

2023 RENEWABLE GASES NOTEBOOK





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DIVERSIFY AND DECARBONIZE THE ENERGY MIX WITH RENEWABLE GASES

Renewable gases will play an increasingly important role in tomorrow's energy mix and represent one of the solutions for accelerating the transition to a carbon neutral world. With its proactive strategy, ENGIE will strengthen their production and make them efficient energies of the future.

The current need to reconcile the transition to a carbon-neutral economy with the increase in global energy demand makes development of the technological sectors for renewable gas production (methanization, methanation, gasification, electrolysis) essential. They contribute to the diversification of the energy mix and to a carbon-neutral economy. Their development will also reduce Europe's dependence on fossil fuel imports while contributing to its energy security.

Finally, renewable gases have a positive impact on the communities: they encourage the creation of jobs that cannot be relocated and contribute to the development of the circular economy through the treatment of waste (agricultural, urban, etc.) and the recovery of residual organic matter in the form of energy, biogenic CO₂ and biofertilizers.

RENEWABLE GASES: ENGIE, A KEY PLAYER IN THIS HIGH-GROWTH MARKET

Driven by the demands of the energy transition and by industrial and

commercial decarbonization needs, the market for renewable gases is poised for strong growth in the coming decade. The war in Ukraine has served as a powerful catalyst in strengthening the Group's commitments.

ENGIE intends to become a major player in this market for renewable gases, both as supplier, continuing its historical activity of selling natural gas, and as producer. The Group's ambition of becoming a major producer of renewable gases in Europe is in line with its strategic objective of being a leader in the energy transition, in particular through the development of a renewable energy production fleet, which would not only be electric but also gas-based.

ENGIE has clear competitive advantages, both in industrial and commercial terms, for achieving this ambition and this is true for all the renewable gases currently being considered, biomethane and synthetic biomethane, e-fuels and renewable hydrogen.

RENEWABLE HYDROGEN, A PARTICULARLY PROMISING GAS

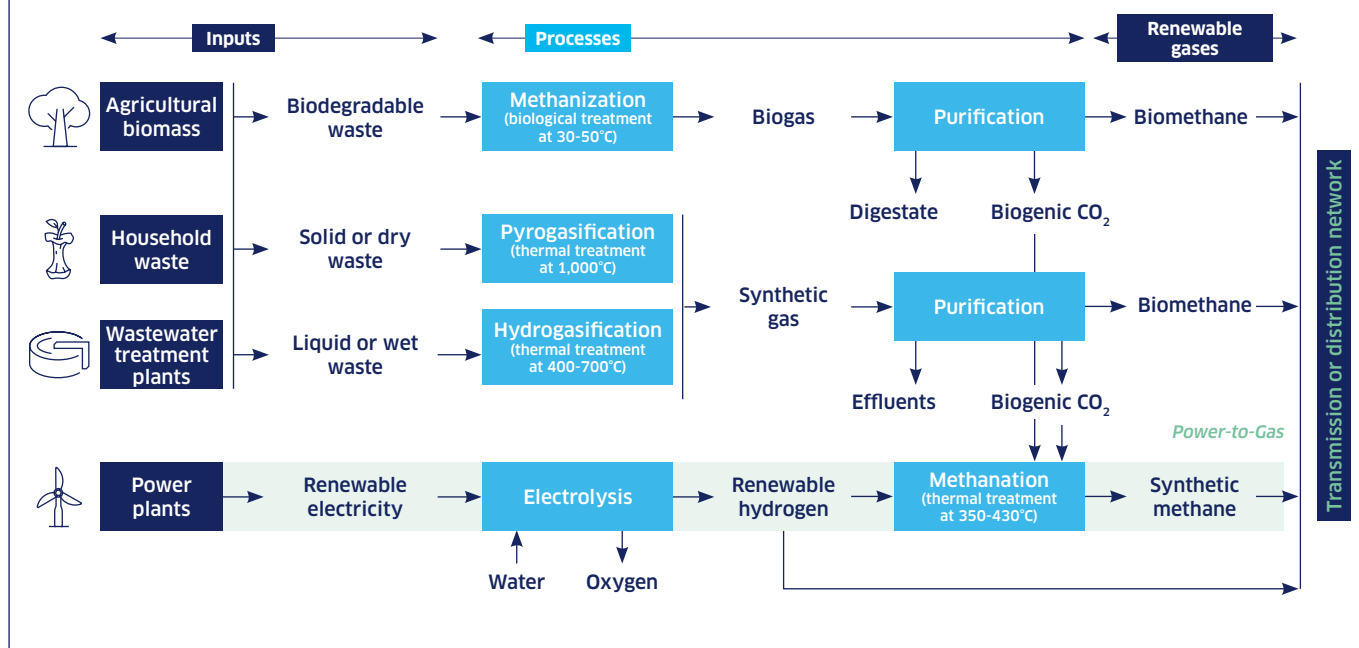
Another vital ingredient to accelerate the transition to carbon neutrality is renewable hydrogen. Produced by water electrolysis from renewable electricity, this gas is now at the heart of decarbonization objectives: it enables renewable electricity to be stored in the form of hydrogen (or methane after a methanation process) and decarbonization for current massive uses of hydrogen (fertilizers, refineries, chemicals, etc.) and for other industrial sectors that are difficult to decarbonize in other ways (steel industry). Finally, renewable hydrogen is expected to progressively contribute to the decarbonization of mobility, whether in heavy mobility with the development of synthetic fuels (maritime, aviation) or in road mobility with the development of "zero emission" vehicles equipped with a fuel cell.

This explains why the European Commission presented a hydrogen strategy for Europe's climate neutrality in 2020 as part of the Green Pact for Europe. Similarly, France adopted a National Strategy for the development of decarbonized hydrogen costing €9 billion for the period to 2030.

Present over the entire hydrogen value chain, from the production of renewable energy to the end usages, ENGIE is positioned as a major player in renewable hydrogen, which could well become a key energy of the future. With 5,800 jobs in 2022, including around 200 at ENGIE, compared with 3,500 in 2021, the French hydrogen segment is rapidly expanding. After being a pioneer for a long period, the Group reached the stage of industrialization of several hydrogen projects in 2022.



SIMPLIFIED VIEW OF THE PROCESSES TO PRODUCE RENEWABLE GASES



IN ADDITIONAL TO METHANIZATION, THREE RENEWABLE GAS PRODUCTION STREAMS WILL PLAY A KEY ROLE

The solutions to produce biomethane by pyrogasification open the way to the production of biomethane from dry biomass: in particular, wood and Solid Recovered Fuels (SRF). Dry biomass represents significant additional volumes to methanization. The first industrial projects will arrive by 2030 to complete the production potential of the methanization sector. For example, ENGIE and its partners are engaged in this development through the GAYA project, a research and development project aimed at validating innovative technological choices and preparing for industrialization of the sector.

Solutions to produce biomethane by hydrogasification. Hydrothermal gasification is a technology for conversion of wet biomass that allows the treatment of residue and organic waste (treatment plant sludge, digestates from methanization that cannot be spread). It uses the water contained in the biomass in its supercritical state as a reaction medium to produce a methane-rich synthetic gas.

The French sector for synthetic methane from methanation of renewable or low-carbon hydrogen is under development with a number of R&D and demonstration projects (TRL 7-9). For example, with the Jupiter 1000[4] project, GRTgaz and its partners aim to implement a synthetic methane production facility at pre-industrial scale.

This sector enables recycling of biogenic CO₂, a co-product of the three sectors discussed above; this recycling improves the sectors' yield and their environmental performance. This synthetic methane will then be injected into the gas transmission network.



€25 billion

of investments in Europe
by 2030 for
hydrogen development
Source: Market update



380 TWh

of biomethane in Europe
in 2030 with REPowerEU



5,800

hydrogen sector jobs in
France in 2022,
including approximately
200 at ENGIE



9,800

jobs in 2022
in the gas production
sector in France

RENEWABLE GAS, AN INDUSTRY OF THE FUTURE

ENGIE is convinced that renewable gases will play an essential role in the European energy mix. Since the first facilities in 2011, the renewable gas production sector in France is today the most dynamic in Europe.

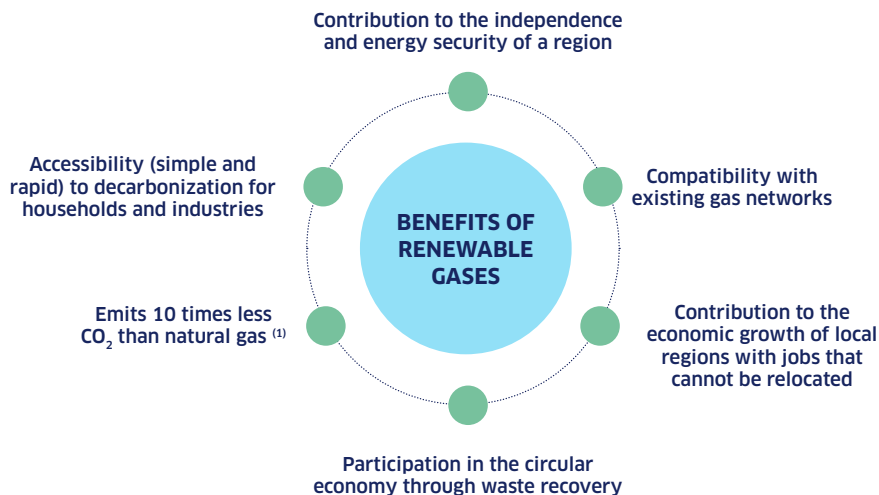
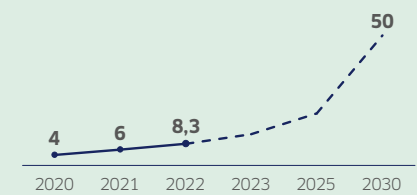
NO DECARBONIZATION WITHOUT RENEWABLE GAS

Renewable gas is a source of sustainable energy, emitting 10 times less CO₂ ⁽¹⁾ than natural gas. Thus, it makes a decisive contribution to the European decarbonization goals at a time when the European Union has announced the doubling of its target for renewable gas production by 2030 (35 billion cubic meters (BCM) / 380 TWh), as part of the REPowerEU plan. Like natural gas, renewable gas is transportable, storable and transformable.

Thus, it is a response to the need for decarbonization of the chemical and energy intensive and transport industries. Its features – reliability, flexibility and lack of intermittency – mean that it can meet energy needs in peak periods, particularly during cold snaps.

France and Europe already produce 6.9 TWh and 30 TWh of renewable gas respectively.

Biogas injection capacities on ENGIE's networks in France (TWh / year)

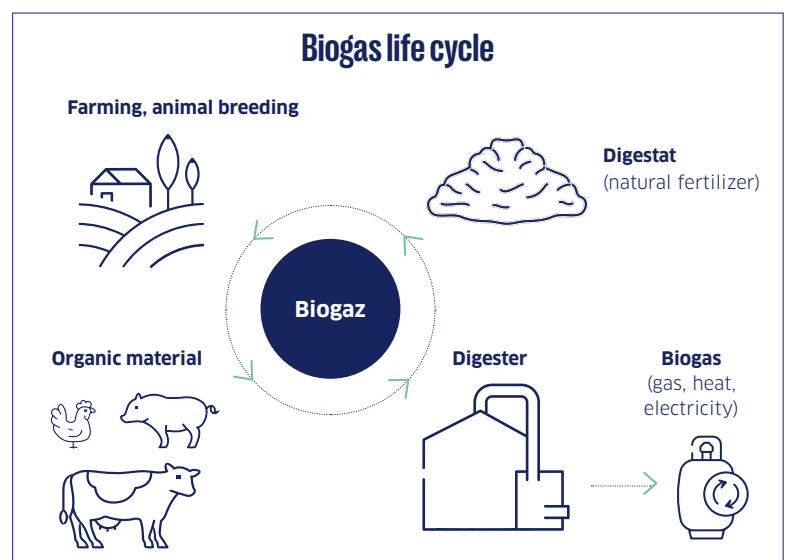


(1) In life-cycle analysis



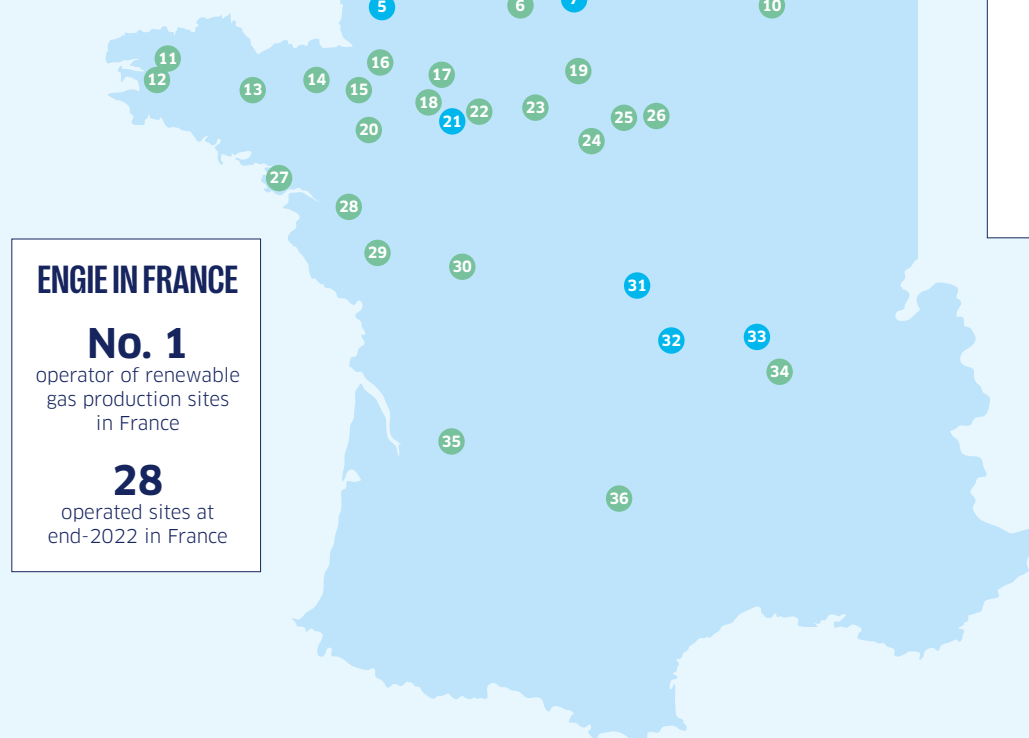
Camille Bonenfant-Jeanneney,
Biomethane Europe Project Director

“Renewable gas, a real driver in the transition to renewable and low-carbon energy, will play an indispensable role in supporting our customers on the path to decarbonization. This is why we are setting up a dedicated organization at the European level, which pools our know-how, to sharply accelerate the development of renewable gases.”



ENGIE BIOZ PRODUCTION SITES IN FRANCE

- Operation
- Construction



ENGIE IN FRANCE

No. 1

operator of renewable gas production sites in France

28

operated sites at end-2022 in France

ENGIE'S BIOMETHANE TARGETS FOR 2030

10 TWh / year

of biomethane production capacity in Europe, including 5 TWh in France

50 TWh / year

of biomethane injection capacity in France on ENGIE networks

30 TWh / year

of biomethane marketing by GEMS B2B & Retail B2C

- | | | | |
|--|--|---|---|
| 1 Eurametha | 10 Chalonnais Biogas Plant | 19 Beauce Alnéloise Biogas Plant | 28 Les Terres de Montaigu Biogas Plant |
| 2 Hautes Falaises Biogas Plant | 11 Kastellin Biogas Plant | 20 CS Congrier Biogaz | 29 Chantonay Biogas Plant |
| 3 Vermandois Biogas Plant | 12 Quimper Biogas Plant | 21 Methagril Loué | 30 Migné Biomethane |
| 4 Caux Vallée de Seine Biomethane Plant | 13 Pays de Pontivy Biogas Plant | 22 Le Mans - Le Monné Biogas Plant | 31 Val de Cher Biomethane Plant |
| 5 Sainte Cécile Biomethane Plant | 14 Montauban-de-Bretagne Biogas Plant | 23 Le Dunois Biogas Plant | 32 Parc de l'Aïze Biogas Plant |
| 6 Neuboug Biogas Plant | 15 Enerfées | 24 Lugère Biogas Plant | 33 Roanne Bio Energie |
| 7 Métha Grands Chênes | 16 Aumaillerie Biogas Plant | 25 Beauce Gâtinais Biogaz | 34 Méthamoly |
| 8 Biometa | 17 Les Coëvrons Biogas Plant | 26 Chaumont Biogas Plant | 35 CVBD |
| 9 Méthabaz | 18 MethaMaine | 27 L'Estuaire Biogas Plant | 36 Prometer |

ENGIE, ALREADY A KEY PLAYER IN THIS MARKET

A leader in the renewable gas value chain, ENGIE is convinced that renewable gases will play an essential role in the European energy mix. With its GBU Networks, ENGIE is currently positioned as a key player in renewable gas production in France and in Europe. This renewable energy will be added to the other renewable energies deployed by the Group. With over 250,000 km of existing gas networks, ENGIE provides a decarbonization solution that is

immediately effective at a lower cost, a renewable energy that complements the other renewable energies deployed by the Group. Its subsidiary ENGIE Bioz is a key player in the French market with 28 production units in operation and an annual production capacity of 600 GWh, based on the recovery of waste primarily from the agri-food industry and agriculture. ENGIE is also developing biomethane production projects outside France, notably in the Netherlands, Belgium, Poland, Germany, the United Kingdom and Italy.

ENGIE BOOSTS ITS MARKETING ACTIVITIES

ENGIE also relies on its energy marketing structure to promote renewable gas; it signed a contract to supply 3 TWh of biomethane over a 10-year period with the Arkema company. It sold 3.3 TWh of renewable gas to its customers in Europe in 2022.

HYDROGEN, A SECTOR IN THE INDUSTRIALIZATION PHASE

Investment decisions, construction startups, commissionings, openings and more...

2022 represented a milestone for the development of renewable hydrogen. While the Group pursued its policy of innovation and research and initiated new projects, it also moved further toward industrialization. A critical prerequisite to make the energy transition a reality.

GOVERNANCE DEDICATED TO HYDROGEN PROJECTS

A trailblazer in renewable energy, the Group today is engaged in around 100 hydrogen projects of different sizes and at different stages of maturity in industry, mobility and networks.

To ensure the best possible sharing of the strategic vision and the roll-out of projects, ENGIE set up an internal **"hydrogen coordination cockpit"**.

This governance body is intended to facilitate interactions among the different Group entities involved in the hydrogen projects and provide better visibility on the actions taken. More broadly, the Group is a founding member of the **Hydrogen Council**, which is pursuing the goal of accelerating the use of hydrogen as an energy transition vector at the global level. It is also a member of **France Hydrogène**, which brings together industry players to structure and accelerate the development of hydrogen solutions in France.



Valérie Ruiz-Domingo, ENGIE Group Hydrogen Vice-President

"Our ambition is to be a leader in renewable hydrogen, even if we will also need low-carbon hydrogen to develop the division and the market. ENGIE is positioned over the entire hydrogen value chain: from production to distribution, including transmission via pipelines and storage in salt caverns."

The challenges posed by the industrialization of the hydrogen sector require the creation of partnerships, particularly to pool the financial risks. Thus, on November 3, 2022, ENGIE inaugurated the **H2 Factory**, a test platform intended to accelerate the development of the renewable hydrogen sector by establishing a connection between R&D and industrial applications with the contribution of many partners, including startups, in the context of European R&D projects within international consortia.

BECOME A WORLD PLAYER IN RENEWABLE HYDROGEN

The Group combines the expertise of all its international and French teams around three axes of development: industrial usages, mobility and hydrogen as an energy vector. This involves the teams from ENGIE Lab CRIGEN, ENGIE Impact, Tractebel, Storengy, ENGIE Solutions, ENGIE Green, GNVERT, GEMS and its GBU Renewables and GBU Flex Gen & Retail.

As such, the Group is positioning itself over the entire hydrogen value chain, from the production of renewable energy to operations, maintenance and distribution, and acts for its customers as integrator, operator and developer of a broad range of industrial-scale solutions, built on partnerships and innovative technologies.

INDUSTRIALIZING THE SOLUTIONS

Numerous projects to produce renewable hydrogen through electrolysis are being rolled out in France and internationally to decarbonize the industry and to develop new industrial divisions and more sustainable mobility (see map opposite).

ADAPTING THE NETWORKS

The production of hydrogen on an industrial scale requires the development and planning of transport and storage networks.

ENGIE is committed to the European H2 Backbone initiative and is supporting the deployment of a network of nearly 40,000 km of hydrogen networks in 21 countries, two-thirds of which would be made up of existing networks that have been repurposed.

ACTING WITH THE COMMUNITIES

ENGIE's local roots are a real asset in uniting the various economic players and institutions in the development of renewable hydrogen in the local communities. To create these new production, operation and distribution circuits, ENGIE relies on trusted partners, its detailed knowledge of the regions in which it is present, and its ability to act over the entire value chain.

In France, ENGIE is actively responding to calls to bid on regional projects launched by the French environmental agency ADEME with solutions intended to accelerate the development of hydrogen uses. Hydrogen holds the promise of a new technological, energy and industrial sector, both locally and globally, with the additional benefit of new jobs. A vital division for contributing to the decarbonization of the energy mix.

COMMITTING TO NATURAL HYDROGEN PRODUCTION

Along with projects to produce hydrogen by electrolysis, the Group is committed to the development of the natural hydrogen production market in order to promote a low-carbon and competitive supply through Storengy. This gas is continuously generated deep within the surface of the Earth and, in particular, can be mined via boreholes. In 2022, Storengy launched a campaign to measure emissions of natural hydrogen to identify areas with high potential for the development of this market.

MAIN HYDROGEN PROJECTS

- Industry
- Mobility
- Networks



ENGIE'S HYDROGEN OBJECTIVES FOR 2030

4 GW

of H₂ production capacity

700 km

of dedicated pipelines

1 TWh

of dedicated underground storage

+100

refueling stations

- 1 HyEx:** Production of renewable hydrogen for a future renewable ammonia plant intended for the mining sector - ENAEX - Chile
- 2 Hydra:** design and testing of a modular engine prototype composed of fuel cells and batteries to replace the conventional diesel engine used in mining trucks - Mining 3 - Chile
- 3 Rhyno:** integrated hydrogen solution (production, compression, storage and refueling) to power the world's first mining truck with such a load size - Anglo-American - South Africa
- 4 Yuri:** construction of a hydrogen facility to produce renewable ammonia - Yara - Australia
- 5 HyNetherlands:** production from 2025 of e-methanol by combining renewable hydrogen and biogenic CO₂ - EEW & OCI - Netherlands
- 6 MultiPLHY:** installation, integration and operation in the Neste biorefinery of the world's first high-temperature electrolyzer (HTE-SOEC tech) on a scale of several megawatts - Neste Sunfire - Paul Wurth - Netherlands
- 7 North-C Hydrogen:** development of a renewable hydrogen facility at the ENGIE power plant in the port of Ghent for the needs of local industries - Consortium of public and industrial partners - Belgium
- 8 Crystal:** development, construction et operation of a hydrogen facility to produce renewable ammonia - Masdar - Fertigllobe - United Arab Emirates
- 9 Columbus:** carbon capture and use (CCU) aimed at concentrating the CO₂ from the lime production process and combining it with renewable hydrogen to produce e-methane intended for the transport and industrial sectors - Carmeuse & John Cockerill - Belgium
- 10 MosaHyc :** 1^{er} projet de canalisation hydrogène transfrontalier d'Europe - GRTgaz - Creos - Encevo - France, Allemagne, GD de Luxembourg
- 11 H2 Freight Trains:** innovative solution allowing the first renewable hydrogen-powered freight train to be put into circulation - Alstom Neslé Waters - France
- 12 Reuze:** production of synthetic fuel in Dunkirk for air and sea transport - Infinium - Arcelor Mittal - France
- 13 HyGo :**Power for the Michelin site and refueling stations for public vehicles - Michelin, France 17 DMSE - Dijon Métropole Smart EnergHy - France
- 14 Dijon Métropole Smart EnergHy (DMSE):** development of a complete zero emission hydrogen ecosystem for the city of Dijon, consisting of two refueling stations with on-site electrolyzers - Dijon Métropole Rougeot Énergie - ENGIE Solutions - France
- 15 Hyspter:** First demonstrator for storage of renewable hydrogen intended for industry and mobility in salt caverns - France
- 16 Zero Emission Valley (ZEV):** development and installation of a network of 20 renewable hydrogen stations for road transport in the Auvergne-Rhône-Alpes region and an initial fleet of 1,200 hydrogen vehicles - Auvergne-Rhône-Alpes region, Michelin and Crédit Agricole - France
- 17 Hygreen Provence:** production of renewable hydrogen from solar power and storage in underground salt caverns - DLVA - France
- 18 Masshylia:** one of the largest renewable hydrogen production sites in France (50 metric tons / day) at the center of the La Mède biorefinery - TotalEnergies - France
- 19 Hyport:** Renewable hydrogen fueling station to fuel five Toulouse airport buses - Occitania Region and Toulouse Blagnac Airport - France
- 20 H2SINES.RDAM:** first liquid H2 supply chain between Portugal and the Netherlands - Shell Vopak - Anthony Veder - Portugal
- 21 GreenH2 Atlantic:** transformation of a former coal-fired power plant into an innovative renewable hydrogen center - Consortium of 13 companies - Portugal
- 22 Cartagena:** construction of the first renewable hydrogen plant in the Escombreras region: 100 MW - Enagas - Repsol - Spain



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