FUTURE ROLE OF RENEWABLE GASES

MED22-34GA - 4.1.1

Empowering Mediterranean regulators for a common energy future

Renewables Working Group (RES WG)

Co-funded by the European Union

ABSTRACT

This document describes the level of development of renewable gases and their future role in the Mediterranean region. Decarbonisation of the energy sector will require the use of all available alternative technologies and energy sources. Hydrogen and biogases will have an important role in the future. In that context, the energy regulators of the Mediterranean have started discussion on the state of play of the development of these technologies, starting with the regulatory framework and the energy strategy of the countries, followed by the existing and planned projects in the region, and finally the support mechanisms that are in place or are planned to be established.
The report is based on the case studies of the MEDREG RES WG members.

AKNOWLEDGMENTS

This report is the result of the work of the MEDREG Environment, Renewable Energy Sources And Energy Efficiency Working Group (RES WG).

ABOUT MEDREG

MEDREG is the association of Mediterranean energy regulators, bringing together 27 regulators from 22 countries across the European Union (EU), the Balkans, and MENA region.

MEDREG acts as a platform for facilitating information exchange and assisting its members, in addition to fostering capacity development activities through webinars, training sessions, and workshops. Mediterranean regulators work together to improve the harmonisation of regional energy markets and legislations, seeking a progressive market integration in the Euro-Mediterranean Basin.

Through constant cooperation and information exchange among members, MEDREG aims at fostering consumer rights, energy efficiency, infrastructure investment, and development by employing safe, secure, cost-effective, and environmentally sustainable energy systems.

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TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

1
INTRODUCTION

1.1. Report Objective

The report provides a general overview on the renewable gases strategies in the Mediterranean region as well as the state of development of the regulatory framework that governs hydrogen and biogases.
The second stage of the report provides a detailed analysis for individual member countries, and the Annexe includes a detailed case study for France (CRE).

1.2. Methodology

This report is based on the MEDREG members' responses to the benchmarking prepared by the RES WG chairs. In addition, the report is enriched by the France case study in the Annexe, detailing the development and the regulatory framework that governs the biogases.
Depending on the competencies of the national regulatory authorities (NRAs), some members of MEDREG were not considered in the report, such as ARH or ministries such as the Jordanian Ministry of Energy or the countries where an NRA is not established (coloured orange in the figure below), such as Tunisia.
The report and benchmarking concerns 21 out of 27 MEDREG members, as depicted in the figure below:

Figure 1. State of Responses on the RES Benchmarking

1.3. State of the Art

MEDREG's Environment, Renewable Energy Sources and Energy Efficiency Working Group (RES WG) has been developing reports and analyses on the legislative and regulatory mechanisms being used to promote the implementation of renewable energy sources (RES) in the Mediterranean region.
The RES WG initiated its series of reports in 2010, with studies on the effects of the introduction of successful mechanisms to promote energy efficiency (EE), RES, and combined heat and power (CHP) plants in non-EU countries in 2010, followed by benchmarking on the EE and RES situation of each Member State of the MEDREG in 2012 and 2013.

Starting from 2015, the development of RES and EE followed a different pace among the MEDREG member countries, with a rapid growth rate on the north shore and slower on the south shore. Therefore, the RES WG studies combined the trending issues on the energy transition, the decarbonisation of the electricity sector and problem-solving tools for MEDREG's members, using knowledge sharing and cooperation among its members. As a result, well oriented and focused reports/analyses were developed, such as the 2015 study to evaluate net metering systems in Mediterranean countries and the 2017 report on Certification Systems of Origin for Electricity from RES and CHP.

An analysis of auction mechanisms to promote RES and a report on the development of smart grids in the Mediterranean region were also released by the RES WG in 2018 and 2019, respectively. The 2020 report on new available regulatory options for Integration of RES drew attention to the evolution of the power system. It started with the recent developments in renewables and changes in support policies, followed by an assessment of different types of self-consumption models along with the presentation of case studies from MEDREG countries. Barriers for regulators in integrating RES in the power system are illustrated with the corresponding recommendations to overcome them. The report also provides a set of recommendations for regulators and policymakers to be prepared for the new power systems era.

The 2021 report extended the analysis to energy efficiency programs and e-mobility in the Mediterranean region, to reach a better understanding of the current evolution of the energy system and how to achieve the energy transition by improving the traditional mechanisms and facilitate the implementation of the new technologies that use new energy carriers such as hydrogen and biogases.[1]

In that regard, this report aims to define the basic regulatory principles and common vision on renewable gases. Furthermore, the lessons learnt from the energy sector in the past show that it is better to first set the market rules and the legal and regulatory framework to ensure fair access to the market for any new energy actor, as well as a fair and transparent competition environment. Furthermore, laying down the regulatory fundamentals will obviate any monopoly that might creep in if an investor owned the majority of the infrastructure property's shares.

[1] All MEDREG RES WG reports are available here: http://www.medreg-regulators.org/Publications/Renewables.aspx

2

RENEWABLE ENERGY SOURCES' INTEGRATION IN THE MEDITERRANEAN REGION

Before providing an overview on the state of development of renewable gases and the national strategies in that perspective, it is important to first understand where the countries stand in terms of renewable energy sources (RES) in the Mediterranean region.

In this chapter, MEDREG's RES WG has mapped the level of integration of the RES through several indicators such as the level of integration of solar photovoltaic (PV) and wind energy in the energy mix of the Mediterranean region and the possibility for the network to integrate more in the future. In case of a high share of RES, the curtailment of the energy due to the lack of capacity to transport it in the network is an additional indicator.

In addition to the most common RES such as solar PV and wind, the energy efficiency level and e-mobility implementation indicates the level of achievement of the energy transition.

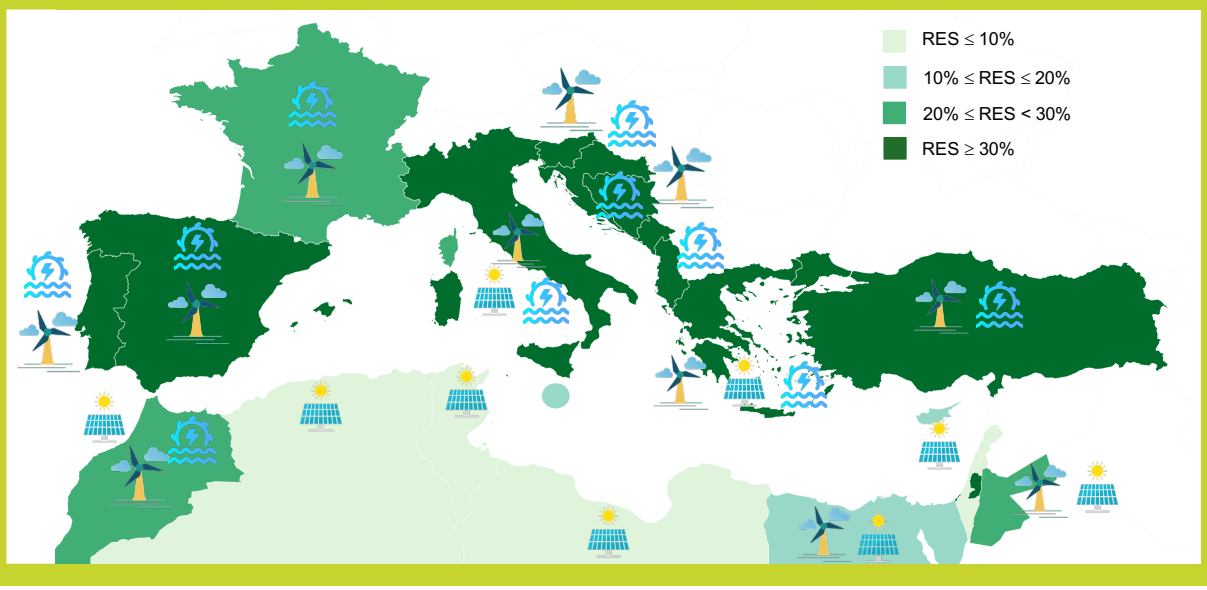
Lastly, the members were asked about the development of hydrogen, biogas, and power-to-gas. This approach to improving the level of integration of renewable energy sources is likely to allow us to comprehend where we stand with regard to RES integration and at least partially achieve the energy transition.

As part of the energy transition, RES integration by itself won't be sufficient to achieve decarbonisation of the energy sector, and RES WG has been analysing the additional sources and mechanisms that we can also consider. In this report we take a closer look at the renewable gases.

State of Development of RES in the Mediterranean Region

The development of renewable energy sources in the Mediterranean region has evolved considerably in recent years, reaching 584 TWh in 2021, which represents 30% of the total Mediterranean region electricity demand.

Figure 2. RES Share in the Mediterranean Region Electricity Mix (% of Electricity Generation)



However, the rate of integration of RES in electricity generation remains uneven between countries; for instance, in 2021 the RES covered all the electricity demand in Albania and at least 60% of the Portuguese electricity demand, but only 1% of the Algerian electricity demand,[2] as shown in the figure 2 below:
In addition, the disparity in the RES integration rate is not related to the availability of the energy source (solar or wind), but to other factors like, among many others, the funding, regulatory framework, and support mechanisms.
For a better understanding of where we stand in terms of RES integration, the MEDREG members were asked seven questions related to RES integration and future perspectives, focusing on the limitations of the electricity network in supporting more RES without technical constraints (without affecting the quality and security of supply). Furthermore, at the medium and high levels of RES integration, RES production curtailment is considered. The main challenges that the NRAs face in terms of RES integration are detailed below, by country.

1- Low RES (solar and wind) and Alternative Technologies (Hydrogen, E-mobility, and Biogases)

Commission de Régulation de l'Électricité et du Gaz – CREG – ALGERIA

The RES integration remains low even though the national strategy is ambitious. The regulatory framework is in place for the main RES sources such as wind and solar PV but is not yet developed for the alternative technologies such biogas and e-mobility, which will require more time to be considered in the energy strategy, except for hydrogen, which is already being used in the ammonia industry.[3]
In terms of challenges that the regulator faces in addressing the renewable energy sources and gases, CREG identified the following main elements:

- Analysis of regulatory texts.
- Identification of the best regulatory practice.
- Identification of relevant regulatory gaps.
- Development of an appropriate regulatory framework.
- Identification of the technical requirements for the preparation of the calls for tender.

Starting from 2025, Algeria is planning to install around 1 GW/year of solar PV until 2030. As for biomass, the strategy is in progress.

Lebanese Center for Energy Conservation – LCEC – Lebanon

By the end of 2020, around 9,2% of the electricity generated in Lebanon was from RES sources. Currently, the level of RES integration is still considered low in Lebanon, but it has huge and growing potential, especially considering that the planned projects include large scale solar and wind farms to reach the 2030 target of having 30% of electricity generated from RES, which are not implemented yet.
The current challenges are mainly the absence of secured funds necessary for large scale RES projects, and the limitations of the national grid in terms of capacity and flexibility.

[2] All the details of the Mediterranean electricity market statistics can be found on MEDREG MEMO+ report available here: Link
[3] More details are provided in the following chapters.

Palestinian Electricity Regulatory Council – PERC – Palestine

The electricity demand in Palestine is met entirely by the electricity imports, 98% in 2021, the remaining 2% being produced by small solar PV projects.

The very inhomogeneous state of the infrastructure in the Palestinian territory and the hurdles to realising "extended" infrastructure (e.g., transmission lines) due to the lack of territorial continuity and/or projects located in area B/C (where Israeli permission is needed) represent the main challenges for the Palestinian regulator.

2- Medium RES Integration (Solar and Wind) but With Low Alternative Technologies.

Cyprus Energy Regulatory Authority – CERA – CYPRUS

The level of RES integration in Cyprus is moderate, with high potential. RES covered 14% of the total electricity demand in 2021. Cyprus is exploring the other alternative technologies to achieve its objectives of energy transition.

In terms of regulatory challenges, the most common are related to the network charges (injection and/or capacity charge) and renumeration mechanisms (net-metering, net-billing, FiT) associated with the integration of RES and its impact on the consumers who will carry the additional costs to fund the mechanisms. Therefore, there is need to find remuneration mechanisms with lowest impact on the consumers, and especially vulnerable consumers.

Regulator for Energy & Water Services – REWS – Malta

The highest contribution towards Malta's renewable energy target is expected to come from solar PVs (in 2021 approximately 12% of total electricity demand).

However, Malta is limited by grid integration constraints inherent in small, peripheral electricity systems, in meeting the target objectives of 2030; ensuring system stability will either require significant spinning capacity or utility scale battery storage or flexible balancing services over the electricity interconnector with Sicily. However, the latter is limited to 200MW (the capacity of the interconnector) and would in practice be lower if already meeting part of the load.

Furthermore, Malta's load and generation profile are very similar to that of Sicily; this means that excess RES generation in Malta would coincide with times of high-RES generation in Sicily, reducing its effective market value.

Currently, Malta has no utility scale battery storage facilities, and keeping large spinning capacity is highly inefficient and may not be technically feasible at all times. An assessment is being carried out by the government to estimate the additional system costs involved to integrate further PV capacity. However,

from the outset it has been clear that the available capacity (and hence balancing capability) of the interconnector is one of the main limiting factors.

Autorité Nationale de Régulation de l'Electricité – ANRE – Morocco

Morocco already has a high integration of RES. In fact, by the end of 2021, RES represented more than 37% of installed capacity and more than 19% of electricity production. Morocco has the main objective of achieving more than 52% installed capacity sourced from RES by 2030. This 52% is divided as follows: 12% hydropower, 20% concentrated solar power (CSP) & PV, and 20% wind. To achieve that objective, Morocco aims to add 10 GW of RES capacities between 2018 and 2030, consisting of 4560 MW of solar, 4200 MW of wind, and 1330 MW of hydropower.

The Moroccan energy sector has seen fast-paced development. Also, the proposed decarbonisation of energy-intensive sectors such as the transportation and the industrial sectors will lead to an exponential increase in energy demand; green electricity demand, to be precise. To succeed in the energy transition and the sector's decarbonisation, Morocco requires high-performance and reliable transmission and distribution networks.

ANRE has the main challenge of achieving an equilibrium between the different factors in the sector. It should ensure that the electricity transmission and distribution networks are reliable and able to work in tandem with the energy transition and the high green energy demand. ANRE should take care that future investments in networks are sufficient to ensure these networks do not constitute a bottleneck for the development of the sector, and at the same time those investments should be reasonable so that ANRE sets cost-reflective and competitive tariffs to attract private investors.

3- High-RES Integration and Medium Implementation of Alternative Technologies (Especially E-mobility).

Commission de Régulation de l'Énergie – CRE – FRANCE

In 2021, France had a share of 24 % of RES in its electricity energy consumption, slightly above its EU 2020 target (23 %). Hydro contributed 12%, while wind at 7% was followed by solar PV with 2,7%, and biomass with 1,9%. Biomass is well developed in France compared to its neighbouring countries in the Mediterranean region. On the other hand, 69% of its total electricity production was generated using the nuclear power plants.

E-mobility and hydrogen are still in their infancy. Nevertheless, France has already started to implement hydrogen pilot projects and is the leader in the Mediterranean region in terms of e-mobility, with approximately 471 000 Electric Vehicles (EV) in 2020.[4]

Among the challenges for RES integration, we can cite the following:

[4] See MEDREG's RES WG report 2021 on Energy efficiency programs and electric mobility in Mediterranean countries.

- The public acceptance of RES projects on the ground (especially for onshore wind farms, but also to a lesser degree biomethane production).
- Grid connection and optimising RES location to reduce its impact on the electricity network (France has a mechanism, the S3REnR, to facilitate RES installation and grid planning).
- Intermittency of RES electricity production in solar PV and onshore wind, which requires advanced forecasting and flexibility.
- Cost competitiveness, especially about renewable gases (even if they have edged closer to competitiveness in the current high market price environment).

Regulatory Authority for Energy – RAE – GREECE

In Greece, the RES share reached 45% of the total electricity generation in 2021, which represents one of the highest rates in the Mediterranean region. During the period 2017–2021, the installed capacity of RES (solar PV and wind) increased significantly, with a 57% increase in installed wind capacity and 28% for solar PV.

Furthermore, this high level of integration is also recorded in competitive auctions. More specifically, during the technology neutral[5] competitive RES auctions held in May 2021, an average weighted price of € 37,6 /MWh was recorded, a price decrease of 35,62% and 40,92% when compared to the technology specific auctions held in 2018.

Even though currently there is a high level of RES penetration, this trend will likely shift as more network investments will be required to accommodate additional RES stations, and investments in energy storage to mitigate the negative effects to the electricity system of the variable RES technologies such as wind and PV. It is important to highlight the importance of the latter investments, as for the first time ever a curtailment of RES units in the interconnected system was recorded in April 2022.

In terms of alternative mechanisms and technologies, the energy efficiency is implemented through several instruments and reforms. For instance, the renovation of more than 100 000 residential buildings will be funded under the Plan "ΕΞΟΙΚΟΝΟΜΩ"; this initiative will result in reducing their primary energy consumption by at least 30% by 2025. Moreover, RAE has organised a public consultation regarding the key performance indicators (KPIs) for monitoring of the TSO operation, which are linked with the Operator's Allowed Revenue (penalty/reward scheme). One of the above-mentioned indicators refers to network energy losses. Such an incentive scheme is already in place for the electricity DSO and will produce results after 2025, providing incentives to the DSO to reduce technical network losses.

Regarding e-mobility, a new unit was established under the provisions of Law 4710/2020 at the Ministry of Energy which will elaborate a national plan and monitor all developments on e-mobility, although this plan has not been developed yet. Greece wants to increase the existing share of new registrations of electric vehicles (BEV and PHEV included) in the Greek market, which was 6,58% in 2021, to at least 8,7% of new registrations in 2024.

Hydrogen and biogas are in the early stages and will require more time to be implemented.

[5] Both PV and wind technologies could participate in the tender.

The main challenge that the Greek regulator was facing, regarding the RES, was the licensing procedure. Due to the many requests submitted by potential RES generators for the issuance of production licenses, the regulator was faced with high workloads and high processing and approval times. However, after the development of an interoperable IT system as well as the simplification of the licensing process by the amendment of the legislation, the administrative procedures have become simpler, smoother, and the application processing periods have decreased.

4- High-RES Integration and High Implementation of Alternative Technologies (Mostly E-mobility and Biogases).

Autorità di Regolazione per Energia Reti e Ambiente – ARERA – ITALY

The RES-generated electricity share reached 35% in 2021, whereas it can be significantly higher in favourable periods (summer-PV). Increase in this share will depend on authorisations and further investments in network capacity.

Moreover, RES production curtailment may, in principle, occur due to network congestions. However, recent TSO investment in transmission networks has made this issue less significant than in the past. As for energy efficiency, results are encouraging also due to the incentive schemes the regulator has run for long. E-mobility is also high on the government's agenda and can build on large EU funding released to curb the COVID-related economic slowdown. Still, its actual development depends on EVs spreading and on electricity price dynamics. Hydrogen production also displays a significant potential due to the RES endowment. Biogas has been supported and currently plays a significant role in terms of gas decarbonisation; power-to-gas is currently debated but not implemented.

In terms of challenges, ARERA is facing the complexity arising from the accommodation of high and rising RES-generated electricity in the energy system—for example, an increasingly fast response is required in networks' adaptation to changing conditions and generation patterns.

In addition, there is a need to pass on to the consumer the technological and economic advantage of RES spreading; that is, when RES production costs fall, final prices should be reduced accordingly. Moreover, regulators must induce cost-reflective and cost-efficient solutions in networks adapting to RES.

Energy Services Regulatory Authority – ERSE – PORTUGAL

In Portugal, the current level of RES integration in electricity is high (at least 60% of the total electricity generation in 2021), with a still great potential for increase (reflected by the energy policy goals). However, with the high share of RES, curtailment may soon be a challenge that Portugal needs to be ready to overcome.

For hydrogen, there are many projects in the scoping and design phase, with some pilot projects in operation. As for biogas, there are examples of projects using biogas in electricity generation.

Currently, Portugal is the EU country with the 6th highest level of renewable integration in the gross final energy consumption and the EU country with the 5th highest level of renewable integration in the electricity sector.

However, the regulator is facing many challenges, as follows:

- The development and planning of the networks is required to connect more renewable generation.
- The system management must account for distributed generation and the renewable energy sources' intermittency.
- Distribution system operators (DSO) have an essential role in planning, local flexibility management, and storage.
- System integration must consider different reversible energy vectors.
- Regarding gas, the development of the network to receive renewable gases, either for pure H_2 or mixing in the existing infrastructure, is also challenging. Quality assessment is a key aspect in this matter and the monitoring of the gas quality, resulting in the limitation of producers in the injection of gas, may be necessary.
- Small producers may be far from the grid injection facilities and the scale of projects may not justify building of direct connections, so other alternatives must be developed.
- Changes in the tariff structure may be unavoidable in case of developing dedicated infrastructure for the H2 injection.
- The development of local energy economies, gas, and power, of the internal energy market, regional systems integration, Mediterranean interconnectors, and a circular energy economy considering residues and processes integration, are today's challenges for the energy transition.

Energy Market Regulatory Authority (EMRA) – Türkiye

The share of renewables in total installed capacity in Türkiye is 53,5%, which is significant, therefore, the integration of RES (especially hydroelectricity, wind, and solar PV development) is required. There is still high potential for additional investments for RES production in terms of all resources, especially for wind, solar PV, and biomass.

For achieving energy transition properly and to reach the net-zero emissions targets, cleaner resources must be used, and electrification & enhanced energy efficiency are necessities for the energy sector. However, Türkiye's energy sector still depends highly on imported gas and imported coal. Although the share of renewables is increasing day by day in the generation mix, conventional power plants still play a significant part in ensuring the security of supply. To enhance the resilience in the system operation in the path to green transition, the application of alternative systems is necessary, such as introduction of demand side management (DSM) services, storage, distributed generation and energy communities, green certificates, and carbon border adjustment mechanisms. Türkiye has put in place regulations related to distributed generation (via unlicensed generation), hybrid power plants, electricity storage, a national renewable energy resources guarantee system (YEK-G), and as an introduction to DSM service "a demand-side reserve" concept has been introduced.

3

TYPES OF RENEWABLE GASES AND CURRENT STATE OF DEVELOPMENT

"Renewable Gases" is a terminology used for all type of gases that can be used in a clean way and don't produce any additional emissions when burnt.

The most common forms are renewable hydrogen and biogas. The first has many types depending on the energy source used to produce the hydrogen. Nowadays, the main types of hydrogen are:

- **Grey hydrogen:** Produced by using natural gas and process release CO_2.
- **Blue hydrogen:** Produced as well by using natural gas, but the CO_2 emissions are captured and stored.
- **Green hydrogen:** the most desired type of hydrogen is green hydrogen, where rather than using fossil fuels a process called electrolysis is used to split water into hydrogen and oxygen, while using a renewable energy source such as wind or solar PV as power for the process.

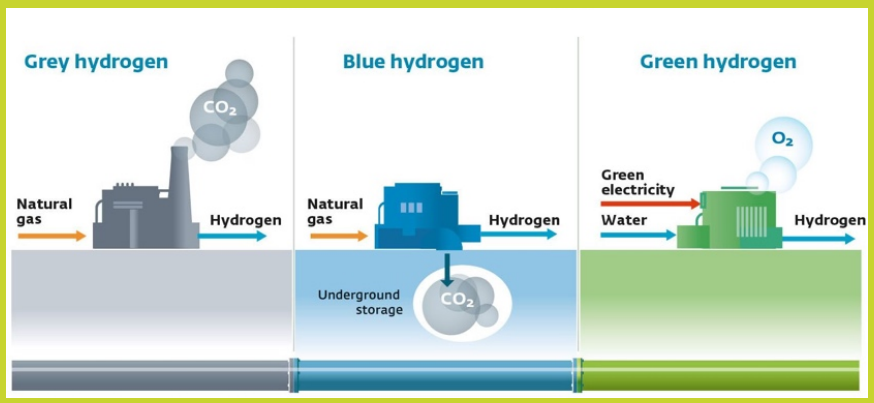
The second common form of renewable gases is biogas, which results from a chemical process called "anaerobic digestion," which involves breaking down organic matter by microorganisms in the absence of oxygen.

In general, the produced gas is composed mainly of methane and carbon dioxide, and can be used for several needs, such as fuel for vehicles or an alternative to natural gas.

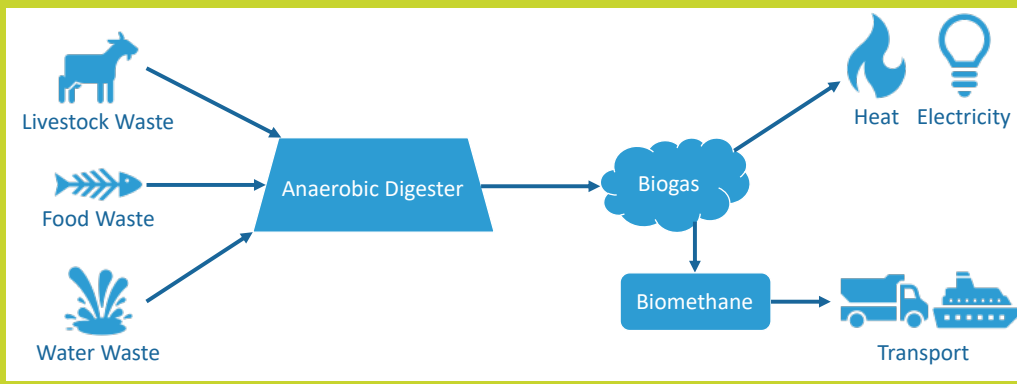
Biomethane is a biogas derivative that has undergone a refining and purification process (upgrading).

The types of renewable gases are summarised in the figure below:

Figure 3. Types of Renewable Gases



Hydrogen most common types.
Source: The world of hydrogen, Gasunie



Biomethane production and uses
Source: MEDREG

3.1. State of Development of Hydrogen

The role of hydrogen in the energy sector is increasingly important, and the interest of several countries and major investors is growing day by day.

In the Mediterranean region, the potential for hydrogen production is very significant, especially green hydrogen. The southern shore of the Mediterranean seems to be among the most promising places to produce green hydrogen, given the availability of renewable energies (which must also be developed) and more importantly the availability of land for large-scale projects.

That said, in the case of difficulty in producing green hydrogen, the south shore countries, particularly Algeria, Egypt, and Israel, have a considerable natural gas reserve which can be used to produce blue or grey hydrogen.

Although the production of hydrogen would need to overcome several constraints, the biggest obstacle remains the transportation of this production to the north shore, where the demand is greater.

Among the solutions is to blend with natural gas and to use the existing infrastructure to also transport hydrogen. In this context, studies and pilot projects have been developed to assess the feasibility of transporting hydrogen through existing gas networks, and the technical limitations thereof. During MEDREG's workshop on hydrogen that took place on the first of November 2021, SNAM mentioned that they arrived at a rate of 15% of blending without any constraints.[6]

Anyhow, important investments will be required in R&D and in the development of the necessary infrastructure to transport the hydrogen from one shore to the other in the Mediterranean region. This leads to the second major challenge related to the market design and the regulatory framework that will govern the hydrogen market. A solid and transparent regulatory framework is a key element to ensure a fruitful hydrogen market and should be developed with a vision of a common strategic approach within the region.

Worldwide, hydrogen is still in its infancy and will require some time to mature and compete with the other available technologies.

At the G20 in Japan in 2019 only three countries had a strategy related to the development of hydrogen. Today, 17 countries have a hydrogen strategy, and many others are following in the next few years. In 2018, the world production reached about 75 million tonnes of pure hydrogen (all types included). The IEA is monitoring closely the development of hydrogen, and in its report "global hydrogen review 2021," the hydrogen demand in 2020 was estimated at 90 million tonnes, mostly for refining and industry.

Europe remains the leader in terms of electrolyser capacity, reaching 40% of the global installed capacity.[7]

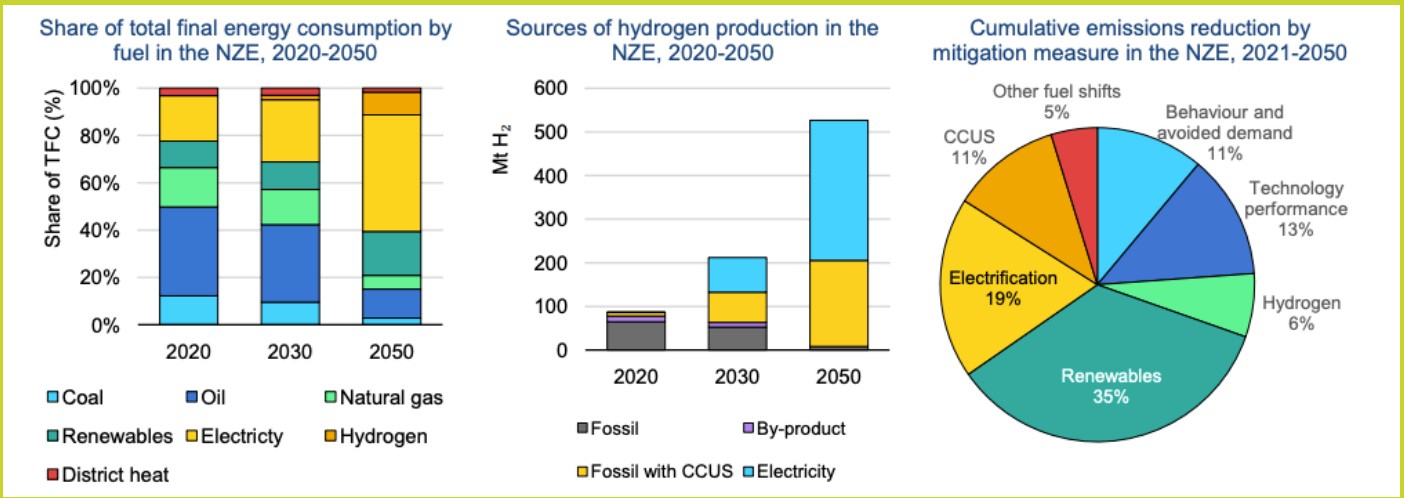
Over the next few years, the Middle East is expected to also develop significant capacity as well, such as the world's largest green hydrogen plant in Saudi Arabia's "NEOM", with a daily production of 650 tons of carbon-free hydrogen. USA and China also announced important projects in the future.

Despite these optimistic expectations, the future of the hydrogen market remains uncertain if the challenges mentioned above persist.

[6] The workshop report is available on the MEDREG website.
[7] IEA report « global hydrogen review 2021 »

Moreover, the net zero emission scenario foresees a significant growth of hydrogen and diversification of its use, including electricity production by 2050. The figure below represents the role of hydrogen by 2050, which will be a key element of the net zero emission goal.

Figure 4. Role and Use of Hydrogen in 2050 – Net Zero Emission (NZE)



TFC: Total final energy consumption

CCUS Carbon Capture, Utilisation, and storage

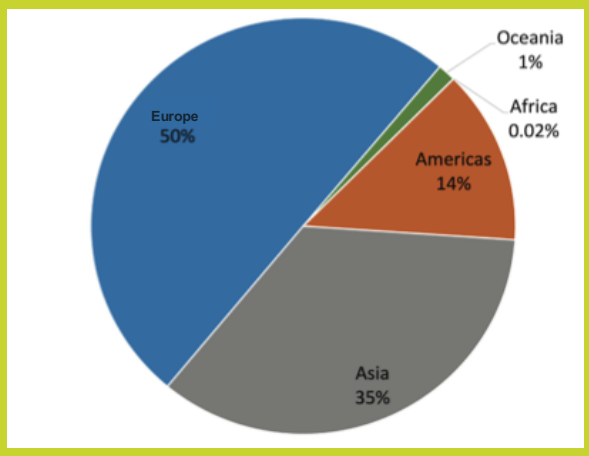
Source: IEA

3.2. State of Development of Biogas

The worldwide production of biogas reached 62,3 billion m^3 in 2019,[8] with an average growth of 9% since 2000. Europe is also the world leader in terms of biogas production, with 50% in 2019 followed by Asia and America, as shown in the figure below:

Figure 5. Biogas Worldwide Production

Evolution of Biogas production



Global biogas supply - 2019

Source: World Bioenergy association

According to the IEA,[9] biogas and biomethane can cover up to 20% of the global gas demand. The Mediterranean region has significant potential in terms of biogas, and many countries already have a well-

[8] World bioenergy report "Global Bioenergy Statistics 2021"
[9] IEA report "Outlook for biogas and biomethane"

developed regulatory framework and market in place, such as France and Italy. Biogas is included in most of the Mediterranean countries' energy strategies to achieve their objectives in terms of energy transition.

Unlike hydrogen, biogas is more oriented towards local production and there is no real intention among countries to export it. In terms of challenges for the development of biogas, the most important is the use of dedicated crops to produce it. As agriculture is a sensitive sector, the use of agricultural lands is strictly controlled to ensure food security, and therefore the production of biogas is limited by the availability of crops.

The second challenge is the lack of incentive and regulatory mechanisms to support and incentivise investments in the biogas sector. The biogas industry needs more visibility and facilitation to improve the technology and thus the efficiency of the sector. Awareness raising at the end-consumer level on the role of biogas can be also an important boost for the biogas market.

Both hydrogen and biogas are in an early stage at both the global and Mediterranean levels. However, both types of RE gases have proved their potential and role in the future of the energy sector, specifically their crucial role to achieve decarbonisation of the electricity market.

In 2022, hydrogen and biogas can be considered as being at the same stage as solar PV and wind technologies were in the 2010s before blooming all over the Mediterranean region. The experience of solar PV and wind has shown that a well-designed regulatory framework and support mechanisms will allow not only the improvement of the technology, but also ensure good development from a long-term perspective.

4

HYDROGEN DEVELOPMENT IN THE MEDITERRANEAN REGION

4.1. Hydrogen Strategies in the Mediterranean Region

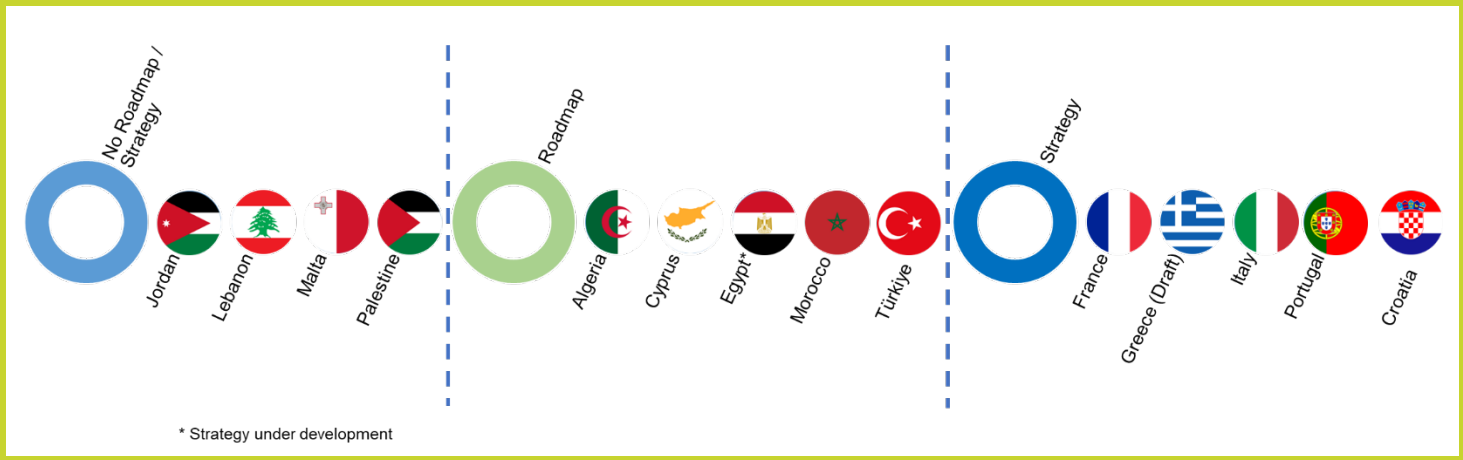
The Mediterranean has significant potential in terms of hydrogen production, and most of the countries have announced their interest in developing a hydrogen market.

In 2022 three country categories have been identified: countries with no strategy or roadmap; countries with a roadmap; and countries with a strategy. In the EU, all countries, except for Malta, have at least a roadmap related to the development of hydrogen. In Greece, the first National Hydrogen Strategy is in the final stages of drafting and is expected to be set for public consultation in the coming months.

On the south shore, Algeria, Egypt, and Morocco have developed a roadmap for hydrogen production. The hydrogen strategy of Egypt is in progress and will be finalised in the coming years.

The figure below presents the type of strategy available in the Mediterranean region, as collected from the responses to the benchmarking sent to the MEDREG members.

Figure 6. Hydrogen strategy in the Mediterranean region



In terms of projects, the Mediterranean region is developing several projects, but at different paces and ranges depending on the hydrogen strategy in place.

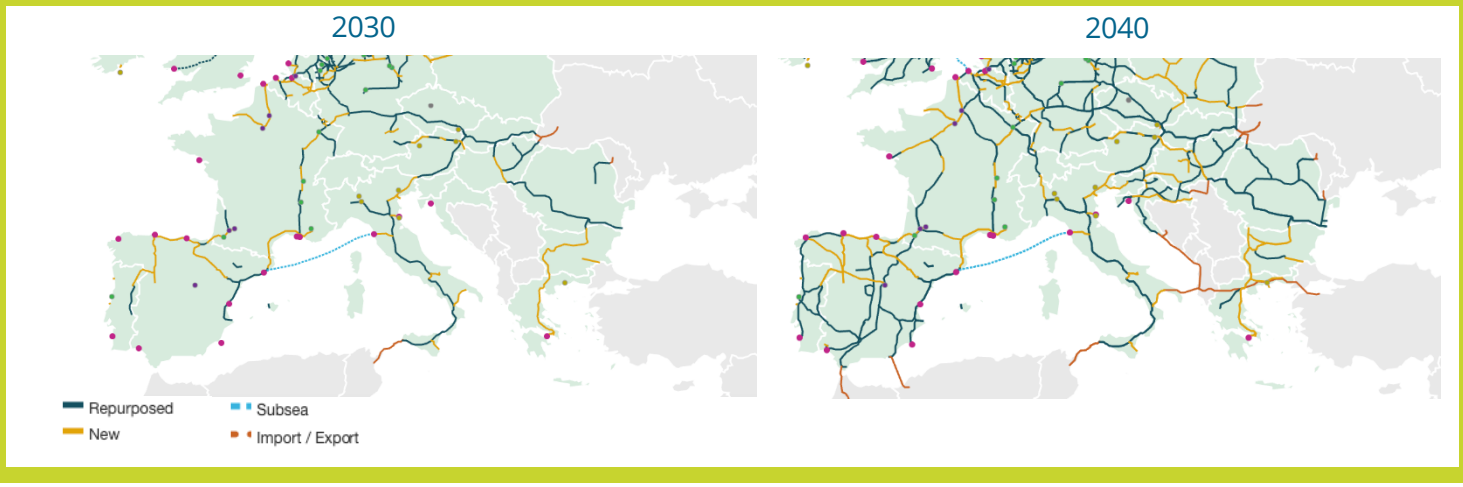
Globally, all projects are at an early stage and are mainly developed for experimental purposes to understand the limits of the hydrogen technology. Furthermore, many projects focus on the integration of the hydrogen into the natural gas infrastructure and its production using RES.

On the Mediterranean north shore, the discussion simultaneously focuses on developing the production of hydrogen and the required infrastructure to transport it. The most important initiative in that regard will be the "The European Clean Hydrogen Alliance" that gathers the industries, public authorities, civil society, and other stakeholders to discuss and develop the large-scale deployment of clean hydrogen technologies by 2030.

Besides the Hydrogen Alliance that offers a discussion platform, a concrete project dedicated to the hydrogen infrastructure is foreseen to be developed by 2040. The project is named "The European Hydrogen Backbone" and it consists of a group of 31 energy infrastructure operators, united through a shared vision of a climate-neutral Europe enabled by a thriving renewable and low-carbon hydrogen

market. The estimated required investment to realise such a project ranges from € 80 to 143 billion. The figure below represents an overview of the hydrogen backbone for 2030 and 2040.

Figure 7 European hydrogen backbone map



On the south shore, the hydrogen development is perceived using another approach. The strategies are more focused at national level and more towards export than local use. For that reason, the roadmaps/strategies include more hydrogen production than development of infrastructure.

The next two sections will detail the hydrogen strategies on both Mediterranean shores.

4.2. Hydrogen Strategies in the Mediterranean South Shore Countries

ALGERIA

In **Algeria**, a preliminary roadmap is being developed, which foresees the production and commercialisation of hydrogen by 2030. The main objectives of the roadmap are as follows:

- To develop a regulatory and normative framework.
- To establish a strategy for human resources development.
- To increase national integration.
- To define financing mechanisms and incentives.
- To establish an industry and adequate infrastructure for the production, transport, and storage of hydrogen.

Hydrogen is currently produced at ammonia-urea complexes, refineries, and methanol complexes. The produced grey hydrogen is directly consumed at the level of these factories.

In addition, power plants produce hydrogen for their own use; the hydrogen produced is dedicated to cooling the alternators.

Morocco

Morocco has developed a Green Hydrogen Roadmap which was published in July 2021. The roadmap presents three pillars defining a sustainable framework to develop the hydrogen industry in Morocco and eight areas of actions. The three pillars are the following:

- Technologies: encompassing technological developments and cost savings;
- Investment and Supply: including the conditions for investment in the hydrogen industry and its derivatives;
- Markets and Demand: referring to the realisation of demand opportunities, giving rise to new markets.

While the eight areas of actions are these:

- Facilitating cost reduction along the power to X—"PtX"—value chain;
- R&D: Setting-up a Moroccan and international cluster;
- Defining the relevant measures for local content;
- Setting up an industry cluster and developing the related infrastructure masterplan;
- Securing financing to develop the PtX industry;
- Creating the conditions for exporting PtX products from Morocco;
- Assessing in detail a storage plan for the electricity sector;
- Developing domestic markets.

The roadmap also identifies opportunities with short-, medium-, and long-term objectives, as follows:

- **Short term (2020–2030)**

Replacing ammonia imports by providing an input for the fertiliser industry and exporting green hydrogen.

- **Medium term (2030–2040)**

Using green hydrogen in the transportation sector: heavy trucks, mining vehicles, city buses, and railways.

- **Long term (2040–2050)**

Using green hydrogen in passenger vehicles, in industrial heating, and in aviation and shipping. In addition, there is a potential demand for power to X in Morocco.

Morocco has no hydrogen projects that are operational yet; most of the projects are pilots in their feasibility study phase. For instance, the Hydrogen Reference project by MASEN (Moroccan Agency for Sustainable Energy) with 100 MW capacity is expected to start production in 2025 with a target of 10 000 tonnes of hydrogen per year. The project will be financed by KfW with an estimated budget between 300 to 500 million USD.

A second pilot project will be developed by L'Institut de Recherche en Énergie Solaire et Énergies Nouvelles (IRESEN/OCP). The project will be used for ammonia production, with a capacity of 5 MW and 4 tonnes of hydrogen per day. The project will be financed by OCP and KfW.

In addition, a mega project has been announced by Total Eren,[10] with a capacity of 10 GW, coupled mainly to wind turbine, with a budget of 10 billion USD. The project is in the south of Morocco on 170 000 hectares. The planning foresees commencement of production by 2027. The hydrogen produced will be used for export and local needs. Lastly, green hydrogen and ammonia farms are planned to be developed with a capacity of 35 000 tons per year and 185 000 tons respectively, by 2026. The project will be developed by HEVO, Portuguese Fusion Fuel Green Technology, and the budget is estimated at 850 million USD. The farms will be powered by an unprecedented off-grid solar hydrogen generator, called HEVO-SOLAR, which enables producing emissions-free hydrogen at very competitive cost in areas with high solar radiation.

Many other investors are interested in developing mega green hydrogen production projects, which are in their feasibility study phase.

EGYPT

In **Egypt**, the strategy is under development. The Egyptian Ministry of Electricity in cooperation with the EU has launched a program for developing Green Certificates (guarantee of origin certificates (GoO) for electricity, gas, and hydrogen certification).

The Egyptian government is expected to announce a $ 40 bn hydrogen strategy this year, which will include a production capacity of 1400 MW by 2030. Several green hydrogen schemes are being planned in the country, including a 1 GW liquid organic hydrogen carrier (LOHC) hub at Egypt's East Port Said by US-based H_2 Industries.

The European Bank for Reconstruction and Development (EBRD) signed a memorandum of understanding with the Egyptian Ministry of Electricity and Renewable Energy and Ministry of Petroleum and Mineral Resources to establish a framework for assessing the potential of low-carbon hydrogen supply chains to support Egypt develop a national low-carbon hydrogen strategy by mapping the current and future expected international supply and demand of the hydrogen market, and conversion and transportation of hydrogen and its derivatives.

The Egyptian cabinet approved the request made by Scatec and its partners to explore the temporary procurement of electricity from the grid for a green hydrogen plant that will be built in Egypt. Scatec unveiled in October a partnership to build a green hydrogen plant in Ain Sokhna in the Suez Governorate with a capacity of 50 MW to 100 MW.

The hydrogen will be used to produce green ammonia that will be supplied to a unit of Fertiglobe plc. New solar and wind capacities will be built up in the years to come to power the electrolyser at the site. An

[10] Subsidiary of Total Energies

investment decision for the project should be made in early 2023, and commercial operation is set to start in 2024.

In terms of projects, Egypt has at least six known active green hydrogen projects under development. They include a green hydrogen pilot project to be developed with Siemens Energy and another with Belgium's Dredging, Environmental & Marine Engineering Group.

In 2021, Norway's Scatec and UAE-based Fertiglobe also agreed with the Sovereign Fund of Egypt (SFE) to develop a 50 MW–100 MW electrolyser facility to produce green hydrogen for green ammonia production in Egypt. Similarly, Italy's Eni signed an agreement in mid-2021 with Egyptian Electricity Holding Company and Egyptian Natural Gas Holding Company to assess the technical and commercial feasibility of projects to produce blue and green hydrogen in the country.

Egypt based Taqa Power and Germany's MAN Energy Solutions also agreed last year to undertake a pilot project to produce green hydrogen to fuel tourist buses in Egypt; EDF, Total EREN, and Masdar too are undertaking pilot green hydrogen projects. So far, the estimated investment in hydrogen is approximatively 10 billion USD.

The remaining south shore countries have not yet developed either a roadmap or a strategy in terms of hydrogen. However, most of the countries have an interest in studying the potential and role of hydrogen in their respective countries. The members of MEDREG can support each other to develop a roadmap/strategy based on the experience gained so far, for the countries which have not evolved a strategy so far.

4.3. Hydrogen Strategies in the Mediterranean North Shore Countries

Most of the countries on the north shore of the Mediterranean, expect for Malta, already have a strategy regarding the development of hydrogen.

CROATIA

The hydrogen strategy in Croatia is a long-term strategy extending up to 2050, with a milestone in 2030.[11] The main indicators in the strategy are the electrolyser capacity, the share of hydrogen in the total consumption, number of hydrogen filling stations, and the number of patents related to a hydrogen-based economy. The details for 2030 and 2050 are given in the figure 8 below.

STRATEGIC GOAL	INDICATOR	INITIAL VALUE	SHORT TERM GOALS	LONG TERM GOALS
		2021/2022	2030	2050
Increasing production of renewable hydrogen	Electrolyzer capacity Unit of measure: MW	0	70	2750
Increasing the exploitation of RES	The share of hydrogen in the total energy consumption, Unit of measure: %	0	0,2	11
Increasing the use of hydrogen	The number of hydrogen filling stations Unit of measure: number	0	15	100
Encouraging the development of science,	The number of patents related to the hydrogen-based economy Unit of measure: number	0	5	50

CYPRUS

Hydrogen in Cyprus is still at a nascent stage, where the CERA along with the National Technical Committee for Hydrogen (established under the Green Deal) is in the process of facilitating a roadmap for the deployment of hydrogen in Cyprus.
CERA is also in an ongoing process for the formulation of a regulatory decision regarding the use of hydrogen in electricity markets.
No hydrogen projects have been developed for the time being and none are expected to be established soon.

FRANCE

The hydrogen strategy in France was adopted in 2020, in the National Strategy for the development of decarbonised hydrogen in France.[12] The objectives of the strategy are set within three periods as follows:

- **Short and medium-term (2028)**

1. For the industrial usage of hydrogen, 10% carbon-free hydrogen by 31 December 2023 is set as the first objective by the government's Multi-Annual Energy Programme (PPE). The objective is upgraded to 20–40%[13] by 31 December 2028.
2. For power-to-gas installations, the objective is 1 to 10 MW by 31 December 2023, and 10 to 100 MW by 31 December 2028.

[11] Available here (In Croatian)
[12] Available here (In French)
[13] Available here (In French)

3. For hydrogen charging and refuelling stations, the objectives are comparatively limited, projecting 100 charging stations by 31 December 2023. By 31 December 2028 there will be 400–1 000 charging stations.
4. For hydrogen-fuelled vehicles, the objective by 2023 is 5 000 light commercial vehicles and 200 heavy-duty vehicles.

- **Long-term objectives**

For 2028, the law has set the objective of 20–40% of total hydrogen and industrial hydrogen consumption supplied by low-carbon and renewable hydrogen. Also, in 2028, the PPE aims for 20 000 to 50 000 light commercial vehicles and 800 to 2 000 heavy-duty vehicles running on hydrogen.

The regulatory framework to achieve the objectives is partially elaborated; for instance, an ordinance adopted based on Article 52 of the Law on Energy and Climate, defines a framework for the support and traceability of renewable and low-carbon hydrogen, regarding the following:

- The qualification or categorisation of hydrogen as renewable, low-carbon, or carbon-based, depending on the production method, the energy used, and the associated greenhouse gas emissions;
- A traceability mechanism to certify the type of hydrogen produced, renewable or low carbon;
- The implementation of a support mechanism to meet the objectives set by law (i.e., to attain 20–40% of low-carbon and renewable hydrogen out of the total hydrogen and industrial hydrogen consumption by 2030) through calls for tenders to produce renewable hydrogen and low-carbon hydrogen by water electrolysis.

This ordinance[14] comes as one of the numerous support actions towards the hydrogen sector in accordance with the "National Strategy for the Development of Low-Carbon Hydrogen" released by the Government on 8 September 2020.

Furthermore, the Law no. 2019-1147 on Energy and Climate dated 8 November 2019 introduced the right for renewable and low-carbon hydrogen producers to access the natural gas grid network. Indeed, the article L. 111-97 of the Energy Code provides that "subject to preserving the proper operation and level of safety of natural gas infrastructures, a right of access to natural gas transmission and distribution facilities as well as liquefied natural gas facilities [...] is guaranteed by the operators who operate these infrastructures to customers, renewable gas producers, low-carbon hydrogen producers [...]."

Additionally, completing the required infrastructures and to promote the development of underground hydrogen storage, the Ordinance has exempted the holders of fuel or natural gas storage concessions from obtaining a new mining title (authorisation) to store hydrogen underground.

Besides the regulatory framework, the infrastructure development is an important key element. In that respect, the French natural gas transmission system operators (GRTgaz and Teréga)—with nine other European gas transmission operators—aim to create dedicated hydrogen transport infrastructure called the "European hydrogen backbone" as mentioned in subsection 4.1. The objective is to have 23 000 km of such network by 2040, with a major part of that infrastructure being the repurposed natural gas pipelines and only a few new pipelines planned to be created.

[14] Available here (In French)

In terms of projects, the most important experimental project is Jupiter 1000,[15] which is co-financed by the European Union and the French government. The project brings together all the players in the power to gas value chain and is coordinated and operated by GRTgaz.

The project consists of an electrolysis system with 2 electrolysers made for the project, with a cumulated power rating of 1 megawatt using 2 different technologies: the ALKALINE and the P.E.M. (Proton Exchange Membrane). 10 Methanisation reactors were needed for the project. The overall budget for the project is € 31,3 M, of which GRTgaz's participation represents 57% and institutional support provides 32% of the remaining requirement.

Two other experimental projects are in place, Project GRHYD[16] and Hypster[17], which bring the total estimated investment to € 60 M.

GREECE

As mentioned previously, the first draft National Hydrogen Strategy is almost finished, and the strategy includes more than 30 key points that concern the production and distribution of hydrogen and renewable gases, the use of hydrogen and biogas, the development of the institutional framework, research, and innovation. The international and geopolitical dimensions have also been considered while developing the Strategy. There are three distinct periods that have been identified in the Greek Hydrogen Strategy.

- **The first phase concerns the period 2022–2027:**

This first phase considers uncertainties, high costs, and lack of the necessary infrastructure to promote hydrogen. During this period, state aid will be required to develop the hydrogen infrastructure.

- **The second phase concerns the period 2027–2030:**

The pilot projects will start to be implemented in the country. During the second phase, the state will remain a key driver for hydrogen development and in particular its incentive policies (tax reduction and state aid), but the success of the phase will also depend on private initiatives.

- **The third phase concerns the period 2027–2030:**

The state incentives will be gradually removed, and the development of the hydrogen market will be based more and more on private initiatives.
In 2022, there are 2 major hydrogen projects planned:

White Dragon – a cluster of projects to produce green hydrogen in West Macedonia through solar energy electrolysis and distribution through DESFA and TAP pipelines. The project involves photovoltaic facilities with an overall capacity of 1.5 GW and is estimated to be worth € 2,5 billion (although the total cost could

[15] Available here.
[16] More details are available here.
[17] More details are available here.

reach € 4 billion). White Dragon aims to contribute to the production of green hydrogen in Western Macedonia through electrolysis powered by solar PV energy. The produced hydrogen will initially be admixed to the currently planned DESFA natural gas network of Western Macedonia. In case the hydrogen production cannot be fully consumed in Western Macedonia, natural gas could be transported to the remainder of the Greek natural gas transmission system or through the TAP pipeline. Later, the Western Macedonia pipeline could be repurposed for dedicated hydrogen transport. The participants of the cluster are the Public Gas Corporation, Advent Technologies, Copelouzos Group (DAMCO ENERGY SA), Corinth Pipelines SA, TAP AG, DESFA, Terna Energy, Motor Oil, and PPC.

Blue Med – a project by Motor Oil to produce low carbon footprint blue hydrogen and green hydrogen, with a timeframe stretching to 2025. The aim of this project is to develop a flexible, scalable, and cost-efficient infrastructure for the production and distribution of renewable & low carbon hydrogen for use in industry and transport (buses and ships). Blue Med is a project that will last 4 to 5 years, with full development by the end of 2025, aimed at demonstrating a South Hydrogen Valley in Greece with a blue hydrogen production of around 25 kt per year. Motor Oil is the leader of the project, and furthermore the participation of DESFA and PPC is expected.

ITALY

Italy's medium to long-term strategy to promote and support hydrogen has been put forward by the 2019 Integrated National Plan for Energy and Climate (PNIEC, as provided for by EU's Energy Governance Regulation and Climate Law) and detailed in the government's Guidelines on Hydrogen Strategy. The national planning documents and guideline foresee that hydrogen's share of final energy consumption will reach 2% by 2030 and then will grow up to 20% by 2050, that is the Green Deal deadline to implement EU-wide carbon neutrality principle. Hydrogen use will grow basically by promoting its use within transport, industry, and gas infrastructure, where a 2% mix with natural gas is considered as technically feasible without structural changes in the gas distribution sector.

As for hydrogen production, Italy's PNIEC foresees a yearly generation of 0,7 million tonnes, mostly through RES, which calls for 5 GW of hydrolysis plants capacity by 2030.

Apart from a few completed projects (SNAM supplying gas to food industry containing a high share of H2, around 30%), several other projects are ongoing or at an early development stage. All projects are developed by private undertakings, sometimes enjoying public financial participation. All of them refer to production/distribution/supply of "green" H2, i.e., produced by RES.

The most common hydrogen producers are Italgas, ENI/ENEL, PEGASUS, and ENEA, and the use of the produced hydrogen is for food and steel industry (SNAM), storage (REFLEX), EU-funded R&D project for H2 heating, or for glass manufacture such as DIVINA. The estimated investment for the SNAM projects is around € 2 billion.

The hydrogen is also used in the transport sector, mostly in ships. For instance, the project "Blue Dolphin" uses hydrogen in 50 ships, railways, or in cars (H2 for highway gas service stations). In terms of distribution infrastructure, SNAM elaborated a distribution network certification for H2 mix.

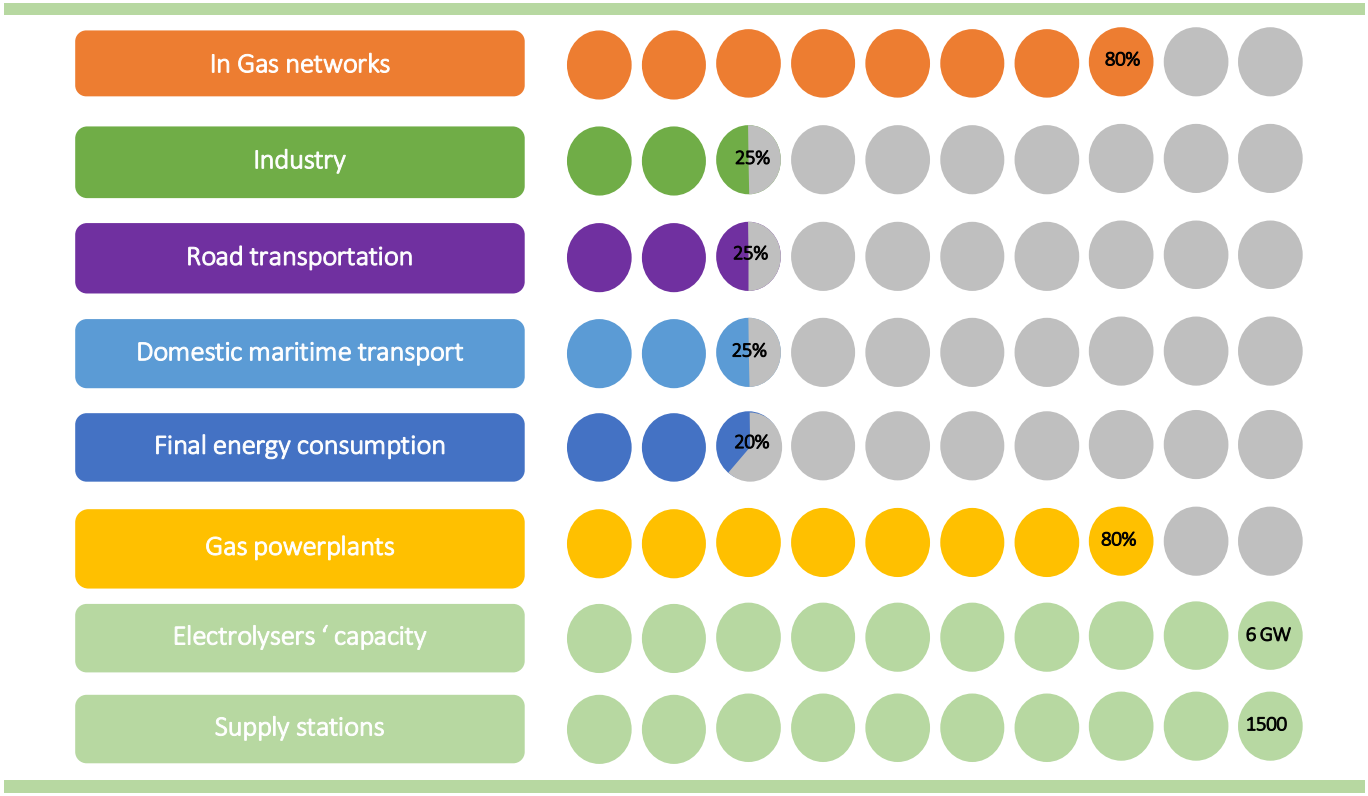
PORTUGAL

The legislative framework related to the hydrogen development in Portugal is implemented through several regulatory frameworks that tackle each aspect of the hydrogen implementation; for instance, the framework for the creation of an infrastructure for alternative fuels—Decree-Law no. 60/2017 of June 9, or the carbon neutrality 2050 roadmap.

However, the national hydrogen strategy (EN-H2) has been approved by the Council of Ministers Resolution no. 63/2020, of August 14.[18] This strategy aims to contribute to the EU's national and decarbonisation objective by introducing an element of incentive and stability for the energy sector, promoting the gradual introduction of hydrogen as a sustainable pillar, and integrated into a broader transition strategy to a decarbonised economy, as well as a strategic opportunity for the sector/country. It aims to promote and boost both supplies and consumption in the various sectors of the economy, creating the necessary conditions for a real hydrogen economy in Portugal.

The objective is to ensure, in the long term (2050), a decarbonisation of the entire natural gas network and power plants and contribute significantly to the decarbonisation of the transport and industry sectors. Until 2030, Portugal foresees the consolidation and the roll-out of projects at the national level. From 2030 onwards the aim is the full development of the national H_2 market. The plan promotes the gradual

Figure 8. Hydrogen Strategy for 2050 - Portugal



*~~Even if the strategy has minimum and max~~imum values established, we only consider the maximum.

[18] Presentation session on support mechanisms and hydrogen road map

introduction of H2 with goals for 2030, 2040, and 2050. The figure below represents value goals for 2050, considering the best scenario.

In terms of infrastructure development, there are no major changes so far, but the gas network will be adapted in the medium to long term. In addition to hydrogen incorporation targets, the strategy also sets other objectives that reveal its ambition by 2030, such as the number of H_2 vehicles (passengers and goods).

Besides the regulatory framework, the Innovation Support Fund is supporting two projects, namely the **Green Pipeline Project** and **SolargasMOVE**. The first one is a pioneering project which will introduce for the first-time green hydrogen in the natural gas network. The latter concerns the production of hydrogen using solar energy. The estimated investment for both projects is around € 3 M. The details of each project are in the annexes.

At the end of 2020, a call for an Operational Programme for Sustainability and Efficient Use of Resources (**POSEUR**) was launched to support projects for the production, distribution, and consumption of energy from renewable sources, which included the hydrogen component, with the deadline being 30 April 2021. Thirteen projects were approved (12 hydrogen+1 biomethane) and must be completed by end of June 2023, with a total funding of € 34 M, with a maximum of 85% co-financing for each project. The details per project are in Annexe 1.

Applications for the first tender for companies in the **Resilience Recovery Plan** (PRR) for the subsidisation of green hydrogen production projects and other renewable gas projects were submitted until 18 February 2022. In this first competition, € 62 M were distributed to support different projects to produce gases of renewable origin, including the development and testing of new technologies or tested technologies that are not yet sufficiently disseminated in the national territory. The initiative is operationalised through the Environmental Fund (FA), at a total of € 185 M through three tenders between 2021 and 2023. The results of the first tender are not yet known.

The project pipeline of the European Clean Hydrogen Alliance includes over 750 projects from all parts of the value chain, including hydrogen production, transmission and distribution, application in industry, transport, energy systems, and buildings. Portugal has 23 projects listed in the northern region, 67 in the centre, 23 in the Metropolitan Area of Lisbon, and 18 in Alentejo; for example: **H2Sines** (ENGIE, RENH2Distribution, REN Portgás Distribuição), **RENH2Grid** (REN Gasodutos, S.A.), **RENH2Mobility** (REN Gasodutos, S.A.), **RENH2Valleys** (REN Gasodutos, S.A.), **Sabor/Mogadouro** (Smartenergy), **Sines Green Energy Park** (Petrogal SA (Galp)), **H2Enable** (Bondalti), **H2Mobility Alenquer** (EDP Energias de Portugal, S.A.), **HyMob Oeste** (Resilient Group Lda.), **HyTagus Cluster** (Iberdrola), **Sines Green Energy Park** (Petrogal SA (Galp)), **Hyperion H2 Setúbal** (Hyperion Renewables).

As far as **H2Sines** is concerned, an industrial unit to produce green hydrogen of at least 1 GW via electrolysis by 2030, powered by solar and wind energies, will be installed. It is based on strategic partnerships (REN, EDP, Galp, Martifer, and Vestas) at national and European level, namely with the Netherlands, with the potential to include other Member States, which will give a significant dimension to European Union to the project as a way of securing the Community's funding. Hydrogen produced in Sines will be drained by three routes: (i) through direct injection into natural gas networks; (ii) distribution by tanker truck to various consumption points (e.g., hydrogen stations and/or final consumers); and (iii) through export via Sines's terminal to Netherlands.

Regarding **REN – National Energy Networks** projects, one may add that in May 2021 REN presented its Strategic Plan for the period 2021–2024. REN expects 33% of the investment to be dedicated to hydrogen projects in gas, representing around € 40 M: € 15 M in the pipeline network and € 25 M in storage, in Carriço infrastructure.

TÜRKIYE

There is no hydrogen strategy/policy document in Türkiye for the time being, however, the governmental organisations (led by Türkiye Energy, Nuclear and Mineral Research Agency (TENMAK)) have been studying the "hydrogen roadmap" including targets in the short and medium term in line with the green energy transition period. The "Strategies for the Hydrogen Technologies and Roadmap" are expected to be finalised and announced by the Ministry of Energy and Natural Resources in a short while.

5

BIOGAS AND BIOMETHANE DEVELOPMENT

The level of development of biomethane in the Mediterranean region is uneven, from one country to another. However, in most of the countries there is at least a roadmap concerning the implementation of biogas within the energy sector.

This chapter presents the status of development of biogas in the Mediterranean region and is enriched by the case studies of France and Italy that are detailed in annexes 2 and 3.

5.1. Biogas Strategy in the Mediterranean Region

Except for Palestine and Malta, all countries of the Mediterranean region have at least a roadmap related to the development of biogas and its implementation within the energy sector.

In some cases, there is a specific strategy related to biogases or waste treatment, such as in Jordan and Lebanon. In the other cases, the objectives of biogas development are included within the energy strategies. For instance, feed-in tariff is in place within the renewable energy sources strategy in Algeria and Egypt to support renewable electricity producers, or the energy transition and decarbonisation strategies tackle biogas, as in Greece, Italy, and Portugal.

In February 2020, the Croatian parliament adopted the Energy Development Strategy of the Republic of Croatia until 2030 with an Outlook to 2050, which represents a step towards achieving a low carbon energy vision and enables transition to a new energy policy ensuring an accessible, secure, and quality energy supply without placing an additional burden on the state budget under state aid and incentives.

The Regulation on quotas for promoting electricity production from renewable energy sources and high-efficiency cogeneration and the Regulation on the Amendments to the Regulation on promoting electricity production from renewable energy sources and high-efficiency cogeneration were adopted in May 2020. The Regulation on quotas provides for an additional 2 265 MW of connection capacity for facilities in the new incentives systems (market premiums and guaranteed purchase price). Even though the explanatory report on the proposal of the Regulation on quotas states that the quotas were set in accordance with the Energy Development Strategy of the Republic of Croatia until 2030 with an Outlook to 2050 "Official Gazette No. 25/20"[19] and the "Integrated national energy and climate plan for the Republic of Croatia for the period 2021–2030," the quotas are higher than the goals for 2030 laid out in these two documents.[20]

In Morocco, for the time being there is no specific strategy for biogas. However, in 2021 a roadmap for energy recovery from biomass was published. The roadmap identified the energy potential for biomass that amounts to approximately 13,4 TWh per year, of which 6,6 TWh per year comes from the agricultural sector, 3,5 TWh from the forestry sector, 3,1 TWh per year from the waste sector, and 0,2 TWh per year from the wastewater sector.

In Lebanon the bioenergy streams and the energy potential in terms of methane potential can reach 1,1 TWh from animal manure, municipal solid waste (MSW), landfill gas, and municipal sewage sludge.[21] The Renewable Energy Outlook for Lebanon includes a strategy for bioenergy as part of the Remap 2030,

[19] Available here. (In Croatian)
[20] The new Act on renewable energy and highly efficient cogenerations. Available here.
[21] The National Bioenergy Strategy for Lebanon

covering the building sector, transport sector, and power sector, with 700 GWh being for space heating, with 1,38% of final energy consumption and 1,5% of electricity generation from renewable energy sources.

In Greece, the NECP includes the promotion and development of biomass/biogas projects with the participation of local livestock cooperatives and self-consumer units with the possibility of utilising existing energy networks. Furthermore, within the scope of the development of environmental markets, the government plans to introduce guarantees of origin for biogas and hydrogen from various forms of energy and the coupling of guarantees of origin systems for different forms of energy, such as electricity, fuel gas, thermal and cooling energy, which will help to increase the penetration of renewables in final consumption.

There is also a plan to use biogas within the next years for district heating. Furthermore, a new environmental licensing procedure for biogas upgrading technologies is expected to increase the investments in these projects. Finally, electricity generation from bioenergy is projected to increase from 0,45 TWh in 2021 to 1,6 TWh in 2030.

Italy aims at developing and supporting biogas production and its upgrading as much as possible to obtain biomethane for transport use and for blending it with natural gas, for both “circular economy” purposes and energy system decarbonisation objectives. Biogas-based electricity generation has been incentivised for long through a feed-in tariff system; incentives to biogas-generated electricity which were discontinued have recently been revamped for “innovative technologies”. Currently, biomethane production stemming from biogas upgrading is supported by public incentives. Economic support is also foreseen for undertakings that upgrade their biogas plants to produce biomethane. As a result, Italy is one of the major biogas producers in Europe and is accelerating its biomethane infrastructure development to maximise the economic and environmental benefits of biogas.

The Energy Transition Law in France of 2015 defined a target of 10% renewable gas in annual average gas consumption by 2030. In France, mechanisation, or anaerobic digestion, is considered the most mature process for biogas production, although other production processes too are being developed.

In Portugal, there is no specific strategy for biogas, unlike the case of hydrogen. However, biogas is included in the legal framework for renewable gases, see Annexe 1.

5.2. Existing Biogas Projects and the Role of the Regulator

In most cases, NRAs are not responsible for the development of biogas in their respective countries. However, all the NRAs are involved at a certain point of the process. For instance, CERA is the competent authority for licensing such projects in Cyprus. Other institutions and actors can be also involved in biogas development, especially where biogas is considered mature technology, as in France:

- ADEME (Agency for the Environment and Energy Management): producers wishing to benefit from "feed-in tariffs" must identify their facilities to that Agency. It may provide them with technical support or financial aid.
- GRDF (Gaz Réseau Distribution France) – the DSO has overseen management of the Guarantee of Origin (GO) scheme since 2012, with the competencies being renewed until 2023.
- Investment aid for methanisation can be granted by some local authorities like departmental councils or through the regions within the framework of the implementation of the European

Agricultural Fund for Rural Development (EAFRD) and the European Regional Development Fund (ERDF). This is granted on a case-by-case basis. Furthermore, the ADEME itself and the National Research Agency (ANR) also fund projects in the field of biogas.

- Public Funds: FEC ("Circular Economy fund") funds biogas recovery facilities by cogeneration and specific biogas treatment equipment; FCR ("Renewable Heat" fund) supports biogas recovery installations by heat or purification/injection and related heat networks.
- Bpifrance (French public investment bank): the agency provides unsecured loans in the form of an "Agricultural methanisation" loan, granted to farmers investing, alone or collectively, in agricultural methanisation plants with a cogeneration capacity of less than 500 kW or an injection capacity of less than 125 Nm^3/h, and a "Methanisation injection" loan, granted to methanisation plants with an injection capacity of more than 125 Nm^3/h.

The next table summarises the main actors in biogas development in each country.

Table 1. Main Actors in Biogas Development per Country

Algeria	**CREG**
• CREG is responsible for issuing the call for tenders by auction, for capacities between 10 and 20 GWh per year. • CREG is responsible for monitoring and controlling compliance with the relevant laws and regulations, and implementation and control of the public electricity service. • The agency issues a guarantee of origin certificate before commissioning power plants.	
Croatia	**HERA, HROTE, Ministry & Private Investors**
• Private investors are responsible for developing biogas capacity. • Monitoring is the responsibility of the Ministry (https://mingor.gov.hr/), HERA (www.hera.hr), and HROTE (www.hrote.hr).	
Cyprus	**CERA**
• CERA is the competent authority for licensing such projects.	
Egypt	**Ministry of Environment**
• The Ministry of Environment is working on expanding biogas technology, whereas the Bioenergy Foundation for Sustainable Rural Development within the Ministry is responsible for implementation of such projects in rural areas.	
France	**Main Actors**
• ADEME (Agency for the Environment and Energy Management). • GRDF (Gaz Réseau Distribution France). • Public Funds: FEC ("Circular Economy fund"). • Bpifrance (French public investment bank).	
Greece	**Ministry of Energy & RAE**
• The Ministry of Energy is responsible for policy related issues regarding all energy technologies including biogas, biomethane, and hydrogen. • RAE is responsible for monitoring energy markets, but it also provides an opinion on various policy related and technical market related issues to the Ministry of Energy. • RAE is also responsible for the issuance of electricity generation certificates to biogas and biomass power plants during the licensing process. • Renewable Energy Sources Operator & Guarantees of Origin S.A. (DAPEEP): DAPEEP is responsible for providing remuneration (at the present time, through feed-in-tariff) of biomass and biogas power plants as well as for the issuance of GOs for those stations.	
Italy	**ARERA and GSE**
• The government sets objectives (in particular, as biomethane production and feeding it into the natural gas network) and establishes incentivising schemes. These schemes are implemented under ARERA regulation and GSE oversight. GSE stands for “Gestore del Sistema Energetico” – Energy System Agency, a publicly-owned company responsible for paying the incentive tariffs to biogas producers.	

Jordan	EMRC
• The entities that are responsible for developing biogas are municipalities and the private sector. • The regulatory body (EMRC) is responsible for monitoring.	
Lebanon	**Ministry of Energy and Water**
• The NRA is not yet established. For now, the Ministry of Environment and the Council of Ministers are responsible for the development & monitoring of biogas projects.	
Malta	**Ministry of Energy**
• The Ministry is responsible for energy, within its general responsibility of ensuring the achievement of RES targets.	
Morocco	**Ministry of Energy, Mines and Environment**
• The entities responsible for developing/monitoring biomass energy sources are not identified yet. • The roadmap states that between 2021–2024, Morocco will be working on setting up an institutional and organisational framework adapted to the biomass. Thus, the entities in charge of developing this should be identified in this phase.	
Portugal	**Main Actors**
• Private stakeholders develop the technologies and projects. Monitoring is a responsibility of the grid operator if there is an injection into the grid. • The Directorate-General for Energy and Geology (DGEG), as the licensing authority, monitors the implementation of projects, is responsible for enforcement of the energy policy, and identifies the key indicators and the production of energy.	
Türkiye	**Ministries**
• The Ministry of Energy and Natural Resources and Ministry of Environment, Urbanisation and Climate Change is responsible for developing strategies and targets for the development of renewable resources. • EMRA issues licenses to companies which aim to construct electricity production facilities using biogas as resource.	

The projects that are already in place are usually small capacity landfill installations and are developed mostly by private companies. However, when the waste management is under the municipalities' scope, these projects are developed by these bodies. In most cases the use of the produced biogas is for electricity or heat production.

In addition, biogas is also injected into the natural gas infrastructure, as in France; the missing requirements will be finalised soon in Italy and Portugal and a share of the biogas production will also be mixed with natural gas.

In Egypt, there is a presidential developmental initiative "Haya Karima" which has launched biogas projects in Egypt's countryside, specifically in Gharbiya governorate to produce natural gas and fertilisers for farmers and livestock farms.

In terms of incentives mechanisms, the biogas industry is still lacking support compared to the other renewable energy sources. Still, in some the countries at least one support mechanism is in place. For instance, in Croatia, incentives are applicable for eligible producers who were benefiting from feed-in tariff from 2005 to 2017. Afterwards, in accordance with the Regulation, in November 2020 HROTE (the Croatian energy market operator) organised the first call for tenders for awarding market premiums and for guaranteed purchase prices to incentivise the production of electricity from renewable sources. Guarantee of origin is still in use; as the authority for issuing guarantees of origin in Croatia, HROTE operates a Register of Guarantees of Origin—a computer system that stores guarantees of origin and is used to issue, transfer, and cancel guarantees of origin as electronic documents. The details about the quota are given in the Annexe.

In Cyprus the feed-in tariff and grant scheme is applicable for biogas projects. In Italy, the projects that inject their production into the natural gas infrastructure receive an economic incentive.

In Palestine on the other hand, the same mechanisms as for solar PV will be applied to biogas projects, while in Portugal POSEUR offers funding for projects, at up to 85% of the investment. In addition, some of the biogas projects may still be working under a feed-in tariff regime when injecting electricity in the grid.

In Türkiye, companies which aim to construct electricity production facilities using biogas as resource can apply for receiving a license from EMRA. EMRA grants licenses to the investors and monitors the construction works during the license period. Strategies and targets for the development of renewable resources including biogas and biomethane are determined by the Ministry of Energy and Natural Resources.

France, on the other hand, has many incentive mechanisms, although the main support remains the feed-in tariff for biomethane injected into the gas networks and electricity produced from biogas. In addition, the guarantee of origin system is also applied, ensuring the traceability of biomethane, a “right to injection", and the reduction of connection costs. The details regarding the support mechanisms in France are presented in Annexe 2.

The list of existing installations is given in the following table.

Table 2. Existing Biogas Projects in the Mediterranean Region

Country	Project	Developer	Usage of the biogas
Algeria	OUED SMAR public landfill site	Public	Electricity production
Croatia	More than 59 projects	Private sector	Electricity and thermal production
Cyprus	N/A	Private sector	Electricity production
Egypt	Algabal Alasfar 1 (25 MW) Algabal Alasfar 2 (27.5 MW), Private projects (3.5 MW), Private projects under development (51 MW)	Public Public Private Private	Electricity production Fertilisers for farmers
France	More than 358 projects	Private	In 2020, biogas was mainly used: 34% to produce electricity, 42% to produce heat, 24% for purification into biomethane before injection into the gas networks.
Greece	As of February 2022: 67 power plants with 109 MW total capacity. 96 power plants are going through the licensing process. Most of these power plants either use landfill gases as fuel (45.53 MW) or biogas produced from biomass (36.51 MW).	Mostly private	Heat and electricity production

Country	Project	Developer	Usage of the biogas
Italy	In Italy around 2 000 plants producing biogas exist; of these, 27 plants produce biomethane.	Private	Electricity production Biogas upgrades deemed to favour the feeding of gas network with biomethane have been growing due to biogas-supporting regulation, as also due to biogas-to-the network incentive schemes.
Jordan	Self-consumption project owned by Greater Amman Municipality with a capacity of 4,7 MW.	Public	Electricity production
Lebanon	**The Naameh Landfill gas:** 7MW, with an average LCOE of 4.55 USD ¢/KWh, generating 59 GWh/Year. **Saida landfill gas:** 2 MW power plant and is estimated to be generating around 17 GWh/Year. The target is to have a total capacity of 13 MW able to generate 100 GWh/ Year by 2030, which needs an additional investment of around 20 million USD.	Public : Electricite du Liban (EDL). Saida plant is implemented by the municipality.	Electricity production Heat production
Malta	4 CHP plants operating on biogas in Malta. The total electrical capacity installed is of 4,56 MWe and during 2021 they generated 7228,5 MWh of electricity.	Public	Biogas is used as fuel in combined heat and power (CHP) plants.

Country	Project	Developer	Usage of the biogas
Morocco	More than 21 biomass projects in operation with a total of 12 MW installed capacity. Those projects are installed at the level of landfills and STEPs. 10 projects in operation with a total capacity of 70 MW installed by industries and hotels.	Mostly private	Electricity production Heat production
Palestine	There is a project under development to generate electricity from solid waste landfills, the project proposed by the government	Private	Electricity production
Portugal	There are more than 60 biogas production facilities in Portugal (*): Municipal Sector - 56%: The municipal sector covers municipal waste (91%) and domestic tributaries (9%). Agricultural - 32%: Animal production (cattle, pigs, poultry, sheep, and goats) represents the greatest potential—treatment of its effluents. Anaerobic digestion allows adding value in the management of farms, making it possible to convert more than 50% of the organic matter of effluents into an energy-carrying vector (biogas/biomethane), leading to the reduction of its volume and obtaining a treated flow of agricultural value for irrigation and/or soil correcting. Food industry - 12%. 51 units are connected to the electricity grid and 6 of these work in cogeneration. There are also 6 other units that do not have connection to the electricity grid, 2 of which operate in cogeneration.	Mostly private	Electricity production Heat production Used in all natural gas replacement applications, i.e. fuel for food preparation, heating of environment It is expected that soon biomethane will be injected into the natural gas grid.
Türkiye	More than 250 Biomass projects (including landfill gas, methanisation, and thermal disposal), whose installed power is 1 838,4 MW.	Mostly private	Electricity generation

CONCLUSION AND RECOMMENDATIONS

This report highlights the potentially significant role of renewable gases in the Mediterranean energy market. It focuses on biogas and hydrogen, which are included in most of the Mediterranean countries' energy strategies.

Biogas is well developed in some countries such as France and Italy. The advantage of biogas is the availability, even if limited, of the feedstock used to produce biogas, like animal manure, municipal solid waste, and wastewater. Therefore, as a first step, countries should assess the potential of the existing feedstock and benefit from its availability to reduce the dependence on fossil fuel in the energy mix. In addition, the regulatory framework is already mature in several countries such as France, Italy, Croatia, Portugal, and Greece.

MEDREG as a knowledge exchange platform can play an important role in facilitating cooperation among its members to develop biogas in the countries where it is not yet developed.

Nevertheless, it is important to highlight that biogas is limited to local use and to small projects. In some countries, it is even more complicated to have dedicated land for biogas production as it is linked to food self-sufficiency.

On the other hand, this report shows that **hydrogen** is in a premature phase, where most of the countries are exploring the potential of using hydrogen as a new energy vector that will support the renewable energy sources and facilitate the energy transition. In addition, NRAs are already developing the regulatory framework and incentive mechanisms that will rule the use of hydrogen.

Many projects have been announced for development in the following years and the R&D is moving towards providing a suitable solution to transport hydrogen either through the existing infrastructure or through new ones.

There is significant interest on the south shore of the Mediterranean region in the production of green hydrogen. On one hand this will enable increasing the RES dedicated to hydrogen production in those countries, and on the other it will facilitate the export of hydrogen to the north shore.

On the opposite shore, projects have already started to be developed and implemented in the energy sector and more initiatives are being put in place to allow development of the necessary infrastructure to transport and use hydrogen to most of the EU countries, as part of the Hydrogen Alliance and the European Hydrogen Backbone.

The complementarity between the north and south shores of the Mediterranean region has not been leveraged so far, except for the electricity interconnection between Morocco and Spain. The potential of the Mediterranean region needs to be unlocked to reach the ambitious objectives of energy transition set by all countries in the region. To implement it, close cooperation is needed among the countries, and energy regulators need to develop a common harmonised and transparent regulatory framework that facilitates and incentivises investors to develop projects within the Mediterranean region.

At national level, collaboration between policy makers, energy regulators, and investors is important to develop a common and appropriate regulatory framework. This is needed to streamline the procedure necessary to realise projects, ensure the bankability of investment, and to reduce the investment risks with a stable and predictable framework.

The NRAs need to protect all customers and ensure affordable energy for society. RES can be part of the solution, as it can act as a shield, since the costs related to RES production are lower compared to fossil fuel-based production and hence would reduce both the impact caused by the surge in energy prices and our demand on key fossil fuels like natural gas.

Lastly, past and recent events in the energy market have shown that the market design and the regulatory framework always need to be up to date to cope with the actual situation and to protect the end-users from the negative impact of a future crisis. Therefore, regulators must develop dynamic regulation and facilitate modernisation of the infrastructures and explore alternative and innovative technology or energy sources, such as renewable gases.

ANNEXE

ANNEXE 1: Portugal Renewable Gases Regulatory Framework:

In addition to the national hydrogen strategy explained in the report, the strategy for hydrogen in Portugal can be identified in a set of regulatory frameworks. For instance, the Decree-Law no. 60/2017 of June 9 sets out the framework for the creation of an infrastructure for alternative fuels, to minimise dependence on oil and to mitigate the environmental impact of transport, transposing into the internal legal order the Directive 2014/94/EU of October 22 of the European Parliament and the Council.

In addition, the Roadmap for Carbon Neutrality 2050 (RNC 2050) sets objectives for decarbonisation and energy, social and economic transition. Namely, it establishes the reduction of greenhouse gas emissions for Portugal by between 85% and 90% by 2050, compared to 2005, and the compensation of other emissions through carbon sequestration using soil and forests.

The RNC 2050 identifies the main future trend lines and the social and economic transformations that will be necessary, involving all sectors of the economy and society, namely: the electricity sector, mobility and transport, various types of industry, residential and service buildings, agriculture, forests and other land uses, waste and wastewater.

The National Energy and Climate Plan 2030 (PNEC 2030), developed in accordance with RNC 2050, sets out the targets and objectives and implements policies and measures for the 2030 horizon towards a carbon-neutral future and the achievement of Portugal's long-term objectives in this area, where renewable gases, with particular emphasis on green hydrogen, are assumed to be central elements in the strategies of decarbonisation. The 2030 PNEC sets the following national targets for 2030, aligned with a path of carbon neutrality by 2050:

Specifically, the Decree-Law no. 62/2020 of August 28 established the organisation and operation of the National Gas System and its legal regime, introducing as new activities both the production of gases of renewable origin as well as the production of low-carbon gases. This decree-law also lays down the regime applicable to the injection of other gases into the national gas network, meeting the goals contained in PNEC 2030 and in the RNC 2050.

In March 2021 ERSE approved the gas sector regulations, completing the adaptation of the regulation to the new legal framework of the sector that now includes the production of renewable gases and low-carbon gases. In this way, ERSE's regulations began to consider these new activities and all the resulting trade relationships, creating a regulatory framework appropriate to the future reception of other gases in the natural gas networks. The approved regulations are as follows: Regulation on Trade Relations (RRC); Tariff Regulation Code (RT); Quality of Service Code (RQS); Access to Networks, Infrastructures, and Interconnections Code (RARII); Infrastructure Operation Code (ROI) and its Global Technical Management Procedures Manual (MPGTG).

The Regulation of the National Gas Transport Network has been amended by the Order no. 806 C/2022 of January 19. This Regulation lays down the technical and safety conditions that must be complied with during the design, construction, operation, maintenance, and out-of-service placement of the infrastructure of the National Gas Transport Network (RNTG) aimed at ensuring adequate gas flow, interoperability with the networks to which they are connected, and the safety of people and property as well as preservation of the

environment. The maximum share of the incorporation of other gases into the RNTG is set at 5 % by volume by 2025, and between 10% and 15% by volume by 2030. The adaptation of existing RNTG infrastructure to new gas mixtures that include the incorporation of renewable gases should be preceded by technical feasibility studies and analysis of the impacts of the solutions.

The Ordinance no. 98-A/2022 of February 18 adopted the Regulation of the Production Support Incentive System of Renewable Hydrogen and other Renewable Gases, with a view to contributing to the goal of carbon neutrality through energy transition by giving support for renewable energies, particularly in the production of hydrogen and other gases of renewable origin. This program also aims to promote economic growth and employment through the development of new industries and associated services, as well as research and development, accelerating technological progress and the emergence of new technological solutions, with high synergies with the business fabric, reducing national energy dependency and thereby contributing significantly to the improvement of the trade balance and enhancing the resilience of the national economy.

More recently, Decree-Law 30-A/2022 of April 18 adopts exceptional measures to ensure the simplification of energy production procedures from renewable sources. It is intended to promote the increase in biomethane and renewable hydrogen production, the deployment of solar and wind energy, the deployment of innovative solutions based on hydrogen and electricity from renewable sources at competitive costs in industrial sectors, as well as the simplification and reduction of deadlines for licensing procedures, which is a precondition for accelerating renewable energy projects.

Projects:

- **Green Pipeline Project** – Place: **Seixal** – Responsible entity: Galp Gás Distribuição: A pioneering project in Portugal which will introduce, for the first time, green hydrogen in the natural gas network. This project will be carried out in a local network in Seixal and will distribute a mixture of hydrogen and natural gas to about 80 consumers in the residential, non-residential, and industrial sectors. The mixture will have 2% hydrogen at an early stage, gradually increasing to 20% within 2 years. The objectives of this project are: (i) To gain technical experience in controlling the injection of H2 into the gas network (injection and mixing stations); (ii) to evaluate the performance of the measurement equipment for gross calorific value (SCP) of H2 and final gas mixture; (iii) to evaluate end-use performance of gas with H2 incorporation of up to 20%; (iv) to develop a billing model adapted to the local gas mixture. The total investment is € 1 M.
- **SolargasMOVE** – Place: **Frielas**/Loures – Responsible entity: Dourogás Renovável: Production of green H_2 (solar) and subsequent renewable methane from CO_2 and wastewater from wastewater treatment station, with an installed capacity of 0,04 MW. The total investment is € 2,088 M.
- **H2MARKET** – Place: **Monforte**/Alentejo (Dourogás) – Responsible entity: LSBPDG - Sociedade de Produção de Energia: Installation of a green hydrogen production unit with an electrolysis power of about 5MW, which will be powered by a solar power plant using generation by photovoltaic conversion with electric power of 10MW. The projected investment of € 14,3 M will be borne in part by the company, through equity and external financing, at around € 9,3 M, as POSEUR subsidisation is set at a maximum of € 5 M.
- **Setúbal Hydrogen Production Center** – Place: Setúbal – Responsible entity: Hyperion Renewables H2: Building a green hydrogen production plant of 5,31 MW to inject 50% of the hydrogen produced in RNTG and 50% in other local industries and replace the consumption of natural gas in their energy

processes. The energy consumed by the electrolysers will be of renewable origin, being produced by a photovoltaic park and through a contract to purchase renewable energy. The projected investment is of € 10,6 M, with a POSEUR funding of € 5 M.

- **H2 Verde @ Sines Refinery** – Place: Sines – Responsible entity: Petrogal: Installation of a green hydrogen production unit by electrolysis (PEM technology) with a total capacity of 2,0 MW and estimated average production of 276 tonnes/year fully destined for self-consumption in the processing units present at the Sines Refinery. The projected investment is of € 2,8 M with a POSEUR funding of € 1,766 M.
- **H2GREENPOWER** – Place: **Maia**/Porto – Responsible entity: Capwatt: Installation of a unit of production of green hydrogen by water electrolysis by PEM technology with a total capacity of 1,2 MW, ensuring the production of green hydrogen to inject into the internal distribution network that feeds the engine of cogeneration of the business site of Sonae Campus. The projected investment is of € 1,793 M with a POSEUR funding of € 0,994 M.
- **HEVO-SUL** – Place: **Sines**/Alentejo – Responsible entity: Fusion Fuel Portugal: Comprises 178 Hevo-Solar units, which will produce approximately 418 tonnes/year of green hydrogen. The hydrogen will be used for several applications, including injection into the natural gas distribution network, as a feedstock for green ammonia production, as well as for bottling in pressurised cylinders for industrial uses. The project has a total investment value of € 7,977 M, of which € 4,291 M is POSEUR funding.
- **H2Metal** – Place: **Aveiro** – Responsible entity: MM, Hidrogenpor: H2 production for natural gas grid injection and direct industrial consumption, with an installed capacity of 0,9 MW. The projected investment is € 3,967 M, with a POSEUR funding of € 2,058 M.
- **PRIOGH2STATION** – Place: **Vila Franca de Xira** – Responsible entity: Prio Energy: Hevo solar photoelectrochemical water electrolysis system by direct conversion of solar energy into green hydrogen and oxygen. In total, 62 trackers of this HEVO Solar system will be installed, 3 of which will be installed in a Prio fuel station of major traffic on the N/S Axis and another 59 in the HyChem industrial park, for the supply of heavy vehicles running with fuel cells. The projected investment is € 3,967 M with a POSEUR funding of € 1,396 M.
- **SINES-GH2-SOLAR** – Place: **Sines**/Alentejo – Responsible entity: Energykeme: Installation of production of green H_2 through photoelectrochemical electrolysis, compression, storage in PED bottles, and subsequent use for electricity production and heavy transport supply. The total capacity of the plant is 1,222 MW, with an estimated annual hydrogen production of 132 tonnes. The projected investment is € 2,545 M with a POSEUR funding of € 1,257 M.
- **H2Grid** – Place: Rio Maior/Alentejo – Responsible entity: Essential Advantage: Production of green hydrogen and injection of up to 10% of H2 of renewable origin in the natural gas network of Rio Maior, which will cover 2834 customers. Annually it will produce 212,87 tonnes of green H2, which will replace fossil fuels, in particular natural gas. The company plans to invest € 2,706 M, with a POSEUR funding of € 1,550 M.
- **EA_H2** – Place: **Paços de Ferreira**/North – Responsible entity: Essential Advantage: Continuous production of green H_2 from an installed power of 1,3 MW electrolysing machines and subsequent injection into the natural gas networks of Paços de Ferreira in a proportion of up to 10% of H_2. An investment of € 2,716 M is estimated, with a POSEUR funding of € 1,558 M.
- **TOH2_Cadaval** – Place: Cadaval/Center – Responsible entity: TOH2 Partners: Implementation of a hydrogen production plant by PEM electrolysis, with an installed capacity of 1,743 MW of hydrogen output, with an annual production estimate of 246 tonnes/year. The predictive use of renewable

hydrogen will be the transport sector supply. The projected investment is € 3,645 M, with a POSEUR funding of € 2,307 M.

- **Projeto Nazaré** – Place: Nazaré/Center – Responsible entity: Reganazaré: Implementation of a green hydrogen production plant with an installed capacity of 4 MW for injection into the public gas network. The energy source to be used for hydrogen production will be 100% renewable, photovoltaic. The projected investment is € 5,842 M with a POSEUR funding of € 3,458 M.
- **Green Pipeline Project** – Place: **Seixal** (Setgás) – Responsible entities: Galp Gás Natural Distribuição (GGND)/ Gestene/PRF/Associação Portuguesa para a Promoção do Hidrogénio (AP2H2)/ISQ: Installation of an electrolysing machine with 50 kW of power to produce about 1kg/hour of hydrogen. It is a pilot project aimed at starting hydrogen injection into the grid, mixed with natural gas in small percentages, which will make it possible to assess the impact on existing infrastructure and heating equipment in homes and industries. For two years it will inject green hydrogen into the gas network serving a cluster of only 80 customers, including 70 residential and a dozen businesses, including an industrial consumer. It started with 2% to 3% hydrogen in the initial phase (January 2022), until it reaches 20% of the mixture (within two years), at a total cost of less than € 1 M.
  This project is already mentioned above as being funded by the Innovation Support Fund.
- **KEME Energy**: Green hydrogen production plant in **Sines**, by electrochemical photo electrolysis, compression, and storage in PED bottles. The first stage of this project will have a total capacity of 1,26 MW, with an annual production of 80 tonnes of hydrogen for use in industry and for electricity production, to supply a renewable energy community to be created in Sines through a fuel pile. The second stage of this project that will double the installed capacity will be submitted to the Environmental Fund of the Resilience Recovery Plan (PRR).
- **Green H2 Atlantic**: Place: **Sines**/Alentejo – Responsible entity: EDP Renováveis: The green hydrogen project will represent a total investment of € 76,6 M, with European funds (Horizonte 2020) contributing € 30 M. This project was foreseen to begin development in December 2021, and it aims to establish and operate an electrolyser with 100 megawatts in this city, to produce green hydrogen using solar and wind energy. Afterwards, the hydrogen produced will be consumed in projects located in Sines. The goal is to create 1 GW of green hydrogen production capacity.

ANNEX 2: France Case Study – Support to Biogas and Biomethane

1. Definitions and Basic Information

1.1. Definitions

Biogas is produced from the anaerobic digestion of organic matter in an insulated and heated environment (a process called méthanisation in French). Microorganisms use the organic matter as food, decomposing it and producing biogas. Its chemical composition is variable, but it consists mainly of methane (CH4) and carbon dioxide (CO2).

Biomethane is obtained following the purification of biogas (by isolating methane from other components such as CO2, NH3, H2S, water, etc.). Biomethane has the same characteristics as natural gas and can be injected into the gas distribution networks.

1.2. Methods for Biogas and Biomethane Use

In France, biogas is mainly used in two ways.

Firstly, it can be transformed via combustion in a turbine to produce heat and/or electricity (cogeneration). The electricity production from biogas is supported by the State. The heat produced can be sold to various users (collective heating, heating or dehydration of agricultural products, etc.).

Secondly, the biogas can be injected into the natural gas networks after its purification into biomethane, or it can be used as a fuel for natural gas vehicles (natural gas for vehicles, NGV, and bioNGV).

The residue of the input materials that are transformed by anaerobic digestion (digestat in French), which is very rich in nitrogen, has strong agronomic qualities. It is collected and can be used as organic fertiliser, in liquid or solid form.

1.3. Main Types of Production Facilities and Nature of Inputs

The anaerobic digestion process takes place in three types of facilities characterised by the nature of the materials used as inputs:

- Anaerobic digestion of materials resulting from wastewater treatment in wastewater treatment plants, such as sludge, fats, and organic liquids. This category accounts for 6 %.
- Anaerobic digestion by capture of biogas produced in landfills (non-hazardous waste storage facilities, installations de stockage de déchets non dangereux or ISDND in French). This concerns only 3 %.
- Finally, anaerobic digestion of biowaste covering all other cases, e.g., agricultural waste, urban household waste, catering waste, and food industry waste, which represent by far the largest category of installations, with a 92 % share.

French law limits the inclusion of dedicated agricultural crops (i.e., agricultural produce that was grown for the purposes of biogas production) to 15 %, to give a clear priority for food use.

2. Statistics and Economic Data

2.1. Current Data on Production Capacity and Use

At the end of 2021, there were more than 1 300 biogas production units in France. Nearly three-quarters of this production (72%) was for heat and/or power generation. The remainder of the production fleet (365 sites) is about injecting biomethane (i.e. purified biogas) into the natural gas network: It includes 309 agricultural facilities, 6 urban household waste facilities, 11 non-hazardous waste storage facilities (ISDND), 13 industrial waste processing facilities, and 26 wastewater treatment plants.

In 2021, the forecast installed production capacity of all biomethane injection sites was 6 417 GWh/year. The actual energy injected into natural gas grids amounted to 4 337 GWh that year (+97% as compared with the previous year). Biomethane represented 0,92 % of natural gas consumption (+85%).

As regards green mobility, in 2021 there were approx. 11 900 light vehicles, 6 500 heavy vehicles, 5 500 buses, and 2 200 rubbish trucks operating on NGV including biomethane. 40 % of buses and 25 % of rubbish trucks in France run on NGV and bioNGV.

These figures and more can be found in France's principal gas TSO's report on renewable gases (in French): https://www.grtgaz.com/sites/default/files/2022-03/Panorama-du-gaz-renouvelable-2021.pdf.

2.2. Costs and Benefits

In 2019, CRE's Foresight Committee (Comité de prospective), which brings together all energy stakeholders in France to identify the future trends of the energy sector over the coming decades, published a report on the "Greening of gas", which is available (in French only) under the following link: https://www.eclairerlavenir.fr/rapports/rapport-2019-gt1/.

In that report, based on 2018 data, the Foresight Committee estimated biomethane production costs at € 90 to 100 /MWh. At the time, this was contrasted with a natural gas market price of €25 /MWh, excluding CO_2 costs (Now, in June 2022, day-ahead as well as monthly and quarterly forward products are priced above € 100 /MWh at the French TRF and Dutch TTF trading hubs. Only calendar products Y+1, Y+2, and Y+3 remain below the €90 /MWh biomethane cost floor.)

While the Foresight Committee saw some potential for further cost reductions for biomethane production, it cautioned against overestimating it: market players quantified the cost reduction potential at about 30 % by 2035. At the time, this was not sufficient to bridge the gap with the natural gas market price, and the Foresight Committee recommended to take into account a range of other benefits of biomethane production and use: the reduction of greenhouse gas emissions linked to the combustion of natural gas; its contribution to local job creation in rural areas and to energy independence; the environmental benefits of using the residue of anaerobic digestion as a natural fertiliser; as well as the environmental benefits of growing intermediate crops for soil regeneration that can be used as input for biomethane production (cultures intermédiaires à vocation énergétique, CIVE). If monetised, these benefits could total between €40 and 70 /MWh, depending on the underlying scenarios and assumption, and therefore could help bridge the gap with a natural market gas price of around €30 /MWh in 2030.

While natural gas prices are currently very high, the expectation is that they will fall again over the next couple of years. This means that the gap between natural gas market prices and biomethane production

costs could widen again, justifying the need to pursue cost reductions in biomethane production (the health crisis, then the impact of the crisis in Ukraine, on the supply of certain materials do not allow us to foresee a drop in production costs for the coming years) and monetising external benefits of biomethane use.

3. Strategic and Regulatory Framework

3.1. Strategic Framework and Targets for Green Gases

France's Multiannual Energy Programme (programmation pluriannuelle de l'énergie, PPE in French) for the period ranging from 2019 to 2028 sets the primary objective of significantly reducing France's greenhouse gas emissions, with a view to reaching carbon neutrality in 2050.

This is to be achieved via two secondary objectives, namely the reduction of energy consumption (energy efficiency) and the diversification of the energy mix towards carbon-free energy sources (mainly renewable energy sources, RES). While the PPE stresses the need for greater electrification of many sectors and processes, it also includes specific targets for renewable gases for 2023 and 2028, compared to the 2016/2017 baseline:

	2016/2017	2023	2028
Biogas production	5.4 TWh	14 TWh	24-32 TWh*
Biomethane injection	0.4 TWh	6 TWh	14-22 TWh**
Final biogas consumption for heating	4 TWh	7 TWh	12-18 TWh

* Assuming a reduction of production costs. / ** This would be equivalent to 6–8 % of the total gas consumption.

In addition, the Energy Transition for Green Growth Law of 17 August 2015 introduced a 10 % biomethane target in annual gas consumption by 2030. This target was reaffirmed by the French government's Economic and Social Resilience Plan of 16 March 2022.

The PPE provides that feed-in tariffs for biomethane injection (on this, see also below under subsection 4.1) will be degressive: The tariff should approach average cost levels of €75 /MWh in 2023 and €60 /MWh in 2028, and feed-in tariffs should not exceed €90 /MWh in 2023 and €80 /MWh in 2028.

The current PPE documents can be found here: https://www.ecologie.gouv.fr/programmations-pluriannuelles-lenergie-ppe#scroll-nav__2

3.2. Legal and Regulatory Framework

The French Energy Code encompasses the legal framework of the energy sector. It is divided into a legislative part (consisting of laws adopted by the Parliament; articles start with an "L") and an executive part (adopted by governmental decrees or orders; articles start with an "R").

The legal framework for biogas is found in Book IV (Rules on gas), Title IV (Rules on the marketing of gas), of the Energy Code, specifically in Chapter VI (Special rules on the sale of biogas; articles 446 et seq.). These provisions deal with certain aspects of the support mechanisms that are set out below in section 4: feed-in premiums, guarantees of origin, sustainability criteria, and biogas production certificates.

Link to the Energy Code: https://www.legifrance.gouv.fr/codes/id/LEGITEXT000023983208/

CRE, the French energy regulator, has several tasks in connection with RES support in general and support for biogas in particular: The government consults CRE on draft tariff orders and on draft tender specifications; the regulator is also tasked with the organisation of RES tenders and the evaluation of bids made; it publishes analytical reports and benchmarking data on the costs and the profitability of RES installations; and it calculates the annual cost of RES support for the public purse (charges de service public).

On 14 November 2019 CRE issued a ruling providing the regulatory framework for the injection of biomethane into the natural gas networks:

•https://www.cre.fr/Documents/Deliberations/Decision/mecanismes-encadrant-l-insertion-du-biomethane-dans-les-reseaux-de-gaz

Then, on 14 April 2022, CRE adopted a series of rulings (délibérations) on the next generation of biomethane tenders. It gave its favourable opinion and some recommendations to the tender specifications:

•https://www.cre.fr/Documents/Deliberations/Avis/projet-de-cahier-des-charges-de-l-appel-d-offres-portant-sur-la-realisation-et-l-exploitation-d-installations-de-production-de-biomethane-injecte-d.

It also approved grid investments and connection zoning by the principal gas distribution system operator to facilitate the injection of biomethane into the network:

•https://www.cre.fr/Documents/Deliberations/Approbation/investissements-de-distribution-de-grdf-associes-au-developpement-du-biomethane4;

• https://www.cre.fr/Documents/Deliberations/Approbation/zonages-de-raccordement-dans-le-cadre-de-l-insertion-du-biomethane-dans-les-reseaux-de-gaz7.

4. Main Support Measures

In France, State support mechanisms for biomethane production involve three main instruments: firstly, support for the injection of biomethane into the public gas networks; secondly, support for the production of biomethane for use as a vehicle fuel; and thirdly experimentation contracts.

4.1. Support for Biomethane Injection

Biomethane production can benefit from a purchase obligation on natural gas suppliers to guarantee offtake over a support period of 15 years. The support varies depending on the biomethane production installation and consists of a basic tariff that decreases with the size of the facility, plus premiums depending on its typology (i.e. whether the input materials come from wastewater treatment, from non-hazardous waste sites, or from any other agricultural or organic waste—see the three categories above in subsection 1.3) (Normally, the suppliers who are “obliged purchasers” pay out the set tariff to biomethane producers, sell biomethane on the market, and are compensated by the State for the difference. But in the current high-price market environment, they make a profit, a part of which they pass on to the State.)

Initially, support was awarded through an “open window” mechanism. But recently, the open window procedure has been limited to installations with an annual production below 25 GWh. Installations above that threshold will be granted support through the tender procedures that are due to start soon.

In addition, the government plans to introduce a biomethane production certificate system (certificats de production de biogaz, CPB) that would be open to (existing and new) biomethane production plants that do not receive support under the purchase obligation. They would be allowed to issue biomethane production certificates, in a number equivalent to the production of their installations, and trade them on a dedicated market.

4.2. Support for Biomethane Produced for Mobility

This is a two-step procedure; first a call for projects, to be followed by tenders to produce biomethane for vehicles using NGV. Under this scheme, producers will receive a feed-in premium over a duration of 15 years.

4.3. Experimentation Contracts

Finally, the Energy Code also provides for a procedure involving a call for projects concerning innovative biogas production projects.

ANNEX 3: Croatia Quota for Promoting Electricity Production From Renewable Energy Sources and High-Efficiency Cogeneration

Guarantees of Origin: As the authority for issuing guarantees of origin in Croatia, HROTE operates a Register of Guarantees of Origin—a computer system that stores guarantees of origin and is used to issue, transfer, and cancel guarantees of origin as electronic documents.

The Register enables the transfer of guarantees of origin from one user account to another, which is the basis for trade in guarantees of origin. HROTE is a full member of the Association of Issuing Bodies (AIB), an international association of competent authorities for guarantees of origin. The Croatian register is connected to other registers in EU Member States via AIB's hub.

HROTE issues guarantees of origin in accordance with the *Regulation on the establishment of the Guarantees of Origin system* and the *Rules for using the Register of Guarantees of Origin*.

The Register has been fully operational since 2 February 2015. By the end of 2020, five producers of electricity, eight suppliers, and three traders had created accounts in the Register.

Total quota for promoting electricity production from renewable energy sources and high-efficiency cogeneration per individual production plant group

Production plant groups	Production plant classification based on primary energy source and installed capacity	Quota [MW]
a.2	Solar power plants with an installed capacity > 50 kW and ≤ 500 kW	210
a.3	Solar power plants with an installed capacity > 500 kW and ≤ 10 MW	240
a.4	Solar power plants with an installed capacity ≥ 10 MW	625
b.1	Hydroelectric power plants with an installed capacity ≤ 50 kW	4
b.2	Hydroelectric power plants with an installed capacity > 50 kW and ≤ 500 kW	10
b.3	Hydroelectric power plants with an installed capacity > 500 kW and ≤ 10 MW	10
c.4	Wind power plants with an installed capacity > 3 MW	1,050
d.2	Biomass power plants with an installed capacity > 50 kW and ≤ 500 kW	6
d.3	Biomass power plants with an installed capacity > 500 kW and ≤ 2 MW	20
d.4	Biomass power plants with an installed capacity > 2 MW and ≤ 5 MW	15
e.2	Geothermal power plants with an installed capacity > 500 kW	20
f.2	Biogas power plants with an installed capacity > 50 kW and ≤ 500 kW (inclusive)	15
f.3	Biogas power plants with an installed capacity > 500 kW and ≤ 2 MW (inclusive)	30
	Innovative technologies, in accordance with the production facility classification from the energy permit, whose development is supported by the European Union.	10

Quotas for production plant groups in the public call for guaranteed purchase prices and for market premiums

Production plant groups	Production plant classification based on primary energy source and installed capacity	Quota [MW]
Guaranteed purchase price incentives		
a.2	Solar power plants with an installed capacity > 50 kW and ≤ 500 kW	50
b.1	Hydroelectric power plants with an installed capacity ≤ 50 kW	4
b.2	Hydroelectric power plants with an installed capacity > 50 kW and ≤ 500 kW	5
d.2	Biomass power plants with an installed capacity > 50 kW and ≤ 500 kW	6
f.2	Biogas power plants with an installed capacity > 50 kW and ≤ 500 kW (inclusive)	7
Guaranteed feed-in tariff incentives – TOTAL		72
Market premium incentives		
d.3	Biomass power plants with an installed capacity > 500 kW and ≤ 2 MW	8
f.3	Biogas power plants with an installed capacity > 500 kW and ≤ 2 MW (inclusive)	8
Market premium incentives – TOTAL		16

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