy consumption has significantly increased, playing an important supporting role in the green transformation and development of energy.
- **Hydrogen's Role in Strategy:** Give full play to hydrogen's supporting role in advancing the goals of carbon peaking and carbon neutrality, further tap its cross-sector application potential, and advance diversified applications tailored to local conditions. It will drive the energy consumption transition of end-use sectors including transportation and industry, facilitate the green development of high-energy-consumption and high-emission industries, and reduce overall greenhouse gas emissions.

International Cooperation & Frameworks

- **Bilateral Agreements:** China-Russia Cross-Border Hydrogen Corridor.
- **International Initiatives:** IPHE participation, G20 involvement.

Hydrogen Status & Key Figures

Key Technologies & R&D Focus Areas

Technology Area	Development Stage	Key Activities/Projects	Lead Organizations	Funding (annual)	Notes
PEM Electrolysis	Commercial	-	-	-	-
Alkaline Electrolysis	Commercial	-	-	-	-
AEM Electrolysis	Pilot	-	-	-	-
SOEC (High-Temp)	Commercial	-	-	-	-
PEMFC (Passenger Vehicles)	Pilot	-	-	-	-
PEMFC (Heavy-Duty)	Commercial	-	-	-	-
SOFC (Stationary)	Commercial	-	-	-	-
H_2 Storage	Commercial	-	-	-	-
Other Focus Areas	[Research/Pilot/Commercial]	-	-	-	-

Project & Demonstration Initiatives

Major Demonstration & Commercial Projects (Selection 2024–2025)

Project Name	Status	Scale & Capacity	Primary Application	Lead Partners	Timeline	Funding	Expected Outcomes
Hainan Demonstration Operation	Operational	50 vehicles	Mobility	Haima Auto	2024-still in operation	N/A	As of October 2025, the total mileage of the 50 deployed vehicles has exceeded 2 million

Project Name	Status	Scale & Capacity	Primary Application	Lead Partners	Timeline	Funding	Expected Outcomes
							kilometers.
Wuhan Demonstration Operation	Operational	30 vehicles (initial deployment)	Mobility	Wuhan Dong Hon Logistics, Dongfeng Auto, Honda Auto	2025-still in operation	N/A	N/A

Hydrogen Valleys & Regional Clusters

Valley/Initiative Name	Location (City/Region)	Primary Focus Sectors	Projected H_2 Demand (kt/year by 2030)	Current Status	Total Investment (€M)
Fuel cell vehicle demonstration city cluster	Hebei City Cluster/ Henan City Cluster/ Guangdong City Cluster/ Beijing-Tianjin-Hebei cluster/ Shanghai City Cluster	Mix	N/A	Operational	N/A

Industry Landscape & Commercial Ecosystem

Key Industry Players % Technology Focus

Company Name	Technology/Product Focus	Type	Capacity/Scale	Development Stage	Applications	Notes
ELECTROLYZER DEVELOPERS						
Shanghai Electric Group	PEM/ALK/ AEM/SOEC	System/Component	N/A	Commercial	Industrial	-

Company Name	Technology/Product Focus	Type	Capacity/Scale	Development Stage	Applications	Notes
FUEL CELL MANUFACTURERS						
SinoHytec	PEMFC/SOFC	Stack/System	N/A	Commercial	Automotive	-
SYSTEM INTEGRATORS & INFRASTRUCTURE						
SinoHytec	Integration/Refueling/Storage	Systems/Services	N/A	Commercial	-	-
H_2 PRODUCTION & SUPPLY						
China Energy Investment Corporation	Distribution	Supplier	N/A	Operational/Planned	Industrial/ Mobility	-

Outlook Challenges & Next Steps

2026 Priorities & Planned Actions

The new hydrogen energy comprehensive application pilot program launched in 2026 provides strong support for the large-scale promotion of hydrogen energy in China.

Key Challenges to H_2 Deployment

The efficiency of hydrogen storage and transportation is relatively low, the cost of hydrogen refueling is relatively high, and the penetration rate of fuel cells in the transportation sector is not growing rapidly.

Strategic Opportunities & Competitive Advantages

The abundant renewable energy resources in the northwest region of China provide favorable conditions for the production of green hydrogen.

References

The Medium- and Long-Term Plan for the Development of Hydrogen Energy Industry (2021-2035)

FRANCE

ExCo Representatives

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REGULATORY FRAMEWORKS & POLICY LANDSCAPE

National Hydrogen Strategy & Climate Targets

- **Strategy Publication Date**: 16th April 2026 = date of released of the revision of the national hydrogen strategy
- **Primary Objectives:**
  - Decarbonizing hydrogen for industry and developing a mass market
  - Preparing the uses of tomorrow: basic research, funding for large scale pilots, developing key components
  - Deployment of the more mature hydrogen industry with dedicated tools
- **Key Climate Goals by 2030/2040/2050:** 55% GHG reduction by 2030 and Net-zero by 2050
- **Hydrogen's Role in Strategy:** After energy sobriety and direct electrification of uses, low carbon hydrogen is one of the key solutions for achieving carbon neutrality: for replacing fossil hydrogen used in industries, for decarbonizing sectors which could be new hydrogen consumers (that concerns some specific industries and transports)

Support Programmes & Funding

All the hydrogen funding (€ 9Md announced, € 3Md effectively engaged) is included in the FRANCE 2030 programme. In detail, the main sub-programmes are:

Programme Name	Focus Area	Budget/Volume	Implementation Period	Key Details
PEPR	R&D (TRL 1-4) on high and low temperature electrolysis, H2 storage, H2 for heavy mobility	€ 80 M	2021-2029	https://www.pepr-hydrogene.fr/
No name	Support for initial and continuing education	€ 30 M	2021-2030	

Programme Name	Focus Area	Budget/Volume	Implementation Period	Key Details
	Demonstrators, technological building blocks and local ecosystems (TRL 7-9)	€ 1Md	2021-2030	
	Remuneration scheme for H2 production	€ 3,5Md	Not yet implemented	First tender is expected in 2026 (for 200MW)
IPCEI	All the H2 value chain	€ 3,3Md	2022-2024	

International Cooperation & Frameworks

- **EU Memberships/Frameworks:** Hy2Tech, Hy2Use, Hy2Infra et Hy2Move
- **Bilateral Agreements:** [Country partnerships for H_2 import/export, hydrogen corridors, regional initiatives]
- **International Initiatives:** IPHE, RD20, IEA H2 and FCE TCP

Hydrogen Status & Key Figures

Energy Systems Overview

Metric	Value	Unit	Year	Source
Gross Inland Energy Consumption: Primary / Final consumption	9,8/5,8	EJ	2024	https://www.statistiques.developpement-durable.gouv.fr/edition-numerique/chiffres-cles-energie/fr/pdf/chiffres-cles-energie-2025.pdf
Renewable Energy Share (in final consumption)	14%	%	2024	Same source

Metric	Value	Unit	Year	Source
Current H_2 Demand (industrial/other uses)	900	kt/year	2025	Estimated
H_2 from Fossil Sources (status quo)	>98%	% of total H_2	2025	No source but renewable and low carbon hydrogen production capacity is 50MW in 2025 (around 5000Mt H2)
Green/Renewable + low carbon H_2 Production Capacity (operational)	50	MW	2025	Actual installed capacity https://www.france-hydrogene.org/app/uploads/sites/4/2026/01/France-Hydrogene_BAROMETRE_27.01.2026.pdf

Hydrogen Infrastructure Status

Infrastructure Type	Operational	Under Construction	Planned/Announced	Target 2030	Notes
Electrolysis Capacity	50 MW	250 MW	7-8 CW	Up to 4,5GW	Technology mix: PEM/AEL

Key Technologies & R&D Focus Areas

The whole R&D is done through the programme named PEPR H2 by CEA and CNRS : roughly € 8-10M in 2025

It concerns electrolysis (PEM, AEL, AEM, SOEC, PCC) technologies, PEMFC and SOFC, liquid, solid and gaseous storage, accelerated stress tests, but also LOHC catalysts, hydrogen and ammonia photo electrochemical production, hydrogen combustion.

Projects & Demonstration Initiatives

Major Demonstration & Commercial Projects

Project Name	Status	Scale & Capacity	Primary Application	Lead Partners	Timeline	Funding	Expected Outcomes
Normand'hy	Construction	250 MW	Production	Air Liquide	[Start in 2026	€[X]M	H2 for refineries

Industry Landscape & Commercial Ecosystem

Key Industry Players & Technology Focus

Company Name	Technology/Product Focus	Type	Capacity/Scale	Development Stage	Applications	Notes
ELECTROLYZER DEVELOPERS						
ELOGEN	PEM	Cell/Stack/System	Range of installed systems: 1-2,5 MW	Commercial	[Industrial/Grid	[Details]
JOHN COCKERILL	AEL	Cell/Stack/System	Stack size: 5 MW; system installed: up to 100MW	Commercial	Industrial/Grid	Bigger projects are in China with Cockerill Jingli Hydrogen
Gen-Hy	AEM	membrane/Stack/System	?	Pilot/pre-commercial		
GENVIA	SOEC	Cell/stack/system	< 1MW	R&D/Pilot	Industrial	Pilot at ArcelorMittal's site in Saint-Chély-d'Apcher in 2026
FUEL CELL MANUFACTURERS						
SYMBIO	PEMFC]	System	75-300 kW range	Commercial	Automotive at the	Symbio was deeply

Company Name	Technology /Product Focus	Type	Capacity/Scale	Development Stage	Applications	Notes
					beginning but…	linked to Stellantis H2 strategy. As Stellantis stopped its H2 activities, Symbio is repositioning itself toward stationary applications
INOCEL	PEMFC	Stack/System	300 kW	Commercial	Stationary/ Maritime	
HDF energy	PEMFC	Stack/system	Multi-MW	Commercial	Grids/railway/maritime	They used to install Ballard FC until recently they decided to build their own FC
SYSTEM INTEGRATORS & INFRASTRUCTURE						
[Company 5]	[Integration /Refueling/ Storage]	[Systems/Services]	[Capacity]	[Development stage]	[Applications]	[Details]
[Company 6]	[Integration /Refueling/ Storage]	[Systems/Services]	[Capacity]	[Development stage]	[Applications]	[Details]
H_2 PRODUCTION & SUPPLY						

Company Name	Technology /Product Focus	Type	Capacity/Scale	Development Stage	Applications	Notes
Air Liquide	Gray/Blue/ Green H_2	Producer/Supplier	1,2 Mt/year	2 or 3 200MW electrolyzer systems in Europe	Industrial/ Mobility	International player
Lhyfe	Green H_2	Producer/Supplier	< 10 000t/year	Several small projects (<20MW)	Industrial/ Mobility	National/EU player

OUTLOOK CHALLENGES & NEXT STEPS

2026 Priorities & Planned Actions

- Major policy or legislative initiative planned for 2026: none
- Significant project milestones or new project launches expected: Air Liquide Normand'hy project: 250MW electrolyzer system will start low carbon (from green and grid electricity) production in 2026

Key Challenges to H_2 Deployment

- Primary barrier: cost competitiveness compared to fossil methane

Strategic Opportunities & Competitive Advantages

- Electricity grid is low carbon, and electricity production is abundant
- Existing industrial base: mainly Air Liquide, 300-400km H2 pipes,
- Manufacturing capabilities: operational factories over all the value chain
- Opportunities: New projects for aviation fuel production will drive H2 demand

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GERMANY

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INITIATIVES, PROGRAMMES AND POLICIES ON HYDROGEN AND FUEL CELLS

Between 2000 and 2025, the share of renewables in Germany's gross electricity consumption increased from 6.3% to 55.1%. Over the same period, the share of renewables in gross final energy consumption increased from 6.2% to 23,8%. [1] The rate at which renewable energy has increased in terms of gross final energy consumption is now comparable to the rate at which it has increased in terms of electricity consumption. This is mainly due to increased deployment of renewable energy in the heating sector. However, the transport sector is still lagging behind. Despite a significant increase in the sale of battery-electric vehicles, only 4% of vehicles are electric. The binding target set out by the Renewable Energy Sources Act in 2021 of achieving 80% renewables in gross electricity consumption by 2030 now seems almost beyond reach. Progress over the last two periods has been too slow. The most important measure for achieving the target remains a significant expansion of renewable electricity generation. Additionally, the target of achieving a 41% share of renewable energy in gross final energy consumption by 2030 [2] will require significant improvements in the efficiency of end-use technologies. Meanwhile, Germany has reduced its GHG emissions by about 48% between 1990 and 2025 and aims to further reduce these emissions by at least 65% by 2030 compared to 1990. Projections indicate that the 2030 target may still be achievable, but more ambitious efforts will be needed, particularly in the transportation sector, to reach the ultimate goal of complete greenhouse gas neutrality by 2045. [3]

Hydrogen and fuel cell technologies have the potential to meet the challenging requirements of the future energy mix and to facilitate the energy transition in Germany. To meet Germany's energy and greenhouse gas emission targets, highly efficient and emission-free fuel cell electric vehicles, fuel cell-based combined heat and power systems for homes, large-scale fuel cell systems for industrial applications, and the ability to store excess electricity from renewable sources as hydrogen through electrolysis are recommended solutions. However, developments in battery technology have significantly limited the potential for fuel cell powertrains in the transportation sector. Currently, visible fuel cell activity is in heavy-duty trucks and buses.

The National Hydrogen Strategy [4], [5], initially published in 2020, remains the cornerstone of Germany's plan to implement hydrogen technologies. In 2021, the Federal Government evaluated the progress [6] of the measures proposed in the National Hydrogen Strategy, before releasing the National Hydrogen Strategy Update in July 2023, which outlines the action plan for achieving the 2030 targets. [5] The corresponding action plan includes short-term (2023) and medium-term (2024/25) initiatives. The strategy emphasizes the need for an "accelerated market introduction of hydrogen", "sufficient availability of hydrogen and its derivatives", the development of hydrogen infrastructure and coherent regulatory conditions at national and international level. [5] In addition, the German government's target of 10 GW of electrolysis capacity was confirmed, along with the instruments to achieve this, including national and European funding programs. However, in a monitoring report on the German 'Energiewende', Minister Katherina Reiche proposed replacing the fixed 10 GW target with more flexible, demand-oriented targets. [7]

The announced import strategy was presented in 2024 [8], which suggests pipelines and ships as transport modes, and ammonia, methane, methanol, naphtha, e-fuels and hydrogen carriers such as LOHC (liquid organic hydrogen carriers) as transport media other than hydrogen. The 2030 vision includes an initial hydrogen network of about 1800 km of pipelines in Germany and 4500 km in Europe, supported by the EU IPCEI funding program. Measures will be taken on the demand side in the industrial, transport and power sectors, as well as in the heat supply for the building sector. Examples include (i) the concept of "green lead markets" in industry, (ii) legislative measures to promote clean vehicles and the establishment of a decentralized hydrogen innovation and technology center in the transport sector, and (iii) the investigation of the requirements for "system-serving electrolysis" alongside various approaches for the use of hydrogen power plants to balance the volatile feed-in of renewable energies in the power sector. [8] In February 2026, the National Hydrogen Council has recently reaffirmed the strategic importance of hydrogen for transport and industry. [9]

In October 2024, the Bundesnetzagentur (German Federal Network Agency) approved the final plan of the hydrogen core pipeline network with a total length of 9040 km. The hydrogen core network is expected to be operational by 2032. [10] According to Germany's association of gas pipeline operators (FNB Gas), 500 km have been realized by the end of 2025. [11]

With the interministerial National Innovation Program Hydrogen and Fuel Cell Technology (NIP) in its second phase from 2016 to 2026, the German government is continuing its strong support for research and development on the one hand, and for market activation in terms of bringing the first products into series production on the other. The Federal Ministry of Digital Affairs and Transport (now Federal Ministry of Transport, BMV) was supporting the technology with €660 million for the period 2016-2024. The total project volume is €1.7 billion, of which approximately €1 billion is in the form of grants. [12] While the BMV's funding is aimed at supporting products that are technically ready but not yet competitive during the market launch phase, the Federal Ministry for Economic Affairs and Climate Protection (now Federal Ministry of Economic Affairs and Energy, BMWE) is supporting applied research and development for hydrogen and fuel cells with an annual budget of €25 million under the 7th Research Framework Programme. Other ministries involved in the NIP are the Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety (BMUKN) and the Federal Ministry of Research, Technology and Space (BMFTR). NOW GmbH coordinates and manages the National Innovation Program (NIP). Since 2016, the BMWE also supports private households in purchasing fuel cell heating appliances. As part of the market activation activities, 14,330 devices were approved for funding in the period from September 2016 to September 2020. There are no updated numbers available. As of now, fuel cell heating appliances are eligible for 30-70% funding. [13]

As of January 2026, Germany had 50 operational public hydrogen refueling stations. [14] Going forward, the stations will be built primarily in areas where demand for commercial vehicles is expected in the short term, and where a public hydrogen refueling station would make sense for a growing network of passenger cars. The plan is to operate a network of 120 stations for medium and heavy-duty vehicles by 2026. [15]

The implementation status of the National Hydrogen Strategy highlights the following flagship programs displayed in Table 1:

Funding Program	Period	Budget
Important Project of Common European Interest (IPCEI)	01/21 - 12/27	8 billion
Carbon Contracts for Difference → 1st round launched in March 2024 → 15 projects approved in October 2024, 5 of which involve hydrogen	01/22 – 12/31	2.8 billion
Renewable Fuels Overall Support Concept	from 2021	1.5 billion
Decarbonization of Industry	01/21 – 06/24	3 billion
Ideas Competition Hydrogen Republic Germany	04/21 – 09/25	0.74 billion
Real Laboratories of the Energy Transition	02/19 – 06/24	p.a. 0.1 billion
Innovation and Technology Center (ITZ)	2021 – 2024	0.29 billion
Implementation of the German-Moroccan Hydrogen Alliance	2021 – 2025	0.09 million
H2Global	01/22 – 12/33	0.9 billion

Information on the status of installed electrolysis capacity in Germany can be found on the Open Energy Tracker. [16] According to the presented data, only 0.18 GW is currently in operation. The cumulative capacity of projects, including electrolyzer plants under construction, those with a positive final investment decision, and those in the feasibility study or concept phase, amounts to 18 GW. However, given that 12 GW of this capacity is still in the initial concept phase, it is questionable whether the 10 GW target set out in the National Hydrogen Strategy will be achieved. Table 2 shows a selection of projects from the current Phase II of the NIP funding programme, which is coming to an end soon, that are allocated to fuel application topics. [17]

Topic	Project acronym(s)	Cumulative funding, € million
National action plan for fuel cell production scaling and cost reduction	**1 project**: H2GO	79
Fuel cell systems for aviation	**3 projects**: H2Sky, BALIS, BALIS 2.0	65
Fuel cell systems for rail applications	**2 projects**: H2goesRail, HyTraGen	23
Fuel cell hybrid for river cruise ship	**1 project**: RiverCell3	9
Material handling	**2 projects**: XLP80Mbedded, KION HyPower-48V	3
Cryo-compressed and liquefied hydrogen truck refueling	**1 project**: ColdHyFuel	13
Fuel cell stacks and systems	**2 projects**: LeBChi, HZwo: SuSyMobil	5
Fuel cell stacking and mass production	**3 projects**: QUALLE, DirectStack2Scale, i-skaB	11
Fuel cell and fuel cell system components	**7 projects**: KontiBIP, HZwoSafeTank,	14

	Parity-4-Reuse, HZwo|G3BIP, M-KaV, DCDC4BZ, CellForm_ZSW_BPP	

In addition to the programs and projects mentioned above, there are various industry collaborations as well as regional initiatives by German states. Relevant examples include the GetH2 initiative, in which companies, municipalities and institutions are planning the realization of pipeline networks, large-scale electrolysis plants and hydrogen applications in industry and transportation. [18] In addition, ThyssenKrupp Steel Europe AG is building a hydrogen-based DRI (Direct Reduced Iron) steel plant in Duisburg as part of the tkH2Steel® project, which is being funded by the federal and state governments. [19] Examples of joint German state initiatives are the Hy-5 initiative (Bremen, Hamburg, Mecklenburg-Western Pomerania, Lower Saxony and Schleswig-Holstein) and the IWO initiative (Saxony-Anhalt, Berlin, Brandenburg, Mecklenburg-Western Pomerania, Thuringia and Saxony). [20], [21]

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ITALY

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REGULATORY FRAMEWORKS & POLICY LANDSCAPE

National Hydrogen Strategy & Climate Targets

- **Strategy Publication Date:** Published in November 2024
- **Primary Objectives:** The Italian National Hydrogen Strategy outlines a roadmap to integrate hydrogen as a key energy vector to achieve climate neutrality by 2050. Aligned with the European Green Deal and Italy's National Integrated Energy and Climate Plan (PNIEC), the strategy views hydrogen as indispensable for decarbonizing "Hard-to-Abate" sectors—industries and transport modes where direct electrification is technically or economically challenging.
- **Key Climate Goals by 2030/2040/2050:** Main National Integrated Energy and Climate Plan (PNIEC 2024) targets

	unit of measurement	Data found	PNIEC 2024: Reference case	PNIEC 2024: Policy scenario 5	FF55 REPowerEU objectives
		2022	2030	2030	2030
GHG emissions and removals					
GHG reduction vs 2005 for all installations bound by ETS legislation	%	– 45 %	– 58 %	– 66 %	– 62 % 6
GHG reduction vs 2005 for all ESR sectors	%	– 20 %	– 29.3 %	– 40.6 %	– 43.7 %7, 8
GHG emissions and removals from LULUCF	$MtCO_2eq$	– 21,2	– 28,4	– 28,4	– 35,8 [3]
Renewable energy					
Share of RES energy in gross final energy consumption (RED 3 calculation criteria)	%	19 %	26 %	39.4 %	38.7 %
Share of RES energy in gross final consumption of energy in transport (RED 3 calculation criteria)	%	8 %	15 %	34 %	29 % 9
Share of RES energy in gross final consumption for heating and cooling (RED 3 calculation criteria)	%	21 %	24 %	36 %	29.6 % [3] – 39.1 %
Share of RES energy in final consumption of the electricity sector	%	37 %	53 %	63 %	not planned
Share of RES hydrogen in total hydrogen used in industry	%	0 %	4 %	54 %	42 % [3]
Energy efficiency					
Primary energy consumption	Mtoe	140	133	123	111
Final energy consumption	Mtoe	112	111	102	93
Cumulative annual savings in final consumption through energy efficiency obligation schemes	Mtoe	3,8		73,4	73,4 [3]

Hydrogen's Role in Strategy:

Hydrogen is expected to be largely employed in the following sectors:

- Industry: Priority is given to primary steel production (transitioning to DRI - Direct Reduced Iron), refineries, and chemical plants.
- Transport: Establishment of Hydrogen Valleys and refueling stations along the TEN-T corridors to support heavy-duty road transport and regional hydrogen-powered trains.
- Research & Innovation: Focused investment in electrolyzer efficiency, advanced storage solutions, and the domestic manufacturing of hydrogen components.

The strategy follows three implementation phases:

- Short Term (until 2030): Launching the First Projects. Until 2030, the evolution of hydrogen demand will be driven by the European RED III (Renewable Energy Directive) obligations within the industrial and transport sectors. Italy has already begun its journey to kickstart the hydrogen market through the National Recovery and Resilience Plan (PNRR), which will fund the initial production projects—all of which must be operational by 2026. In this timeframe, the national strategy aims to:
  - Facilitate Project Implementation: Streamline the rollout of these projects by establishing incentive schemes to lower the cost of hydrogen.
  - Value Chain Support: Provide backing from production to the end-user.
  - Regulatory Framework: Improve environmental permitting, safety standards, and general legislation.
  - Hydrogen Valleys: Develop localized production and consumption ecosystems. These hubs will create synergies between different sectors, such as local mobility and nearby industrial plants.
  - Standardization: Utilize hydrogen types defined by European Delegated Acts (renewable and low-carbon hydrogen) to ensure significant early volumes are available with specific Guarantees of Origin.
  - Alternative Carriers: Promote production from renewable energy carriers like ammonia and methanol, making more RFNBOs (Renewable Fuels of Non-Biological Origin) available.
- Medium Term (2030–2040): Scaling Up and Market Development. This phase focuses on a set of measures designed to follow up on PNRR initiatives and build a true hydrogen market.
  - Cost Reduction: Transition toward large-scale solutions capable of significantly lowering operating costs.
  - Policy Drivers: Potential growth will be fueled by emission reduction policies and the increasing availability of "H2-ready" technologies.
  - Expanding Demand: Beyond early adopters, demand will rise in maritime and air transport, "Hard-to-Abate" (HtA) industries, and long-range heavy-duty road transport.
  - Infrastructure: Distribution and production infrastructure will play a central role in supporting increased consumption and ensuring a competitive supply.
- Long Term (2040–2050): Centralization, Mass Volumes, and Infrastructure. The year 2050 marks the finish line for Net Zero commitments, with hydrogen potentially reaching:
  - 18% of final energy consumption in HtA industries.
  - 30% of final energy consumption in the transport sector.

During this phase, hydrogen will expand into new roles, such as grid balancing (Power-to-Gas and Power-to-Power) and long-term energy storage. Infrastructure will be the protagonist, facilitating energy exchange with other countries and consolidating Italy's role as a European import hub. This will be achieved through:

- Gas networks connected to North Africa.
- A network of ports (on both the Tyrrhenian and Adriatic coasts) equipped for the import of hydrogen and other energy carriers like ammonia and methanol.

Support Programmes & Funding

Programme Name	Focus Area	Budget/Volume	Implementation Period	Key Details
Important Projects of Common European Interest (IPCEI)	Production/Infrastructure/Mobility/R&D	€ 2.32 billion	2025-2029	The Italian ministry redistributed € 2.32 billion across hydrogen, microelectronics and cloud infrastructure. Hydrogen projects now account for nearly half the total. Funding will go towards projects under the IPCEI Hy2Tech (EUR 909 million), Hy2Use (€ 395 million), Hy2Move (€ 22 million) and H2Infra (EUR 994 million) schemes.
National Recovery and Resilience Plan - Mission 2 (PNRR M2C2)	Production/Infrastructure/Mobility/R&D	€ 3.64 billion	2021-2026	The objectives of the Italian National Recovery and Resilience plan are to develop low-carbon technologies and settle a more sustainable and resilient electricity and transport sector. This component includes five objectives: increase energy from renewable sources;

Programme Name	Focus Area	Budget/Volume	Implementation Period	Key Details
				improvement and digitalization of the electricity grid; production, distribution and final use of hydrogen; sustainable transport; R&D for the main clean technologies supply chains. Hydrogen in turn has six areas with a total budget of € 3.64 billion from 2021 to 2026 - Production of hydrogen in brownfield sites (hydrogen valleys) (Area 3.1): € 500 million - Hydrogen use in hard-to-abate industry (Area 3.2): € 2 billion - Hydrogen testing for road transport (Area 3.3): € 230 million - Hydrogen testing for rail (Area 3.4): EUR 300 million - Hydrogen R&D (Area 3.5): € 160 million - R&D on hydrogen (Area 5.2): € 450 million
Mission Innovation 2.0	Production/Infrastructure/Mobility/R&D	€ 118 million	2023-2026	€ 118 million for Clean Hydrogen Mission (DM n. 386 November 17th, 2023) to fund R&D activities and industrial prototypes

International Cooperation & Frameworks

- **EU Memberships/Frameworks:** IPCEI H2, H2ME
- **Bilateral Agreements:** Hydrogen backbone south corridor, Collaboration agreement with Japan
- **International Initiatives:** IPHE participation, G7 and G20 involvement, RD20, Clean Energy Ministerial CEM

Hydrogen Status & Key Figures

Energy Systems Overview

Metric	Value	Unit	Year	Source
Gross Inland Energy Consumption	[311.3]	TWh	2025	[https://www.terna.it/en/media/press-releases/detail/electricity-consumption-2025]
Renewable Energy Share (in final consumption)	[41] %	%	2025	[https://www.terna.it/en/media/press-releases/detail/electricity-consumption-2025]
Current H_2 Demand (industrial/other uses)	[829610]	kt/year	2025	Estimated/
H_2 from Fossil Sources (status quo)	[95.3] %	% of total H_2	2025	[https://observatory.clean-hydrogen.europa.eu/hydrogen-landscape/production-trade-and-cost/hydrogen-production]
Green/Renewable H_2 Production Capacity (operational)	[1.5]	MW	2025	[Actual installed capacity]

Hydrogen Infrastructure Status

Infrastructure Type	Operational	Under Construction	Planned/Announced	Target 2030	Notes
Electrolysis Capacity	1.5 MW	at least 39 MW from regional hydrogen valleys and at least 73.5 MW from EU funded hydrogen valleys	/	3 GW	Mostly AEL and PEM
EU Hydrogen South Corridor	/	/	/	/	The Italian H2 Backbone is composed of around 2,300 km of pipelines (73% repurposed, 27% new built) and several hundred MW of compressor stations, expected to become dedicated hydrogen assets by 2030
Storage Infrastructure	/	/	/	/	/

Key Technologies & R&D Focus Areas

Total Public R&D Funding (2024/2025): € 6 billion
Main Research Institutions: ENEA, FBK, CNR, RSE, several Italian universities from all regions

Projects & Demonstration Initiatives

Major Demonstration & Commercial Projects

Project Name	Status	Scale & Capacity	Primary Application	Lead Partners	Timeline	Funding	Expected Outcome
IPCEI Hy2Tech	Construction	/	Manufacturing	ENEA FBK FINCANTIERI SNAM IVECO ANSALDO ENERGIA	2023-2028	€ 5 billion	/
Mission Innovation – Hydrogen Demo Valley	Construction	/	Production, Infrastructure, End Use	ENEA CNR	2020-2026	€ 17 million	/
POR H2 National Recovery and Resilience Plan - Mission 2	Operational	/	Production, Infrastructure, End Use	ENEA CNR RSE	2022/2026	€ 120 million	/
Implementing Fuel Cells and Hydrogen Technologies in Ports [H2Ports]	/	/	Mobility	ATENA SCARL, ENEA	2019-2025	€ 4.1 million	/
Hydrogen Production by Means of solar heat and power in high Temperature Solid	/	/	Production	ENEA, FBK, SOLYDERA	2021-2026	€ 2.6 million	/

Project Name	Status	Scale & Capacity	Primary Application	Lead Partners	Timeline	Funding	Expected Outcome
Oxide Electrolyzers [PROMETEO]							
Solid oxide fuel cell combined heat and power: Future-ready Energy [SO-FREE]	/	/	Final Use	ENEA	2021-2026	€ 2.8 million	

Hydrogen Valleys & Regional Clusters

Valley/Initiative Name	Location (City/Region)	Primary Focus Sectors	Projected H_2 Demand (kt/year by 2030)	Current Status	Total Investment (€M)
H2iseO hydrogen valley	Brescia	Mobility	0.8 kt	Early Construction	/
Hydrogen Valley South Tyrol	Bolzano	Mobility	0.1315 kt	Early Construction	55
HydrogER	Ravenna	Mobility/Mix	9.25 kt	Planning	270
North Adriatic Hydrogen Valley	Multiple cities across Slovenia, Croatia and Friuli Venezia Giulia in Italy	Industry/Mobility/Power	5 kt	Planning	/
TH2ICINO	Milano Malpensa	Mobility	0.5 kt	Planning	55

54 PNRR Hydrogen valleys	See attached file	See attached file	See attached file	See attached file	See attached file
Hydrogen DEMO Valley	ENEA Casaccia	Mix	/	Early Construction	14

Industry Landscape & Commercial Ecosystem

Key Industry Players & Technology Focus

Company Name	Technology /Product Focus	Type	Capacity/Scale	Development Stage	Applications	Notes
ELECTROLYZER DEVELOPERS						
Ansaldo Green Tech	AEM/SOEC	Stack and System	/	Commercial	Hard to abate, flexible production	https://www.ansaldoenergia.com/it/chi-siamo/companies/ansaldo-green-tech-spa
Arco Technologies	AEM	Stack and System	/	Pilot	Hydrogen production	https://www.arco.tech
De Nora	Electrodes	Component	/	Commercial	Hydrogen production	https://denora.com/en
Enapter	AEM	System	/	Commercial	Hydrogen production	https://enapter.com/it/
Erredue Gas	PEM/AEL	Stack and System	/	Commercial	Hydrogen production	https://www.erreduegas.it/
H2Energy	PEM/AEL/AEM	Stack and System	/	Commercial	Hydrogen production	https://www.h2e.it/
Hyter - Pietro Fiorentini	PEM/AEM	System	/	Commercial	Hydrogen production	https://hyter.it/
ILT Energia	AEL	Stack and System	/	Commercial	Hydrogen production	https://iltenergia.it/
IMI Vivo	PEM	System	/	Commercial	Hydrogen production	https://processautomation.imiplc.com/about-

Company Name	Technology /Product Focus	Type	Capacity/Scale	Development Stage	Applications	Notes
						us/brands/imi-vivo
SolydERA	SOEC	Stack and System	/	Commercial	Hydrogen production	https://www.solydera.com/it/
FUEL CELL MANUFACTURERS						
Arco Technologies	PEMFC	Stack and System	/	Pilot	Mobility	https://www.arco.tech
Cefla	SOFC	Stack and System	/	Commercial	Stationary	https://www.cefla.com/it/
Eldor	PEMFC	Stack and System	/	Commercial	Automotive	/
Nuvera - HYSTER YALE	PEMFC]	Stack and System	/	Commercial	Mobility	https://www.nuvera.com/about/nuvera-europe/
SolydERA	SOFC	Stack and System	/	Commercial	Stationary	https://www.solydera.com/it/
SYSTEM INTEGRATORS & INFRASTRUCTURE						
ATENA	Integration	Systems	/	Pilot	Heavy Duty mobility	https://www.atenaweb.com/
Bluenergy revolution	Integration	Systems	/	Commercial	Hydrogen production	https://bluenergyrevolution.com/
CTS H2	Integration	Systems	/	Commercial	Production and use in residential and commercial sector	https://www.ctsh2.com/it/
Simplifhy	Integration	Systems	/	Commercial	Mobility, industry, buildings	https://simplifhy.com/

Company Name	Technology /Product Focus	Type	Capacity/Scale	Development Stage	Applications	Notes
Hybitat	Storage	Systems	/	Commercial	Production and use in residential and commercial sector	https://hybitat.tech/

Outlook, Challenges & Next Steps

2026 Priorities & Planned Actions

- European Commission approved an incentive mechanism to produce renewable and biogenic hydrogen, based on bilateral Contracts for Difference (CfD). Ministerial decree in preparation for the overall amount of € 6 billion. The scheme should support the production of 200.000 tons of hydrogen per year until 2029

Key Challenges to H_2 Deployment

- High and uncertain energy cost affecting levelized cost of hydrogen
- Not fully developed supply chain resulting in high technology cost
- The hydrogen uptake requires infrastructure development which is affected from long permitting times and from the relatively limited number of technology providers and skilled labor with respect to the sudden increase of hydrogen projects
- Approaching the policy-related barriers for hydrogen refueling station permitting and operations, aligning with the European landscape

Strategic Opportunities & Competitive Advantages

- High Renewable Energy sources development potential
- Strategic geographical position for import and trading of hydrogen from partners in the mediterranean area
- Internationally relevant companies within the whole value chain
- International and European collaborations

References

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https://commission.europa.eu/publications/italy-final-updated-necp-2021-2030-submitted-2024_en
https://www.h2it.it/
https://h2v.eu/hydrogen-valley-platform
https://www.clean-hydrogen.europa.eu/projects-dashboard_en

JAPAN

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REGULATORY FRAMEWORKS & POLICY LANDSCAPE

National Hydrogen Strategy & Climate Targets

Strategy Publication Date: June 2023

Primary Objectives: To achieve carbon neutrality by 2050 based on the domestic and international situations, the updated Basic Hydrogen Strategy presents the recognition and vision common to the public and private sectors in terms of achieving the goal, while clarifying challenges and policy initiatives, and demonstrates the nation's aspiration of achieving the early realization of a hydrogen society.

The strategy includes the following as important pillars.

- (1) Overall objective
- (2) Hydrogen industry strategy (for enhancing the hydrogen industry's competitiveness)
- (3) Hydrogen safety strategy (for the safe use of hydrogen)

In addition to the current target of expanding consumption of hydrogen to around 3 million tons per year by 2030 and about 20 million tons per year by 2050, the strategy sets forth a new target of about 12 million tons per year (including ammonia) for 2040.

Key Climate Goals by 2030/2040/2050: 46%GHG reduction by 2030, Net-zero by 2050.

Hydrogen's Role in Strategy: As hydrogen is expected to make various contributions, including to the decarbonization of heat utilization, the development of zero-emission power sources, and the production of recycled carbon products like synthetic fuels (efuel) and e-methane, its roles are anticipated to expand further in the future.

Support Programmes & Funding

Programme Name	Focus Area	Budget/Volume	Implementation Period	Key Details
Development of Technologies for Realizing a Hydrogen Society	Production/Infrastructure /Mobility	€23 million in 2026	2026 to 2030	Aims to realize a hydrogen-based society by establishing a hydrogen supply chain within a defined region and developing utilization and business models for its deployment.

Programme Name	Focus Area	Budget/Volume	Implementation Period	Key Details
Technology Development Project for Building a Competitive Hydrogen Supply Chain	Production/Infrastructure/R&D	€ 37 million in 2026	2023 - 2027	This project aims to advance and reduce the cost of hydrogen-related infrastructure for production, storage, transport, and use, while also supporting regulatory development and international standardization. *1

International Cooperation & Frameworks

- **International Initiatives:** IEA, IPHE, CHP, G7 / G20, etc.

Hydrogen Status & Key Figures

Energy Systems Overview

Metric	Value	Unit	Year	Source
Gross Inland Energy Consumption	18,480	PJ	2024	https://www.enecho.meti.go.jp/statistics/total_energy/pdf/gaiyou2024fykaku.pdf
Renewable Energy Share (in final consumption)	10 %	%	2024	https://www.enecho.meti.go.jp/about/whitepaper/

Key Technologies & R&D Focus Areas

Technology Area	Development Stage	Key Activities/Projects	Lead Organizations	Funding (annual)	Notes
PEM Electrolysis	Research	Development of Low-	Yamanashi University, Ishifuku	-	Materials Development

Technology Area	Development Stage	Key Activities/Projects	Lead Organizations	Funding (annual)	Notes
		Iridium Catalysts	Metal Industries Co., Ltd., etc.		
Alkaline Electrolysis	Research	Development of Highly Catalytic and Durable Pyrochlore Oxide for OER	Doshisha University, etc.	-	Materials Development
AEM Electrolysis	Research	Development of High-Performance PFAS-Free Anion Exchange Membranes	Yamanashi University, Takahata Precision Co., Ltd., etc.	-	Electrolytic Cells & Materials Development
SOEC (High-Temp)	Research	Development of Proton-conducting ceramic electrolytic cell	Tohoku University, National Institute of Advanced Industrial Science and Technology, etc.	-	Electrolytic Cells & Materials Development
PEMFC (Passenger Vehicles)	Research	Development of Highly Active Low-Platinum Catalysts	Doshisha University, National Institute of Advanced Industrial Science and Technology, etc.	-	Materials Development
PEMFC (Heavy-Duty)	Research	Development of PFAS-Free Electrolyte Membranes with High Proton Conductivity under Low Humidity	Tokyo Metropolitan University, etc.	-	Materials Development for HDV

Technology Area	Development Stage	Key Activities/Projects	Lead Organizations	Funding (annual)	Notes
SOFC (Stationary)	Pilot	Development of High-Efficiency Fuel Cells for Commercial Applications and Fuel Diversification	DENSO Corporation	-	Industrial applications
H_2 Storage	Research	Development of a Segmented-Preform CFRP High-Pressure Hydrogen Tank	Kanazawa Institute of Technology, etc.	-	700 bar Tank
Other Focus Areas	Research	Development of Low-Cost Carbon Fibers Using Sustainable Resources	Gifu University, Kyushu University, etc.	-	Materials Development for 700 bar Tank

Total Public R&D Funding (2024/2025):

- Collaborative Industry-Academia-Government R&D Project for Solving Common Challenges Toward Dramatically Expanded Use of Fuel Cells and Related Equipment (2024FY) €43million
- Project to Develop Common Platforms Supporting the Widespread Use of Hydrogen (2025FY) € 40 million *1 € =180 Yen

Main Research Institutions: Hydrogen Institute for Sustainability Kyushu University, Hydrogen and Fuel Cell Nanomaterials Center University of Yamanashi, FC-Cubic Association, National Institute of Advanced Industrial Science and Technology

Projects & Demonstration Initiatives

Major Demonstration & Commercial Projects

Project Name	Status	Scale & Capacity	Primary Application	Lead Partners	Timeline	Funding	Expected Outcomes
The Fukushima Hydrogen Energy Research	Operational	10 MW/ 1200Nm3 /h(Max)	Production/Infrastructure/Industry	Toshiba ESS, Tohoku Electric	2016 - 2028		The project develops large-scale green

Project Name	Status	Scale & Capacity	Primary Application	Lead Partners	Timeline	Funding	Expected Outcomes
Field : FH2R				Power Co., Inc. Iwatani Corporation			hydrogen demand response and sales business models
LH2 Carrier Suiso Frontier	Operational	1250m3	Infrastructure	HySTRA	2015-2026		World First LH2 Carrier with 1250m3
Development of large-size LH2 Tank	Under Development	200,000m3 class LH2 tank	Infrastructure	Kawasaki Heavy Industries	2023-2026		Development of commercial-sized LH2 tank
Development of Gas Turbine Power Generation	Under Development	450MW class	Industry	Mitsubishi Heavy Industries	2023-2027		Power Generation with 30 vol% Hydrogen Co-Firing

Hydrogen Valley & Regional Clusters

Valley/Initiative Name	Location (City/Region)	Primary Focus Sectors	Projected H_2 Demand (kt/year by 2030)	Current Status	Total Investment (€M)
Development of the Yamanashi Model for a Decarbonized Energy Network Using Hydrogen as a Heat Source	Yamanashi, Saitama, Fukushima, Shizuoka Pref.	Industry	-	Operational	-
Technology Development for Efficiency and	Hyogo Pref.	Power	-	Operational	-

Valley/Initiative Name	Location (City/Region)	Primary Focus Sectors	Projected H_2 Demand (kt/year by 2030)	Current Status	Total Investment (€M)
Advancement of Hydrogen Fuel Supply Systems in Regional Hydrogen CGS Models					
Development of an Aluminum Melting Furnace Using Hydrogen Burners and On-site Hydrogen Infrastructure Technologies	Aichi Pref.	Industry	-	Advanced	-

Industry Landscape & Commercial Ecosystem

Key Industry Players & Technology Focus

Japan is home to a wide range of companies that play leading roles on a global scale in the fields of water electrolysis technology, fuel cell manufacturing, system integration, and hydrogen production and supply. Representative examples of these companies can be identified among the participants in the projects outlined below.

https://green-innovation.nedo.go.jp/en/project/hydrogen-production-water-electrolysis-utilizing/scheme/#anchorContents

https://green-innovation.nedo.go.jp/en/project/hydrogen-supply-chain/scheme/#anchorContents

https://green-innovation.nedo.go.jp/en/project/utilization-hydrogen-steelmaking/scheme/#anchorContents

Outlook, Challenges & Next Steps

Japan has taken a strategic, policy-driven approach to hydrogen from an early stage. In 2017, it established the world's first national hydrogen strategy, the "Basic Hydrogen Strategy," presenting a long-term vision toward 2050. This was followed by the declaration of Japan's goal of achieving carbon neutrality by 2050 in October 2020 and the announcement of the "Green Growth Strategy Through Achieving Carbon Neutrality in 2050," which positioned hydrogen as a key area for future industrial growth. The subsequent approval of the Sixth Basic Energy Plan in October 2021 and the Seventh Basic Energy Plan in February 2025 clearly identified hydrogen and ammonia as central pillars of Japan's energy supply. In addition, the revised Basic Hydrogen Strategy released in June 2023 strengthened the focus on industrial competitiveness and international expansion, introducing ambitious targets such as the introduction of 12 million tons of hydrogen by 2040 and the deployment of 15 GW of water electrolysis capacity linked to Japanese companies by 2030.

Institutional foundations have also been significantly reinforced. The Hydrogen Society Promotion Act came into effect on October 23, 2024, becoming the world's first legislation dedicated exclusively to hydrogen. By establishing a national certification framework and enabling long-term support measures, including price differential compensation and assistance for hydrogen hub development, the Act provided greater policy continuity, stability, and predictability for investors and businesses. At the same time, Japan has played an active role in shaping international frameworks. Since 2018, the Ministry of Economy, Trade and Industry (METI) and NEDO have jointly organized Hydrogen Ministerial Meetings to promote global dialogue. The 7th meeting, held in Osaka Prefecture in September 2025, brought together a wide range of countries, regions, and international organizations to advance discussions on international standards, certification systems, and safety regulations.

Considering these developments, Japan will continue to proactively advance its efforts toward the realization of a hydrogen-based society beyond 2026.

Spain

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Regulatory Frameworks & Policy Landscape

National Hydrogen Strategy & Climate Targets

Strategy Publication Date: "Hoja de Ruta del Hidrógeno: una apuesta por el hidrógeno renovable" (Hydrogen Roadmap), approved by the Council of Ministers in October 2020. Ambition subsequently raised through the updated National Energy and Climate Plan (PNIEC) 2023–2030, approved in September 2024. A draft Hydrogen Act was announced by Ministry in January 2026 and is under preparation.

Primary Objectives: Spanish policy is focused on renewable hydrogen; no national support scheme exists for fossil-based or low-carbon hydrogen. Hydrogen is outlined as (i) a decarbonisation solution for hard-to-abate sectors (refining, ammonia and fertilisers, chemicals, steel, high-temperature industrial heat, heavy road transport, maritime and aviation fuels); (ii) an industrial policy instrument to build a domestic value chain, technological capability and skilled employment; and (iii) a contribution to European energy security, with Spain positioned as a competitive production and export hub.

Key Climate Goals by 2030/2040/2050: 32% GHG emissions by 2030 vs 1990; 48% renewables in gross final energy consumption by 2030; 81% renewable electricity generation by 2030; 43% improvement in energy efficiency by 2030; climate neutrality no later than 2050 with a 100% renewable electricity system (Law 7/2021 on Climate Change and Energy Transition; PNIEC 2023–2030 update).

Hydrogen's Role in Strategy: 12 GW of installed electrolysis by 2030 (PNIEC update, raising from 4 GW of the 2020 Roadmap, the single largest national target in the EU. Some milestones from the roadmap: at least 25% of hydrogen consumed by industry to be of renewable origin by 2030; a network of at least 100 hydrogen refuelling stations; 150 fuel-cell buses; 5,000 light and heavy fuel-cell vehicles; two commercial hydrogen rail services on non-electrified lines; and export of production surpluses to north-west Europe through the H2Med corridor.

Support Programmes & Funding

Programme Name	Focus Area	Budget/Volume	Implementation Period	Key Details
H2 Valles (Hydrogen Valleys / Clusters)	Production + integrated industrial clusters	€1,223M	2025–2030	Flagship PERTE ERHA line, managed by IDAE with NextGenerationEU funds (PRTR component 31/RePowerEU addendum). Final award June 2025 to 7 clusters in Aragón, Andalusia, Castilla y León, Catalonia and Galicia: 2,292.8 MW of electrolysis across 12 sites, 269,142 t/y of renewable hydrogen and €5,821 million of mobilized investment. Minimum 100 MW per cluster and binding offtake commitments for at least 60% of output.
H2 Pioneros (calls 1 and 2)	Production/industrial demonstration/ mobility	€300M (€150M + €150M)	2022–2026	31 pioneering, commercially oriented projects combining local renewable production and consumption. The second call raised the project ceiling to 50 MW, reflecting the

Programme Name	Focus Area	Budget/Volume	Implementation Period	Key Details
				growing average project size.
H2 Cadena de Valor (Incentive Programmes 1–4)	Manufacturing capacity, R&D infrastructure, industrial integration, fundamental research and training	Sub-programme budgets of €20M (manufacturing plants), €10M (test facilities), €60M (large electrolyzer integration); €44.2M awarded to 25 R&D projects in the 2nd call of Programme 4	2022–2027	The value-chain line is the main national instrument supporting technology developers, research centers and universities. Castilla-La Mancha, Madrid, Valencia, Andalusia and the Basque Country concentrate the largest volumes of R&D aid.
IPCEI Hy2Tech/Hy2Use/Hy2Move	Technology development and first industrial deployment	Project-level awards (e.g. €24.9M H2B2; €11.6M Nordex; €10M Sener)	2022–2030	Spain participates in three of the four hydrogen IPCEIs. Spanish participants include H2B2 (PEM, AEM and SOEC electrolyzer manufacturing), Sener (alkaline electrolyzer factory), Nordex (alkaline electrolyzer factory), Iveco (fuel-cell heavy vehicles), Repsol (Cartagena Hydrogen Network) and Petronor (Bay of Biscay Hydrogen).

Programme Name	Focus Area	Budget/Volume	Implementation Period	Key Details
European Hydrogen Bank – Auctions-as-a-Service (AaaS)	RFNBO production (fixed premium per kg)	€659.4M (€220.02M + €439.4M)	2025–2026	Managed by IDAE under RD 535/2025. First national call: €220.02M to 3 projects pre-selected in the Bank's second general auction. Second call resolved May 2026: €439.4M to 3 projects from the third auction, totaling 250 MW of electrolysis and exhausting the €440M State aid scheme approved by the Commission in March 2026. One Spanish project (Turn2X, Miajadas, Cáceres) was also directly selected in the third EU auction.
PERTE ERHA (umbrella instrument)	Renewables, renewable hydrogen and storage	> €3,100M of EU funds allocated to hydrogen	2021–2026	Strategic Project for Economic Recovery and Transformation that aggregates the national hydrogen lines under PRTR components 7, 9 and 31. More than one hundred hydrogen developments are under way across Spain as a result.

Programme Name	Focus Area	Budget/Volume	Implementation Period	Key Details
Plan Complementario de Energía e Hidrógeno Renovable	Public R&D (State–Regions co-funded)	€88.5M. (State and regional co-financing)	2022–2025 (closed)	Joint MICIU–Autonomous Communities research programme. It financed new laboratory and pilot-plant capacity at CNH2 and partner centers, including portable pilot units for waste valorization and fuel synthesis now being commissioned.

International Cooperation & Frameworks

EU Memberships/Frameworks: IPCEI Hy2Tech, Hy2Use and Hy2Move; Clean Hydrogen Partnership (Clean Hydrogen JU); European Hydrogen Bank, including the Auctions-as-a-Service mechanism; European Hydrogen Backbone (Enagás); European Clean Hydrogen Alliance; Hydrogen Valleys initiative under the S3 Partnership and Mission Innovation. Project of Common Interest (PCI) status has been granted to H2Med (CelZa and BarMar sections), to the Spanish Hydrogen Trunk Network (PCI 9.1.3) and to two associated underground storage sites. Implementation of RED III and the RFNBO delegated acts, the Hydrogen and Decarbonised Gas Market Directive (EU) 2024/1788, AFIR and NZIA is under way.

Bilateral Agreements: H2Med corridor with Portugal, France and Germany, developed at TSO level by Enagás, REN, GRTgaz, Teréga and OGE, with capacity to deliver up to 2 Mt/y of renewable hydrogen to Europe (around 20% of the REPowerEU 2030 target). Iberian coordination with Portugal through the CelZa interconnection (Celorico da Beira–Zamora). Bilateral hydrogen cooperation with Germany; port-to-port export corridor agreements between Spanish ports (Algeciras, Bilbao, Huelva, Valencia) and Rotterdam; and technical cooperation with Latin American partners (notably Uruguay, Chile and Colombia), in which CNH2 acts as technical advisor on regulatory and knowledge-agenda development.

International Initiatives: Member of IPHE. Participation in IEA Technology Collaboration Programmes, including the Fuel Cells Electrolyzer TCP and Hydrogen TCP, in which Spain is represented by CNH2 and INTA respectively. Participation in IRENA, EERA, the Mission Innovation Clean Hydrogen Mission and the Hydrogen Valley Platform. Spain attends the G20 as a permanent guest invitee. Standardisation work in ISO/TC 197 and CEN-CENELEC JTC 6 is coordinated nationally through UNE with CNH2 participation.

Hydrogen Status & Key Figures

Energy Systems Overview

Metric	Value	Unit	Year	Source
Gross Inland Energy Consumption	≈ 4,900	PJ (≈117 Mtoe)	2024	MITECO energy balances/Eurostat (provisional)
Renewable Energy Share (in gross final consumption)	≈ 25	%	2023–2024	Eurostat SHARES/PNIEC 2023–2030 (2030 target: 48%)
Renewable Energy Share (electricity generation)	55.5 (56.6 incl. self-consumption)	% of the generation mix	2025	Red Eléctrica, 'El sistema eléctrico español 2025'
Current H_2 Demand (industrial/other uses)	> 500	kt/year	2025	MITECO Hydrogen Roadmap; refining, ammonia/fertilizers and chemicals
H_2 from Fossil Sources (status quo)	> 95	% of total H_2	2025	Estimated; almost entirely on-site or merchant SMR ("grey" hydrogen)
Green/Renewable H_2 Production Capacity (operational)	≈ 50	MW	2025	CNH2 estimate. Dominated by the 20 MW Puertollano plant; the remainder is c. 30 installations mostly below 5 MW
Renewable H_2 capacity awarded/under development	≈ 3,000 (2026–2028 COD)/13,300 planned for 2030	MW	2025–2030	National project census; 145 commercial projects would reach ≈20 GW and 2.65 Mt/y if fully executed

Hydrogen Infrastructure Status

Infrastructure type	Operational	Under construction / deployment	Planned / announced	2030 target	Notes
Electrolysis Capacity	≈ 50 MW	≈ 300–400 MW	≈ 20 GW announced (13.3 GW credible)	12 GW	Technology mix: alkaline dominant in awarded utility-scale projects (majority of H2 Valleys capacity); PEM in early flagship plants (Puertollano, Petronor) and in mobility-linked units; AEM and SOEC at pilot/demonstration scale
Storage Infrastructure	Pressurized vessels and tube trailers at production and consumption sites; no large-scale storage in operation	None at large scale	Two underground salt-cavern storages (Cantabria and the Basque Country), developed by Enagás as PCIs (linked to H2MED)	First cavern targeted for the early 2030s; line pack in the trunk network from 2030	Salt caverns/compressed gaseous/pipeline line pack. Small-scale solid-state (metal hydride) and liquid organic carrier storage are at research and demonstration stage, with dedicated CNH2 facilities
Transmission Pipelines	None	None (works to start in 2026)	Spanish Hydrogen Trunk Network: ≈2,600 km on five axes (Cantabrian Coast, Ebro Valley, Levante, Vía de la Plata with a connection to the Puertollano	≈2,600 km in operation from 2030; H2Med (CelZa + BarMar) from 2032	Enagás designated provisional Hydrogen Transmission Network Operator under RDL 8/2023. In January 2025 CINEA granted 100% of the CEF funding requested for the study phase (€32.5M). An 18-month public participation plan (April 2025–

Infrastructure type	Operational	Under construction / deployment	Planned / announced	2030 target	Notes
			hydrogen valley, and the Castilla-La Mancha Transversal); a further ≈1,480 km in the expansion plan		October 2026) covers 13 regions and more than 500 municipalities
Refueling Stations (HRS)	≈ 12 (Iberian Peninsula, July 2025)	≈ 8	Sector projections of ≈75–150 stations by 2030, concentrated on the Mediterranean and Atlantic corridors, border crossings, ports and industrial hubs	≥ 100 (Hydrogen Roadmap); AFIR requires one station every 200 km on the TEN-T core network and in urban nodes (79 needed to comply with)	≈115 fuel-cell vehicles registered nationally (2025). Bus fleets in Barcelona, Madrid and Palma de Mallorca are the main anchor demand; CNH2/Fha operates a fixed station (since 2015); and portable refueling units covering both pressures are present at CNH2

Key Technologies & R&D Focus Areas

Technology Area	Development Stage	Key Activities/Projects	Lead Organizations	Funding (annual)	Notes
PEM Electrolysis	Commercial	Domestic manufacturing of stacks and systems; testing, validation and certification of stacks and balance of plant; degradation and dynamic-	H2B2, Accelera by Cummins, Ingeteam, CNH2, CSIC, Tecnalia, Fha	n.d.	kW to multi-MW range. Accelera operates an electrolyzer Gigafactory in Guadalajara; H2B2 manufactures entirely in Spain and exports

Technology Area	Development Stage	Key Activities/Projects	Lead Organizations	Funding (annual)	Notes
		operation studies under variable renewable supply			
Alkaline Electrolysis	Commercial	Establishment of domestic manufacturing capacity; pressurized alkaline stack development; integration with large industrial off-takers	Ariema, Sener, Nordex, Ingeteam, CNH2, Tecnalia, Fha	n.d.	The dominant technology choice among awarded H2 Valles projects; c. 90% of electrolyzers in those projects are of European manufacture
AEM Electrolysis	Research/Pilot	Membrane and catalyst development, non-noble-metal electrocatalysis, short-stack testing	H2B2 (IPCEI Hy2Tech), CSIC, CNH2, universities	n.d.	Positioned as a cost-reduction route for distributed and mobility-linked production
SOEC (High-Temp)	Research/Pilot	Cell and stack development, reversible operation (rSOC), co-electrolysis for synthetic fuels, integration with industrial waste heat	CNH2 (incl. the SymSOEC project), IREC, CSIC, Tecnalia, H2B2	n.d.	Industrial-integration focus: refining, steel, high temperature industrial processes, and e-fuel synthesis
PEMFC (Passenger Vehicles)	Research/early market	Testing and homologation support; fleet demonstration	AJUSA, CNH2, universities, Fha, vehicle importers	n.d.	No domestic passenger FCEV manufacturing. ≈115 fuel-cell vehicles registered nationally;

Technology Area	Development Stage	Key Activities/Projects	Lead Organizations	Funding (annual)	Notes
					deployment constrained by refueling infrastructure
PEMFC (Heavy-Duty)	Pilot/early commercial	Fuel-cell trucks, buses and coaches; hydrogen trains; non-road and port machinery	Iveco Group (IPCEI Hy2Tech), Irizar-Alsa, CAF (FCH2RAIL), Talgo, CNH2, Fundación Valenciaport	n.d.	The most dynamic mobility segment. Examples include the Irizar i6S Efficient H2 coach in real operation with ALSA in Madrid, and the CAF FCH2RAIL demonstrator tested on the Spanish network
SOFC (Stationary)	Research	Materials and cell development, µ-CHP and industrial integration concepts, ammonia- and biogas-fueled operation	CSIC, IREC, CNH2, universities	n.d.	Limited domestic market; activity concentrated in materials research and system-level testing
H_2 Storage	Research/Pilot/Commercial	700 bar and 350 bar vessel testing; metal hydrides and solid-state carriers; ammonia as a carrier and cracking; underground storage feasibility	CNH2, Calvera Hydrogen, Hiperbaric, Enagás, CSIC (Instituto de Carboquímica), Tecnalia	n.d.	700 bar automotive, bulk gaseous transport and materials-based storage. Underground salt-cavern storage is in the study phase

Technology Area	Development Stage	Key Activities/Projects	Lead Organizations	Funding (annual)	Notes
Other Focus Areas	Research/Pilot	e-SAF and e-methanol synthesis, green ammonia, RFNBO traceability and certification, safety and regulatory testing, digitalization and predictive maintenance of hydrogen assets, waste valorization to hydrogen	CNH2, Moeve, Repsol-Petronor, RIC Energy, BP, CSIC, IMDEA Energía, Fha	n.d.	Aviation and maritime fuels are a strategic priority: a dedicated basket of the European Hydrogen Bank AaaS budget (€136.4M) is reserved for RFNBOs supplying these sectors. Pilot plants available at CNH2 to test and validate components, performance and improvements on Power to X project

Total Public R&D Funding (2024/2025):

No consolidated national figure is published for hydrogen and fuel-cell R&D alone. Identifiable competitive R&D awards include €44.2M to 25 projects in the second call of H2 Cadena de Valor Programme 4 (2024), together with the State–Regions Plan Complementario de Energía e Hidrógeno Renovable (closed in 2025), regional programmes and Spanish participation in Clean Hydrogen JU and Horizon Europe calls. These sit alongside deployment aid of a different order of magnitude (€1,223M for H2 Valleys and €659.4M under the European Hydrogen Bank AaaS).

Main Research Institutions: Centro Nacional del Hidrógeno (CNH2, Puertollano), the national reference center, with 14 laboratories and 4 auxiliary facilities covering the whole value chain, including testing, validation, homologation and certification; CSIC (Instituto de Carboquímica, ITQ, ICP, ICMAB); CIEMAT; Tecnalia, Universidad de Mondragón, CIDETEC and CIC energiGUNE (Basque Country); IMDEA Energía (Madrid); IREC (Catalonia); Fundación Hidrógeno Aragón; and university groups at UCLM, Universidad de Zaragoza, UPV, Universidad de Sevilla, Universidad de Santiago, Universidad de Vigo, UPM and UPC. The Comillas–ICAI Hydrogen Chair provides the sector's principal independent techno-economic monitoring.

PROJECTS & DEMONSTRATION INITIATIVES

Major Demonstration & Commercial Projects

Project Name	Status	Scale & Capacity	Primary Application	Lead Partners	Timeline	Funding	Expected Outcomes
Puertollano Green Hydrogen Plant	Operational (since 2022)	20 MW PEM; 100 MWp PV; 20 MWh battery; ≈1,500 t H_2/y	Industry (green ammonia and fertilizers) + mobility	Iberdrola, Fertiberia, Enagás	2020–2022	≈ €150M	Europe's largest green hydrogen plant for industrial use at commissioning and Spain's first operating hydrogen valley. Four years of real operating experience on grid integration, renewable intermittency and continuous industrial supply. On-site refueling station
Cartagena Large Scale Electrolyzer	Construction (FID 2025)	100 MW; ≈15,000 t H_2/y	Industry (refinery, HVO and SAF production)	Repsol	2025–2028	IPCEI Hy2Use support	One of only two European FIDs above 20 MW in 2025 and the largest in

Project Name	Status	Scale & Capacity	Primary Application	Lead Partners	Timeline	Funding	Expected Outcomes
							Spain to date. Anchor asset of the Cartagena hydrogen valley
Andalusian Green Hydrogen Valley – Onuba phase	Construction (FID March 2026)	300 MW (+100 MW option); ≈45,000 t H_2/y	Industry, e-fuels, maritime and aviation	Moeve, Enagás Renovable (Enalter)	2026–2030	€304M (H2 Valleys) of > €1,000M phase 1	Largest green hydrogen initiative in southern Europe; European PCI. Includes a dedicated self-consumption PV plant and associated infrastructure at Palos de la Frontera (Huelva)
Catalina	Planning/ early construction	500 MW	Industry (green ammonia and fertilizers)	Copenhagen Infrastructure Partners, Enagás Renovable, Vestas, Fertiberia	2025–2030	€245M (H2 Valleys)	Largest single award under H2 Valleys; located in Andorra (Teruel), a just-transition and demographic-

Project Name	Status	Scale & Capacity	Primary Application	Lead Partners	Timeline	Funding	Expected Outcomes
							challenge municipality, with connected renewable generation
León Green Hydrogen Valley	Planning	415.2 MW	Industry (ammonia and fertilizers)	Naturgy, Enagás Renovable, Fertiberia (off-taker)	2025–2030	€180M (H2 Vallesy)	Reindustrialization of the La Robla just-transition area, supplying renewable hydrogen to Fertiberia
Compostilla	Planning	220 MW	e-SAF for aviation (H_2 + biogenic CO_2)	RIC Energy	2025–2030	€81.4M (H2 Valles)	Combines renewable hydrogen with captured biogenic CO_2 to produce sustainable aviation fuel at Cubillos del Sil (León)
Green Hysland	Operational	7.5 MW; ≈300 t H_2/y	Mobility, port, stationary power and gas-grid injection	Acciona, Enagás, Redexis, Balearic Islands Government, Clean Hydrogen	2021–2025	EU (Clean Hydrogen JU)	First hydrogen valley in southern Europe and a reference for island

Project Name	Status	Scale & Capacity	Primary Application	Lead Partners	Timeline	Funding	Expected Outcomes
				JU consortium			decarbonization: fuel-cell buses, port applications, fuel-cell CHP in public buildings and blending into the local gas network
H2Ports	Completed/in operation	Reach stacker, yard tractor and a mobile refueling station	Port machinery and heavy non-road mobility	Fundación Valenciaport, Port Authority of Valencia, CNH2, Enea, Atena, MSC, Grimaldi	2019–2025	EU (Clean Hydrogen JU)	First demonstration in Europe of fuel-cell container-handling equipment in real port operations, with a mobile hydrogen supply station validated by CNH2

Hydrogen Valleys & Regional Clusters

Valley/Initiative Name	Location (City/Region)	Primary Focus Sectors	Projected H_2 Demand (kt/year by 2030)	Current Status	Total Investment (€M)
Andalusian Green Hydrogen Valley (Onuba	Huelva and Cádiz, Andalusia	Industry, e-fuels, maritime and aviation	≈ 45 (phase 1)	Early construction; FID taken March 2026	> €1,000 (phase 1); €304M public

Valley/Initiative Name	Location (City/Region)	Primary Focus Sectors	Projected H_2 Demand (kt/year by 2030)	Current Status	Total Investment (€M)
+ Campo de Gibraltar)					
Catalina + HyBERUS	Andorra (Teruel), Fabara (Zaragoza) and Ascó (Tarragona), Aragón–Catalonia	Industry, fertilizers and e-fuels	≈ 90 combined	Planning/early construction	≈ €1,500; €383.6M public
Castilla y León Hydrogen Cluster (León Valley + Compostilla)	La Robla and Cubillos del Sil (León)	Industry, fertilizers and aviation e-fuels	≈ 70 combined	Planning	≈ €1,300; €261M public
A Coruña Hydrogen Valley	A Coruña, Galicia	Industry and mobility	≈ 30	Planning	≈ €700; €170M public
T-HYNET (Tarragona)	La Pobla de Mafumet, Catalonia	Industry (refining and petrochemicals)	≈ 25	Planning	≈ €600; €165M public
Puertollano Hydrogen Valley	Puertollano, Castilla-La Mancha	Industry (fertilizers), R&D, testing and certification, mobility	≈ 2 (operating today)	Operational; the only fully operating valley in Spain	≈ €150 executed
Green Hysland	Mallorca, Balearic Islands	Mixed: mobility, port, power and gas grid	≈ 0.3	Operational	≈ €50
Basque Hydrogen Corridor (BH2C)	Basque Country	Industry, mobility and manufacturing value chain	≈ 20	Planning/partly under execution	≈ €1,500 announced

Industry Landscape & Commercial Ecosystem

Key Industry Players & Technology Focus

Company Name	Technology /Product Focus	Type	Capacity/Scale	Development Stage	Applications	Notes
ELECTROLYZER DEVELOPERS						
Accelera by Cummins	PEM	Stack + system	Gigafactory in Guadalajara; systems up to 100 MW	Commercial	Industrial and grid-connected	Largest electrolyzer manufacturing facility in Spain; supplies European flagship projects
H2B2 Electrolysis Technologies	PEM (AEM and SOEC in development)	Stack, system and turnkey plants	kW to multi-MW	Commercial (PEM)/R&D (AEM, SOEC)	Industrial, mobility and off-grid	Seville-based; fully domestic design and manufacturing, strong export orientation. IPCEI Hy2Tech project Tecnopropia (€24.9M)
Sener	Alkaline	Stack + system + EPC	MW scale	Pilot to commercial	Industrial	Electrolyzer factory in the Basque Country under IPCEI Hy2Tech (€10M); first phase alkaline, second phase proprietary technology
ARIEMA	Alkaline	Stack, system and	kW to multi-MW	Commercial	Industrial and off-grid	Electrolyzer factory in

Company Name	Technology /Product Focus	Type	Capacity/Scale	Development Stage	Applications	Notes
		turnkey plants				Huelva); proprietary technology
Nordex	Electrolysis technology development	System	MW scale	R&D/pilot	Renewable-coupled production	IPCEI Hy2Tech participant (€11.6M)
Ingeteam	Power electronics and rectifiers for electrolyzers; plant control	Component + system	Up to hundreds of MW	Commercial	Industrial and grid integration	Critical enabling supplier; also active in dedicated R&D test facilities
FUEL CELL MANUFACTURERS						
AJUSA	PEMFC	Stack + system	hundreds of kW	Commercial	Industrial, mobility and off-grid	Production plant in Albacete (Castilla La Mancha). Proprietary technology.
FUEL CELL & VEHICLE MANUFACTURERS						
Iveco Group	PEMFC heavy vehicles	Vehicle integration	Trucks and buses	Pilot/early commercial	Heavy road transport	IPCEI Hy2Tech; investment in Madrid, Valladolid and Barcelona sites, including the first series of fuel-cell pilot vehicles

Company Name	Technology /Product Focus	Type	Capacity/Scale	Development Stage	Applications	Notes
Irizar	PEMFC buses, coaches and rigid trucks	Vehicle integration	≈ 100–200 kW per unit	Early commercial	Urban and intercity passenger transport	The i6S Efficient H2 coach (190 kW stack, >1,000 km range) is in real operation with ALSA in Madrid
CAF	PEMFC rail traction	Vehicle integration	MW-class trainsets	Demonstration	Rail on non-electrified lines	FCH2RAIL demonstrator tested on the Spanish network; a route to the roadmap target of two commercial hydrogen rail services
Talgo	PEMFC rail traction (Vittal One)	Vehicle integration	Regional trainset	Demonstration	Regional rail	Domestic hydrogen train development programme
SYSTEM INTEGRATORS & INFRASTRUCTURE						
Enagás/Enagás Infraestructuras de Hidrógeno	Transmission, storage and refueling infrastructure	Systems and services	≈2,600 km network; 2 salt caverns storage	Development/permitting	National transport and export	Provisional Hydrogen Transmission Network Operator (RDL 8/2023); promoter of H2Med. Enagás

Company Name	Technology /Product Focus	Type	Capacity/Scale	Development Stage	Applications	Notes
						Renovable is also a co-developer of several H2 Valleys projects
Calvera Hydrogen	High-pressure storage, transport modules and refueling stations	Systems and services	200–500 bar transport; 350/700 bar dispensing	Commercial	Distribution and mobility	Zaragoza-based; supplier to Spanish and European refueling projects
Hiperbaric	Hydrogen compression	Component + system	Up to 1,000 bars	Commercial	Refueling and industrial	Burgos-based; diversification from high-pressure food processing into hydrogen compression
H_2 PRODUCTION & SUPPLY						
Iberdrola	Green H_2 production	Producer	20 MW operational; 350 kt/y targeted by 2030 (group-wide)	Operational + planned	Industry and mobility	Operator of the Puertollano plant and of the public refueling station (Zona Franca, Barcelona) supplying TMB buses

Company Name	Technology /Product Focus	Type	Capacity/Scale	Development Stage	Applications	Notes
Moeve (formerly Cepsa)	Green H_2 and derivatives	Producer/supplier	300 MW phase 1; ambition of 2 GW by 2030	Under construction	Industry, maritime and aviation	Andalusian Green Hydrogen Valley; European PCI status
Repsol	Green H_2 and renewable fuels	Producer/supplier	100 MW under construction; ≈600–700 MW targeted by 2030	Under construction + planned	Refining, HVO/SAF and e-fuels	Cartagena, Petronor (Bay of Biscay) and Tarragona; the revision illustrates the sector-wide reassessment of 2030 ambitions
Fertiberia	Green ammonia and fertilizers	Offtaker/producer	Anchor demand for >1 GW of announced electrolysis	Operational (Puertollano) + planned	Industry	The single most important industrial off-taker in the Spanish hydrogen economy
Naturgy, Acciona, EDP, Endesa, Ignis, RIC Energy, Armonía Green Galicia	Green H_2 project development	Developers	Ten to hundreds of MW each	Planning to construction	Industry and e-fuels	Principal utility and independent developers behind the awarded valleys
Air Liquide, Carburos Metálicos (Air Products), Messer, Nippon Gases	Industrial gas supply and distribution	Suppliers	> 500 kt/y of hydrogen supplied nationally today	Operational	Industry and mobility	Incumbent suppliers of predominantly fossil-based hydrogen; progressively integrating

Company Name	Technology /Product Focus	Type	Capacity/Scale	Development Stage	Applications	Notes
						renewable volumes

Outlook, Challenges & Next Steps

2026 Priorities & Planned Actions

Hydrogen Act: preparation and public consultation of the "Anteproyecto de Ley" announced by MITECO in January 2026, designed to give medium and long-term visibility, and stability to investment and to adapt energy markets to renewable molecules, including transposition of Directive (EU) 2024/1788 and the permanent designation and regulation of the hydrogen network operator.

Transport and renewable fuels: implementation of the Royal Decree on decarbonization of transport and promotion of renewable fuels, approved in July 2026, which sets the framework to 2040, introduces an e-credits mechanism and reinforces traceability along the value chain.

Certification and traceability: development of the national sustainability and GHG verification system for renewable gases, allowing the Spanish gas system to be treated integrally through the Virtual Balancing Tank and reducing audit and certification costs relative to voluntary schemes.

Infrastructure: start of construction of the Spanish Hydrogen Trunk Network in 2026 with an investment of ≈€2,645M towards 2030 operation; completion in October 2026 of the 18-month public participation plan covering 13 regions and more than 500 municipalities; continued engineering and environmental permitting for H2Med (BarMar and CelZa, operation targeted for 2032).

Funding: execution of the €1,223M awarded under H2 Valleys and of the €659.4M allocated through the European Hydrogen Bank Auctions-as-a-Service mechanism; resolution of grid demand-capacity tenders, several of which are linked to renewable hydrogen projects; first cogeneration auction (600 MW in 2026, hydrogen-ready plants).

Projects: first large-scale electrolyzers moving into commissioning, led by Cartagena and Bilbao (100 MW each) and the Onuba phase of the Andalusian valley (300 MW); further FIDs expected across the awarded valleys.

R&D: consolidation of new CNH2 capabilities for higher-TRL work, including portable pilot plants for waste valorization and fuel synthesis, expansion of SOEC and rSOC activity, RFNBO traceability and certification methodologies, and OT/IT security and digital-twin approaches for hydrogen assets. Other research actors are planned to also increase their capabilities too (Ciemat, Universities, IMDEA Energy, Fha…).

Sector coordination: Spain hosts the European Hydrogen Energy Conference (EHEC 2026) in Seville, organized by the Spanish Hydrogen Association (AeH2), expected to gather around 2,000 participants from 45 countries. Other associations are also creating a partnership scope to move all together forward (i.e. Crecemos, Shyne, AEAR, regional valleys and/or clusters…).

Key Challenges to H_2 Deployment

Cost competitiveness and demand creation: renewable hydrogen remains substantially more expensive than fossil-based hydrogen, and off-take contracts are the binding constraint. Industry leaders have publicly acknowledged repeated delays on final investment decisions; out of thirteen potential European FIDs to be taken in 2025 (≈450 MW), only two exceeded 20 MW, one of them in Spain.

Gap between announced and bankable capacity: the announced pipeline reaches ≈20 GW, while credible 2030 capacity is estimated at ≈13.3 GW and operating capacity in 2030 at roughly 4.85 GW on current commitments. Managing this gap without eroding confidence is the central execution challenge.

Grid access and electricity costs: saturation of grid connection capacity and the treatment of network charges and levies for electrolyzers directly determine load factors and levelized cost. Demand-capacity tenders are a first response but do not yet cover all industrial hubs.

Regulatory completeness and permitting: the hydrogen and decarbonized gas market framework is not yet fully transposed, and the interaction between RFNBO delegated acts, guarantees of origin, pressure equipment and safety regulation, and environmental permitting lengthens development timelines. The announced Hydrogen Act is intended to close this gap.

Technology development needs: durability and dynamic operation of stacks under highly variable renewable input; cost and criticality of materials; lowering critical raw materials use; scale-up of AEM and SOEC; efficient integration of high-temperature electrolysis with industrial processes; hydrogen quality assurance for fuel-cell applications; and large-scale storage, where no operational asset yet exists in Spain.

Industrial base: absence of large-scale domestic fuel-cell stack manufacturing and dependence on imported components and critical raw materials for both electrolyzers and fuel cells.

Mobility infrastructure: with ≈12 operational refueling stations and ≈115 registered fuel-cell vehicles, the classic chicken-and-egg problem persists. Captive fleets (urban buses, coaches, port and logistics equipment) remain the realistic entry route.

Water availability and social acceptance: several of the best resource areas are in water-stressed regions, making water sourcing, efficiency and transparent public participation a key condition for project development.

Skills: shortage of specialized technical profiles for construction, operation, maintenance and inspection of hydrogen installations, addressed in part through training requirements embedded in national funding programmes.

Strategic Opportunities & Competitive Advantages

Renewable resource: the best combined solar and wind resource in the European Union, with 55.5% of electricity generated from renewables in 2025 (56.6% including self-consumption) and close to 10 GW of new solar and wind capacity commissioned in that year alone. This underpins the potential to produce among the most competitive renewable hydrogen in Europe.

Land and siting: the second largest country in the EU by area, with substantial land availability adjacent to renewable resources and to just-transition territories where hydrogen projects deliver reindustrialization (Puertollano, Andorra (Teruel), La Robla and Cubillos del Sil among them).

Existing demand to substitute more than 500 kt/y of fossil-based hydrogen already consumed in refining, ammonia and chemicals provides a large, located and immediately addressable market, avoiding the need to create demand from scratch.

Geographic position and export: H2Med and the trunk network position Spain as a supply hub for north-west Europe, with capacity for up to 2 Mt/y, around 20% of expected EU 2030 production, together with Atlantic and Mediterranean port infrastructure suited to ammonia, methanol and e-fuel export.

Derivatives and regulatory pull: e-SAF, e-methanol and green ammonia benefit from the ReFuelEU Aviation and FuelEU Maritime mandates, and several awarded valleys already integrate synthesis, storage and transport of derivatives rather than hydrogen development alone.

Industrial and technological base: electrolyzer manufacturing of European significance (Accelera, H2B2, Sener, Nordex, Ariema), a strong power-electronics and EPC sector, and internationally competitive rail and bus manufacturers positioned in fuel-cell heavy mobility.

Testing, validation and certification infrastructure: CNH2 offers full value-chain laboratory and pilot capability, production, storage and distribution, transformation and end use, available to the national and international scientific, technological and industrial community, and is a natural partner for FCE TCP collaborative work on testing protocols, durability and safety. Other institutions working on hydrogen for many years also collaborate in developing the hydrogen ecosystem in Spain such as Ciemat, several universities, IMDEA Energy, Fha, among others.

International collaboration: active participation in the IEA Technology Collaboration Programmes, the Clean Hydrogen Partnership, IPCEIs, IPHE and Mission Innovation, together with an established technical cooperation channel with Latin America through which Spanish know-how on regulation and project development is being transferred.

References & Information Sources

- MITECO - Hoja de Ruta del Hidrógeno: una apuesta por el hidrógeno renovable (2020); Plan Nacional Integrado de Energía y Clima 2023–2030, update approved September 2024; hydrogen policy and legislation pages; press releases 2025–2026.
- IDAE H2 Valles, H2 Pioneros and H2 Cadena de Valor calls and awards; Auctions-as-a-Service calls under RD 535/2025; electronic register resolutions.
- Plan de Recuperación, Transformación y Resiliencia (PERTE ERHA) — project fact sheets and award publications.
- Enagás/Enagás Infraestructuras de Hidrógeno - Spanish Hydrogen Trunk Network, associated storage and H2Med; public participation plan documentation; sector publications.
- Red Eléctrica, Informe del sistema eléctrico español 2025 and Las renovables en el sistema eléctrico español 2025.
- European Commission/CINEA - European Hydrogen Bank auction results; IPCEI Hy2Tech, Hy2Use and Hy2Move decisions; PCI lists; Clean Hydrogen Partnership project portfolio.

- Asociación Española del Hidrógeno (AeH2) and Gasnam-Neutral Transport - sector statistics, projects, refuelling infrastructure, workshops, and EHEC 2026.
- Cátedra de Estudios sobre el Hidrógeno, Universidad Pontificia Comillas - annual report on renewable hydrogen in Spain.
- CNH2 - laboratory and pilot-plant capabilities, project portfolio and technical publications (www.cnh2.es).
- Company and project sources: Iberdrola, Moeve, Repsol, Naturgy, Fertiberia, Acciona, RIC Energy, H2B2, Accelera by Cummins, Sener, Irizar, CAF, Talgo, Calvera Hydrogen, Hiperbaric, Fundación Valenciaport.

Task Updates

TASK 30

Electrolysis

Task manager

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Contact

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FACTS & DEMONSTRATED PROGRESS

- Round Robin test on PEM, AEL and AEM as well as start of gas crossover Round Robin for PEM
- Industrial view on AEL launched
- Perspectives/Opinion Paper on AST testing protocols
- Knowledge share on stainless steel production at Alleima, Direct reduction of Iron with hydrogen, 20 MW AEL electrolyzer installation at Ovako, Platinum mining, visit of a gold/Platinum or chemical processing asset and South Africa hydrogen infrastructure
- Breakout groups were created in 2016, refined and revised in 2022 after the 2020-2021 forced pandemic pause to both improve communication and pool expertise
- Activity on system and balance of plant included from 2025 to reflect the scale-up process
- Round robin 2 for PEM and round robin1 for AEL completed
- knowledge shared across members
- synergy search with H2 TCP
- Webinar with Task30 community with 6 presentations in 2025
- Technology contributes to industry decarbonization, emissions reduction, reduction of renewable energy curtailment and negative pricing

OPINION & STRATEGIC ASSESSMENT

Key barriers remaining and their priority for R&D focus

- Degradation mechanism: prediction and control
- Safety and part load operation

Expected developments/trends for next 12–24 months

- Next generation cell development with PFAS -free membrane, low Ir catalysts

Recommendations for accelerating technology deployment or addressing critical challenges

- Extend the lifetime of electrolyzers: Understand and mitigate degradation mechanisms at cell and components level

Task Overview & Objectives

Mission & Scope

The objective of the Annex is to provide a platform for international information sharing and learning between electrolyzer technologies experts from academia and industries. The aim is to provide innovative solutions to accelerate the commercialization of the following technologies:

- Proton Exchange Membrane (PEM) water electrolysis
- Alkaline electrolysis,
- Anion Exchange Membrane (AEM) electrolysis

The group concentrates mainly on the low temperature technologies and updates on the high temperature technology based on Solid Oxide Electrochemical Cell (SOEC) with presentations by lead experts and industries. In addition to information exchange, the standardization of definitions, harmonization of test procedures/protocols is the focus of the current activity. By that Task30, electrolysis is fully integrated within the FCE TCP's goals to develop fuel cell and electrolyzer technologies and promote their applications internationally.

Subtasks/Working Groups:

Working Group	Lead/Co-Lead	Primary Focus
[Subtask A / Joint Activities]	A. Léon, B. Bensmann	[Round robin test, industrial view]
Subtask B / Flash talks	A. Léon	Research and Industry highlights
Subtask C / Breakout session	See section technical working group	Cell components, system and balance of plant
Subtask D / Webinar	B. Bensmann	International exchange on water electrolysis research topics

Task Duration & History

- **Established:** 2014
- **Current Cycle:** 2024-2027
- **Previous Operating Agents:** Dr. Marcelo Carmo (2014-2021), Dr. Guido Bender (2023-2024)
- **Key Milestones in Task History:** Major achievements (group of participants from industry and academic that gather to advance the electrolyzer technology; international round robin tests, industrial view on technology, international webinars, visit of industries linked with hydrogen), structural changes (change of the management every two years, new structure for the breakout session to better reflect the changes in the technology, significant publications on the round robin test in PEM and AEL technology)

Activities & Work executed in 2025

Workshops & Meetings

Format & Structure: - **Number of Workshops:** [2] in-person meetings held in 2025 - **Typical Duration:** [3 days] - **Participant Capacity:** [Typical attendance: 50 to 70 people] - **Meeting Locations & Dates:** - Spring 2025: [Alleima, Sandviken, Sweden] — [7-9 May 2025] - Fall 2025: [NWU, Gauteng, South Africa] — [28-31 October 2025]

Typical Workshop Agenda Structure: - **Presentations (40% of time):** Keynotes, technical talks, industry updates, round-table discussions - **Working Group Sessions (50% of time):** Focused technical discussions, breakout groups, harmonization activities - **Networking & Knowledge Exchange (10% of time):** Informal discussions, bilateral meetings, facility tours - **Governance/Administrative (150 h per year):** Task planning, reporting, decision-making, meeting attendance; additional time along the year with meetings every two weeks with the host and meetings with the core team as well as speakers invitation

Technical Working Groups & Harmonization Efforts

Breakout Group 1:

Cell Components Integration - **Leads:** Boris Bensmann, Meital Shviro, Kensaku Nagasaki

Focus: To identify key technical challenges, R&D priorities, and collaboration opportunities related to cell component integration (membranes, electrodes, separators, interfaces …) across alkaline, AEM, and PEM technologies, focusing on performance, degradation, and durability.

2025 Achievements: Survey about key integration challenges, degradation of origin and mechanisms and diagnostics and characterization tools. Starting an AST focus paper aiming discussion a publication. Started discussions about common share point for data about minimum requirements for materials in certain layers.

Key Findings: Identifying the catalyst layer/GDL-interface and gas crossover as main topics of interest and triggered discussion about that.

2026 Plan: Aligning lab and industrial stack testing regarding hardware and testing protocol. Submission of AST perspectives paper.

Breakout Group 2: Electrodes

Leads: [Jochen Loffler, Serhiy Cherevko, Iryna Zenyuk, Oluf Jens]

Focus: Electrodes and catalysts for PEM, AEM and AWE — identifying challenges, prioritizing research needs, and outlining collaborative actions across industry and academia.

2025 Achievements: Revisited recent publications in high-ranked journals. Agreed about current key challenges in the field based on presentations from industry and R&D. Active exchange through presentations between members in the working group about latest activities at their organization.

Key Findings: Optimal 3D structures and stable low-PGM catalysts remain relevant challenges for all 3 electrolyzer technologies. Ongoing debate about (dis)advantages of catalyst coated membranes and catalyst coated electrodes, lack of full understanding of degradation phenomena, and optimal trade-off between performance of 3-d structures versus cost and manufacturability.

2026 Plan: Continue exchanging latest developments and challenging the CCM and PTE concepts and manufacturing. Find synergies between AEM and PEM, as well as between AWE and AEM. Also highlight specific challenges for individual technologies.

Breakout Group 3: Membrane Separator

Leads: Carolin Klose, Steven Holdcroft, Jan Lender

Focus: Membranes and separators for PEM/AEM and alkaline electrolysis — identifying challenges, prioritizing research needs, and outlining collaborative actions across industry and academia.

2025 Achievements: Revisited and updated the 2019 membrane degradation survey; expanded scope to include AEM systems and fluorine-free membranes; discussed water quality impacts and measurement techniques; initiated development of a degradation stressor questionnaire.

Key Findings: Membrane thinning, creeping, and pinhole formation remain critical stress-related degradation mechanisms. Standardized testing protocols are lacking, and water contaminants pose a significant durability risk with notable economic implications.

2026 Plan: Update the 2019 degradation table to include AEMs and mitigation strategies; distribute and evaluate the degradation questionnaire; map existing test protocols for harmonization; explore collaborative studies on water contamination. The ongoing goal of the group is to identify pain points in industry and distribute that understanding to the broader IEA working group to foster future academic research

Breakout Group 4: System and Balance of plants

Leads: Tom Smolinka, Christopher Capuano, Joris Beckler

Focus: Perform the status of current installation. Discuss the main challenges and learn how industrial are moving forward with these challenges and how research can help to move forward. What is needed to keep up progress?

2025 Achievements: WG4 will concentrate on Generic system layout of electrolysis system, lifetime and durability, cost structure for low and high temperature electrolyzer

Key Findings: Create a general system design for EL systems as common platform for further discussion (AEL, AEMEL, PEMEL, HTEL) ▪Derive generic system layouts for small (5 MW) & Large (100 MW) by including parts list and dimensioning of main components

2026 Plan: Establish the layout and provide a cost structure; Benefit for EL community: ▪Freely accessible tool with a high degree of transparency ▪ Identification of current plant cost bottlenecks and drivers ▪Where are potentials to reduce costs on the BoP side?

Publications & Standardization Activities

Standards Development & Harmonization Documents: Round-Robin Tests on PEM (round 3), Alkaline (round 2) and AEM (round 1). Shipment of samples, tests are ongoing

Other Dissemination Activities: Webinars: international 5 organized in 2025

Participating Organizations & Network

Member Countries & Key Organizations

Country	Participating Organizations
Austria	TU Graz
Belgium	Bekaert, Chemours
Brazil	Embrapa, Uni Federal de São Carlos
Canada	SFU, NRC
Chile	Mining3
China	Dalian Institute of Chemical physics
Czech Republic	TU Prague
Denmark	DTU, Topsoe
France	CEA
Germany	EIFER, LUH, Cen-Mat, Quest one, FZJ, Fh. ISE, IWES, IFAM, DLR, Siemens Energy, HIERN, TU Clausthal, Schaeffler, ZBT, RWE, Propuls, Uni Freiburg, Robert Bosch, Heraeus, Air Liquide, element 22, Hahn-Sickhard, Elementarhy,
Italy	ENEA, UFI hydrogen SPA, F2N green
Japan	AGC inc., Toyota, AIST, Daido Metal Co, Green Ammonia Research center, DeNora Permelec, Nagoya University
Norway	Sintef
South Africa	Northwest University, HySA, Metix, Syensqo, Valterra Platinum, Sasol, Isondo Precious Metals, Sanedi, Minerals Council of South Africa, Toyota South Africa Motors
Spain	Matteco
Sweden	Alleima, Ionuatics, Hydroyal, Redoxme, Stegra, Hybrit, Vätgas Sverige, Smoltek
The Netherlands	TNO
United Kingdom	Honeywell
USA	NRL, UCI, Nel Hydrogen, Uni Connecticut, Hplus Inc, Honeywell UOP

Total Participating Institutions (cumulative since Task inception)

- **Academic/Research Institutions:** 50
- **Industry Companies:** 40
- **Government/National Labs:** 10
- **Total Organizations:** 100+

- **Total Individual Experts:** Approx. 100
- **Countries Represented:** 19

Work Plan for 2026

Planned Meetings & Activities

Activity	Format	Location/Topic	Planned Date	Expected Participants
Spring Workshop	In-person	Petten, The Netherlands	May 2026	65-70 people
Fall Workshop	In-person	UBC, Canada	October 2026	50–70 people
Webinar Series	Virtual	Electrolyzer related topics	Monthly	25 to 30 people

Priority Work Areas & Milestones

1. **Round Robin 2 -AEL**
   - **Objective:** Complete the test, analyze the data
   - **Key Deliverables:** Publication
   - **Leading Group/Expert:** T. Turek
   - **Planned Completion:** End 2026
2. **Industrial View AEL**
   - **Objective:** Finalize the industrial view on AEL
   - **Key Deliverables:** Publication
   - **Leading Group/Expert:** A. Léon
   - **Planned Completion:** End 2026
3. **Perspective paper AEL**
   - **Objective:** Provide perspective for scaling AEL
   - **Key Deliverables:** Publication
   - **Leading Group/Expert:** M. Shivro
   - **Planned Completion:** Submission April 2026
4. **Round Robin 3 PEM**
   - **Objective:** Complete the test, analyze the data
   - **Key Deliverables:** Publication
   - **Leading Group/Expert:** T. Smolinka
5. **Planned Completion:** End 2026 **Round Robin 1 AEM**
   - **Objective:** Finalize tests and complete the test, analyze the data
   - **Key Deliverables:** Publication
   - **Leading Group/Expert:** J. Loffler
   - **Planned Completion:** End 2026
6. **Round Robin 1 Gas Crossover PEM**
   - **Objective:** Analyze the data

- **Key Deliverables:** Publication
- **Leading Group/Expert:** G. Bender
- **Planned Completion:** End 2026

7. **AST Perspectives Paper**
   - **Objective:** Finalize overview and send to Task 30 review panel
   - **Key Deliverables:** Paper, Task 30 internal and international standard
   - **Leading Group/Expert:** M. Shivro, J. Loffler, B. Bensmann
   - **Planned Completion:** End 2026

TASK 33

Fuel Cells for Stationary Applications

Task manager

Matteo Genovese

Contact

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FACTS & DEMONSTRATED PROGRESS

- Task 33 expanded international participation significantly, growing from the 2025 Connecticut meeting toward a broader expected 2026 Austria collaboration network including industry, academia and public agencies from Europe, North America and Asia.
- Preparation of technical reports, benchmarking studies and dissemination materials were developed on stationary fuel cells, climate-neutral districts, resilient power systems and telecom backup applications.
- Comparative analyses confirmed increasing deployment momentum for PEMFC and SOFC systems in telecom infrastructure, distributed generation, CHP and resilient power applications.
- New international collaboration activities involved stakeholders from China, India, the United States, Canada and Europe, strengthening knowledge exchange on deployment trends, durability and system integration.
- The Task contributed to decarbonization strategies by promoting stationary fuel cells as low-emission alternatives to diesel generators for critical infrastructure and distributed energy system

OPINION & STRATEGIC ASSESSMENT

- Stationary fuel cells are transitioning from demonstration activities toward early commercial deployment, particularly in resilient power, telecom backup and data-center applications.
- Hydrogen infrastructure availability, system CAPEX and long-term durability remain key barriers requiring continued R&D and industrial scale-up.
- Strong growth is expected in hybrid fuel-cell architectures integrating batteries, renewable energy and hydrogen storage over the next 12–24 months.
- Standardization, deployment benchmarking and harmonized performance reporting will become increasingly important to accelerate market confidence and investment.
- Cross-sector integration with hydrogen valleys, climate-neutral districts and resilient microgrids represents a major opportunity for stationary fuel cell deployment.

Task Overview Objectives

Mission & Scope

Task 33 focuses on the development, deployment and benchmarking of stationary fuel cell technologies for distributed generation, combined heat and power (CHP), resilient power and climate-neutral energy systems. Activities cover PEMFC, SOFC, PAFC and MCFC technologies, including system integration, durability, market deployment, hybrid architectures and hydrogen ecosystem applications. The Task supports AFC TCP objectives by promoting international collaboration among industry, academia and public institutions, while developing technical reports, benchmarking methodologies and dissemination activities to accelerate commercialization and large-scale deployment of stationary fuel cell systems.

Subtasks/Working Groups:

Working Group	Lead/Co-Lead	Primary Focus
Deployment & Market Analysis	University of Calabria/ Industrial Partners	Global deployment tracking, market intelligence and benchmarking
Climate-Neutral Districts	Austrian Energy Agency	Hydrogen districts, CHP and resilient energy systems
Resilient Power Applications	CNH2	Telecom backup, off-grid systems and diesel replacement
Fuel Cells in Energy Hubs & Hydrogen Valley	ENEA	Fuel Cell Role in Energy Hubs & Hydrogen Valley

Activities & Work Executed in 2025

Workshops & Meetings

Format & Structure

- Number of Workshops:
  - 1 in-person international meeting
  - Multiple virtual coordination meetings and technical exchanges during 2025
- Typical Duration:
  - 2–3 days
- Participant Capacity:
  - Typical attendance: ~20 participants (2025 Connecticut meeting)

Meeting Locations & Dates

- Spring 2025:
  - East Hartford (Connecticut), USA — May 2025
- Fall 2025:
  - Virtual internal coordination and technical working-group meetings
- Additional Activities:
  - AFC TCP dissemination exchanges
  - International technical discussions and collaboration meeting

Typical Workshop Agenda Structure

Presentations (~45%)

- Technical presentations
- Industry updates
- Deployment case studies
- Research activities
- International market trends

Working Group Sessions (~30%)

- Benchmarking discussions
- Deployment tracking
- Climate-neutral districts
- Telecom and resilient power applications
- Harmonization of methodologies

Networking & Knowledge Exchange (~15%)

- Bilateral discussions
- Collaboration planning
- Informal technical exchanges

Governance / Administrative (~10%)

- Task planning
- Reporting activities
- Future meeting organization
- Dissemination planning

Technical Working Groups & Harmonization Efforts

Breakout Group 1: Deployment & Market Analysis

- **Leads:** University of Calabria/ENEA
- **Focus:** Global stationary fuel cell deployment tracking and market benchmarking
- **2025 Achievements:**
  - Development of global deployment infographics and regional market analysis
  - Collection of international deployment and participation datasets
- **Key Findings:**
  - Strong growth in resilient power, telecom and distributed generation applications
  - Increasing participation from Asia and North America
- **2026 Plan:**
  - Expand deployment database
  - Improve harmonization of market and deployment methodologies

Breakout Group 2: Climate-Neutral Districts & CHP

- **Leads:** Austrian Energy Agency
- **Focus:** Hydrogen districts, CHP integration and resilient local energy systems
- **2025 Achievements:**
  - Publication of the report: *Deployment Use of Stationary Fuel Cells for Climate-neutral Districts and Neighborhoods*
- **Key Findings:**
  - Fuel cells provide strong opportunities for seasonal storage, CHP and district resilience

- **2026 Plan:**
  - Expand case studies and techno-economic assessment activities

Breakout Group 3: Resilient Power & Non-Traditional Applications

- **Leads:** CNH2
- **Focus:** Telecom backup, off-grid power and diesel replacement applications
- **2025 Achievements:**
  - Roles of fuel cells in Niche Applications
  - Resilient power deployment frameworks
- **Key Findings:**
  - PEMFC and SOFC systems show strong potential for telecom and critical infrastructure applications
- **2026 Plan:**
  - Expand work on hybrid architectures integrating batteries and hydrogen storage
  - Increase engagement with industrial stakeholders

Publications & Standardization Activities

Peer Review Publications:

- Genovese, M. "Stationary Fuel Cell System." Encyclopedia, MDP. 2021.
- Viviana Cigolotti, Matteo Genovese, Francesco Piraino, Petronilla Fragiacomo, Applications | Overview of Energy Storage Systems, Editor(s): Jürgen Garche, Encyclopedia of Electrochemical Power Sources (Second Edition), Elsevier, 2025, Pages 47-59, ISBN 9780323958226, https://doi.org/10.1016/B978-0-323-96022-9.00091-8. – Scopus
- Matteo Genovese, Viviana Cigolotti, G. Monteleone, Francesco Piraino, O. Corigliano, Petronilla Fragiacomo, Applications – Transportation Applications | Auxiliary Power Units - Fuel Cells, Editor(s): Jürgen Garche, Encyclopedia of Electrochemical Power Sources (Second Edition), Elsevier, 2025, Pages 358-372, ISBN 9780323958226, https://doi.org/10.1016/B978-0-323-96022-9.00198-5. (https://www.sciencedirect.com/science/article/pii/B9780323960229001985) –Scopus
- V. Cigolotti, M. Genovese, P. Fragiacomo (2021), Comprehensive review on fuel cell technology for stationary applications as sustainable and efficient poly-generation energy systems. Energies, 14(16), 4963; DOI: https://doi.org/10.3390/en14164963, Scopus

Technical Reports & White Papers

- *Deployment Use of Stationary Fuel Cells for Climate-neutral Districts and Neighborhoods.* IEA AFC TCP Task 33, 2024, https://ieafuelcell.com/wp-content/uploads/2025/09/IEA_AFC_TCP_Task33_hydrogen-in-neighborhoods_final_revised.pdf
- *Deep Dive Hydrogen Infrastructure – Chapter 2 (DOI): 10.34734/FZJ-2025-04235*
- Cigolotti, M. Genovese (2021), Stationary Fuel Cell Applications: Tracking Market Trends, Advanced Fuel Cells Technology Collaboration Programme (AFC TCP) - International Energy Agency (IEA),

https://www.ieafuelcell.com/fileadmin/publications/2021/2021_AFCTCP_Stationary_Application_MarketTrend.pdf

- V. Cigolotti, M. Genovese (2021), Stationary Fuel Cell Applications: Current and Future Technologies - Costs, Performances, and Potential", Advanced Fuel Cells Technology Collaboration Programme (AFC TCP) - International Energy Agency (IEA), https://www.ieafuelcell.com/fileadmin/publications/2021/2021_AFCTCP_Stationary_Application_Performance.pdf

Standards Development & Harmonization Documents

- Comparative evaluation frameworks for:
  - stationary PEMFC and SOFC systems,
  - CHP applications,
  - telecom backup systems.

Other Dissemination Activities

- Development of:
  - technical infographics,
  - deployment maps,
  - benchmarking graphics,
  - market overviews,
  - executive summaries.
- Stationary Fuel Cell Data Set, "***Stationary Fuel Cells"*** —IEA FCE TCP Website, Global Status of Stationary Fuel Cells. **–Public,** https://ieafuelcell.com/output/stationary-fuel-cells/
- International collaboration meetings and dissemination activities involving:
  - industry,
  - academia,
  - public agencies
- Preparation of communication material supporting Task 33 workshops and international outreach activities.

Technical Developments & Scientific Advances

Major Research Achievements (2025)

Achievement 1: Climate-Neutral Districts Using Stationary Fuel Cells

- **Background:**
  Need for resilient and low-carbon district energy systems integrating hydrogen technologies and CHP applications.
- **Methodology / Approach:** Comparative simulation and deployment analysis of stationary fuel cell integration in urban, rural and industrial energy districts.
- **Results:**
  Demonstrated strong potential for:
  - seasonal hydrogen storage,

    - CHP integration,
    - resilient microgrids,
    - improved renewable energy utilization.
- **Impact:**
  Supports development of climate-neutral districts and hydrogen-based local energy systems.
- **Partners / Institutions Involved:** ENEA, Austrian Energy Agency, University of Calabria, Task 33 contributors.
- **Publication / Reference:** *Deployment Use of Stationary Fuel Cells for Climate-neutral Districts and Neighborhoods* (IEA AFC TCP Task 33).

Achievement 2: Global Deployment & Market Benchmarking of Stationary Fuel Cells

- **Background:** Lack of harmonized benchmarking methodologies and updated deployment tracking for stationary fuel cell systems.
- **Methodology / Approach:** Development of global deployment datasets, regional market analysis and technology benchmarking.
- **Results:**
  Identified:
    - strong growth of PEMFC and SOFC systems,
    - increasing deployment in telecom and resilient power,
    - expansion of industrial participation from Asia, Europe and North America.
- **Impact:** Improved international understanding of market trends and deployment pathways.
- **Partners / Institutions Involved:** ENEA, University of Calabria, AFC TCP contributors and industrial stakeholders.
- **Publication / Reference:** *Stationary Fuel Cells – Global Deployment & Market Outlook* (Task 33 dissemination material).

Achievement 3: Fuel Cells for Resilient & Non-Traditional Applications

- **Background:** Increasing demand for low-emission alternatives to diesel generators in telecom, temporary power and critical infrastructure applications.
- **Methodology / Approach:** PEMFC and SOFC systems for telecom backup, off-grid power and hybrid PV–battery–fuel-cell systems.
- **Results:**
  Fuel Cell Key Features in these applications:
    - high operational reliability,

- low-noise operation,
- reduced emissions,
- strong potential for hybrid resilient-power architectures.

- **Impact:**
  Supports commercialization of stationary fuel cells in non-traditional and high-value applications.

- **Partners / Institutions Involved:** CNH2, Task 33 participants.

Cost & Performance Status

- **Parameter:** Net Electrical Efficiency (SOFC systems)—Status 2025: ~50–60% net AC efficiency—Target 2030: >65% net AC efficiency — Progress: Improved thermal integration and CHP optimization.

- **Parameter:** CHP Total Efficiency — Status 2025: ~80–90% total efficiency — Target 2030: >90% optimized CHP utilization — Progress: Enhanced heat recovery and hybrid system integration.

- **Parameter:** Durability / Lifetime — Status 2025: ~40,000–60,000 operating hours — Target 2030: >80,000 hours — Progress: Reduced degradation rates through improved materials and BoP optimization.

- **Parameter:** Fuel Cell Deployment Scale — Status 2025: Increasing MW-scale deployment in telecom, CHP and resilient power systems — Target 2030: Large-scale commercial deployment and infrastructure integration — Progress: Rapid growth in Asia and North America.

PARTICIPATING ORGANIZATIONS & NETWORK

Member Countries & Key Organizations)

Country	Participating Organizations	Key Contact
Austria	Austrian Energy Agency	Günter Simader
Canada	University of British Columbia, Ballard, Cell Centric	Nicolas Pocard
Finland	VTT, Convion	Jari Kivihao
France	Engie, EODev	Thibault Tallieu
Germany	Sunfire, DLR	Dana Schonvogel
Israel	GenCell, HydroLite	ErvinTal Gutelmacher
Italy	ENEA, University of Calabria (Task Manager), SolydERA	Viviana Cigolotti / Matteo Genovese
Japan	Toshiba, Panasonic	Noboru Hashimoto
Spain	CNH2	Emilio Nieto
Sweden	PowerCell	Per Ekdunge
Switzerland	Beratung Renz Consulting	Beratung Renz Consulting
USA	DOE, California Hydrogen Business Council, Gaia, HyAxiom, T2M	Katrina Fritz / Sridhar Kanuri

Total Participating Institutions (cumulative since Task inception)

- **Academic / Research Institutions:** ~10
- **Industry Companies:** ~18
- **Government / National Labs:** ~8
- **Total Organizations:** 30+
- **Total Individual Experts:** ~20 active participants in 2025 meetings
- **Countries Represented:** 12

Work Plan for 2026

Planned Meetings & Activities

Activity	Format	Location/Topic	Planned Date	Expected Participants
Spring Workshop	In-person	Austria – Stationary Fuel Cells & Resilient Power	Spring 2026	40+
Fall Internal Meeting	Hybrid	Deployment Benchmarking & Market Outlook within Subtasks	Fall 2026	10+
Dissemination Activities	Hybrid	AFC TCP outreach and collaboration	Throughout 2026	International

Priority Work Areas & Milestones

Deployment Benchmarking & Market Intelligence

- **Objective:**
  Expand harmonized global deployment tracking for stationary fuel cells.
- **Key Deliverables:** Updated market outlooks, deployment maps and benchmarking reports.
- **Leading Group / Expert:** ENEA / University of Calabria
- **Planned Completion:** Q4 2026

Resilient Power & Telecom Applications

- **Objective:**
  Analyze fuel-cell deployment in telecom, backup power and off-grid systems.
- **Key Deliverables:** Comparative technical reports and resilient-power case studies.
- **Leading Group / Expert:** University of Calabria / Industrial Partners
- **Planned Completion:** Q3 2026

Climate-Neutral Districts & Hybrid Systems

- **Objective:**
  Develop methodologies for integrating fuel cells with hydrogen storage, batteries and renewable systems.
- **Key Deliverables:** Technical guidelines, case studies and dissemination material.
- **Leading Group / Expert:** Austrian Energy Agency / ENEA
- **Planned Completion:** Q4 2026

Cross-Task Collaboration & Synergies

- Collaboration with AFC TCP Activity on Fuel Cell Electric Vehicles & Hydrogen Refueling Stations:
  - Joint discussion on hydrogen supply-chain challenges relevant to mobility applications and hydrogen refueling stations.
    - Deep Dive Hydrogen Infrastructure – Chapter 2 (DOI): 10.34734/FZJ-2025-04235

- Horizontal Integration:
  - Task 33 contributes to the AFC TCP strategy by supporting:
    - hydrogen-based decarbonization,
    - resilient distributed energy systems,
    - CHP deployment,
    - integration of fuel cells with renewable energy and hydrogen storage,
    - commercialization of hydrogen technologies for critical infrastructure applications.

KEY CHALLENGES & SUCCESS FACTORS

Critical Barriers to Technology Deployment

- Durability, cost and system integration challenges, particularly related to stack degradation, balance-of-plant reliability and thermal management.
- Hydrogen infrastructure and market barriers, including hydrogen availability, logistics, permitting complexity and investment uncertainty.
- Need for harmonized benchmarking and international coordination, especially for deployment metrics, performance reporting and resilient-power applications.

Critical Success Factors for 2025

- Reduction of fuel cell system CAPEX and improved manufacturing scalability, particularly for PEMFC and SOFC stack production and balance-of-plant components.
- Improved durability and operational lifetime, including mitigation of stack degradation, thermal cycling effects, catalyst degradation and interconnect corrosion.
- Expansion of hydrogen infrastructure and reliable fuel logistics, especially for telecom, resilient power and off-grid stationary applications.
- Development of hybrid architectures integrating fuel cells, batteries and renewable energy systems to improve resilience, operational flexibility and energy efficiency.
- Standardization and harmonized performance assessment methodologies to increase market confidence, comparability and bankability of stationary fuel cell systems.
- Growth of commercial deployment in high-value applications such as telecom backup, data centers, climate-neutral districts and critical infrastructure.

References & Further Reading

Task Related Publications & Resources

- Viviana Cigolotti, Matteo Genovese, Francesco Piraino, Petronilla Fragiacomo, Applications | Overview of Energy Storage Systems, Editor(s): Jürgen Garche, Encyclopedia of Electrochemical Power Sources (Second Edition), Elsevier,2025, Pages 47-59, ISBN 9780323958226, https://doi.org/10.1016/B978-0-323-96022-9.00091-8. – Scopus
- Matteo Genovese, Viviana Cigolotti, G. Monteleone, Francesco Piraino, O. Corigliano, Petronilla Fragiacomo, Applications – Transportation Applications | Auxiliary Power Units - Fuel Cells, Editor(s): Jürgen Garche, Encyclopedia of Electrochemical Power Sources (Second Edition), Elsevier, 2025, Pages 358-372, ISBN 9780323958226, https://doi.org/10.1016/B978-0-323-96022-9.00198-5. (https://www.sciencedirect.com/science/article/pii/B9780323960229001985) –Scopus
- V. Cigolotti, M. Genovese, P. Fragiacomo (2021), Comprehensive review on fuel cell technology for stationary applications as sustainable and efficient poly-generation energy systems. Energies, 14(16), 4963; DOI: https://doi.org/10.3390/en14164963, Scopus
- Deployment Use of Stationary Fuel Cells for Climate-neutral Districts and Neighbourhoods. IEA AFC TCP Task 33, 2024, https://ieafuelcell.com/wp-content/uploads/2025/09/IEA_AFC_TCP_Task33_hydrogen-in-neighborhoods_final_revised.pdf
- Deep Dive Hydrogen Infrastructure – Chapter 2 (DOI): 10.34734/FZJ-2025-04235
- Cigolotti, M. Genovese (2021), Stationary Fuel Cell Applications: Tracking Market Trends, Advanced Fuel Cells Technology Collaboration Programme (AFC TCP) - International Energy Agency (IEA), https://www.ieafuelcell.com/fileadmin/publications/2021/2021_AFCTCP_Stationary_Application_MarketTrend.pdf
- Genovese, M. “Stationary Fuel Cell System.” Encyclopedia, MDP. 2021.
- V. Cigolotti, M. Genovese (2021), Stationary Fuel Cell Applications: Current And Future Technologies - Costs, Performances, and Potential", Advanced Fuel Cells Technology Collaboration Programme (AFC TCP) - International Energy Agency (IEA), https://www.ieafuelcell.com/fileadmin/publications/2021/2021_AFCTCP_Stationary_Application_Performance.pdf
- Stationary Fuel Cell Data Set, “Stationary Fuel Cells” —IEA FCE TCP Website, Global Status of Stationary Fuel Cells. –Public, https://ieafuelcell.com/output/stationary-fuel-cells/

TASK 37

Modelling of Fuel Cell Systems

Task manager

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Contact

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FACTS & DEMONSTRATED PROGRESS

- Fuel cell modeling continues to have a stable impact. The focus consists of model consolidation and integration and sees a rise in AI assisted modeling, including digital twins, real-time capable models, surrogate. Models. Model validation and calibration as well as uncertainty quantification works are increasing
- Open-source software continues to increase in relevance, as software and data publication metrics become increasingly important
- The last Task 37 workshop, held in October 2025, brought key modeling groups together to start model benchmarking activities

OPTION & STRATEGIC ASSESSMENT

- hybrid physics-ML models becoming standard
- standardized open models are still lacking
- tighter coupling with electrochemistry and materials informatics
- increased industrialization, transitioning from academic modeling to engineering tool chains

TASK OVERVIEW & OBJECTIVES

Mission & Scope

Task 37 aims to identify limitations in current modelling approaches and promote the exchange of closure equations for fuel cell materials and components. It also explores methodologies for coupling different model types, such as partial differential equation-based models with pore-network models, to enable more comprehensive simulations. A further goal is to develop benchmark cases for model validation, starting from simplified systems and progressing to higher spatial and temporal resolutions. Additionally, Task 37 advocates for the needs of the fuel cell modelling community, supporting collaboration and the integration of modelling into broader research efforts.

Subtasks/Working Groups

Subtask	Primary Focus
Code Development	Collaboratively develop open-source CFD software tailored for fuel cell applications, enabling researchers to simulate fuel cell systems with accuracy and efficiency.
Experimental Validation	Gather experimental data for model validation, focusing on solid oxide fuel cells (SOFCs) and polymer electrolyte fuel cells (PEFCs), and adopting standardized protocols to ensure robust validation practices.
Best Practices in Model Equations	Defining state-of-the-art physics and mathematics for fuel cell modelling, ensuring consistency and reliability in modelling approaches across research groups.

Activities & Work Executed in 2025

Workshops & Meetings

Format & Structure: - **Number of Workshops:** [1] in-person held in 2025 - **Typical Duration:** 1 day- **Participant Capacity:** Typical attendance: 12–25 people - **Meeting Locations & Dates:** - Fall 2025: Chicago, USA — October 16th

Work Plan for 2026

Planned Meetings & Activities

Activity	Format	Location/Topic	Planned Date	Expected Participants
Fall Workshop	In-person	Calgary, Canada	October 2026	15–25 people
Model Benchmarking	Student exchange	Students will benchmark 2 different model codes via a student exchange	Fall 2026	

Priority Work Areas & Milestones

Model Benchmarking

- **Objective:** Benchmark current Open Access Codes
- **Key Deliverables:** Joint publication, Guidelines for selecting the best model for the targeted objective
- **Leading Group/Expert:** Start with the groups of Thomas Kadyk/FZJ/Germany and Marc Secanell/University of Alberta/Canada.

– **Planned Completion:** Q4 2024

Fast or Real-Time Capable Surrogate Models

– **Objective:** Train AI tools or use model reduction techniques to gain speedy surrogate models capable of working e.g. in digital twins or automated test stations to guide experiments in real time

– **Key Deliverables:** Surrogate models and their performance description (speed vs. accuracy

– **Leading Group/Expert:** Thomas Kadyk and Kourosh Malek/FZJ/Germany, Marc Secanell/University of Alberta/Canada

– **Planned Completion:** Q4 2026

Cross-Task Collaboration & Synergies

- **Collaboration with Task 33:** Supply high-level Fuel Cell models, create a "Fuel Cell QuickCheck" tool for energy consultants, researchers, small companies for performance predictions to guide decision making and benchmark different fuel cell solutions
- **Collaboration with Task 31:** Work on the question, how fuel cell models and knowledge can be transferred to water electrolysis. Which knowledge is transferrable, which knowledge gaps exist?
- **Horizontal Integration:** Open Access Modeling tools developed and deployed within the task guide and accelerate research and development efforts not only in fuel cells, but also adjacent technologies (see collaboration with Task 31). Furthermore, the technology models can be used in higher-level system or energy system models, e.g. to evaluate market potential or develop energy transition roadmaps (see collaboration with Task 33).