MEDREG

Task Force Report

Task Force on Hydrogen Development

Empowering Mediterranean regulators for a common energy future

Gas Working Group (GAS WG)

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ABSTRACT

The global pursuit of combating climate change and transitioning towards clean energy solutions has highlighted hydrogen as a promising and versatile clean energy source with significant potential.

This report explores the development and integration of hydrogen technologies in the current energy systems, to support households, but also to play a role in heavy industries such as cement processing, steel manufacturing, and in heavy transport. With that being said, the report investigates strategies, legal frameworks, research and development contributions, policies, regulatory measures, and financial incentives associated with advancing green hydrogen. The aim is to provide insights and recommendations essential for fostering widespread adoption of green hydrogen, pivotal for a low-carbon and renewable energy future.

Additionally, the report evaluates the renewable energy capacity and the potential for green hydrogen development, examining current hydrogen production landscapes and forecasting future initiatives. It extensively discusses hydrogen applications and identifies key drivers propelling its development while analysing barriers hindering widespread adoption. By synthesizing critical aspects, the report offers stakeholders, policymakers, and industry players a conclusive overview, aiding in understanding potential, challenges, and factors essential for advancing the sustainable use of green hydrogen across various sectors.

The report's methodology involves analysing questionnaire responses from MEDREG members, prepared collaboratively with the Moroccan Electricity Regulatory Authority - ANRE (Morocco) and GAS Working Group chairs, in coordination with the MEDREG Secretariat.

AKNOWLEDGMENTS

This report is the result of a project carried out by the MEDREG XX Working Group (YY WG), which provided the data and comments. MEDREG wishes to thank the GAS Working Group for their contribution and efforts.

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ABOUT MEDREG

MEDREG is the association of Mediterranean energy regulators, bringing together 28 members from 23 countries that span 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 harmonization 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.

The MEDREG Secretariat is in Milan, Italy.
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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1

INTRODUCTION

1.1 Report Objective

In the pursuit of combating climate change and transitioning towards clean energy solutions, hydrogen emerges as a promising clean source of energy with significant potential. Its versatility and efficiency in various sectors, including transportation, industry, and energy storage, position hydrogen as a key player in reducing greenhouse gas emissions. As a clean energy carrier, hydrogen offers a sustainable alternative, particularly when produced through renewable sources like wind and solar power. The integration of green hydrogen into existing energy systems holds the promise of not only reducing reliance on fossil fuels but also mitigating carbon emissions, thereby contributing significantly to the global efforts aimed at addressing climate change. Hydrogen can also play a big role in decarbonising various energy consuming sectors, such as steel making, cement processing, and transport. By harnessing the power of hydrogen as a clean energy source, there lies an opportunity to drive innovation, foster economic growth, and pave the way towards a more sustainable future while curbing the detrimental impacts of climate change.

The report aims to comprehensively analyse and evaluate the complexities surrounding the development, implementation, and integration of green hydrogen technologies into our everyday lives through energy. It explores strategies, legal frameworks, certification mechanisms, research and development contributions, policies, regulatory measures, and financial incentives associated with the advancement of green hydrogen. It also examines and assesses the potential for green hydrogen development, evaluating the capacity for renewable energy in fostering green hydrogen production. Furthermore, the report explores the status of hydrogen production, ongoing efforts, and forecasts future initiatives geared towards green hydrogen production. In addition, the report would explore the diverse applications of hydrogen in the Mediterranean Region, while analysing the drivers propelling the development of green hydrogen and the barriers hindering its widespread adoption. The report aims to provide a conclusive overview to aid stakeholders, policymakers, and industry players in understanding the potential, challenges, and key factors essential for advancing the sustainable use of green hydrogen in various sectors.

1.2 Structure and Methodology

The report sets the stage by looking at legal aspects of the topic from a regulatory perspective as well as countries' efforts in adopting laws and strategies that facilitate hydrogen development and use within the energy systems. After that, data on the renewable energy potential is provided to show the potential of the region in terms of green hydrogen development.

The report then discusses the current and potential applications of hydrogen in the Mediterranean countries involved in the study. From that, the report explores the barriers for green hydrogen development and use in the energy systems.

The report is based on a comprehensive analysis gathered from the replies of the MEDREG members to a questionnaire prepared by the ANRE (Morocco) and the GAS Working Group chairs in collaboration with the MEDREG Secretariat during the 4th Quarter of 2023.

The questionnaire communicated with the WG members and chairs contained 4 parts shown below to address the report objectives:

1. Policy and Regulation
2. Potential for the Development of Green Hydrogen
3. Current and Future Hydrogen Market Outlook
4. Drivers and Barriers for Green Hydrogen Development

Figure 1 - Countries assessed in the study (Map by mapcharts.net)

1.3 Limitations

While every effort has been made to ensure the accuracy and comprehensiveness of the information presented in this report, it is important to acknowledge that the issue is a dynamic and evolving one. Nevertheless, the report would offer the countries' status quo in terms of the potential of developing hydrogen projects in the region.

Furthermore, among the limitation include the data availability and the differing national opportunities, which can often hinder the harmonisation of the analysis of the various country replies.

2

STATE OF PLAY

The surveyed countries of the Mediterranean region have, for the most part, crafted comprehensive strategies concerning Green Hydrogen, signalling a growing global commitment to hydrogen's role as a sustainable energy source. Nonetheless, a conspicuous void becomes apparent within these endeavours, as most of these countries lack a dedicated legal framework for Green Hydrogen development. The absence of such a legal framework implies the potential for ambiguity and inconsistency in the regulations and requirements that oversee the production, distribution, and utilisation of green hydrogen. Furthermore, the responsibility for hydrogen development is primarily concentrated within the ministries of energy in these countries, indicating a centralisation of authority within the energy sector. Intriguingly, approximately half of these countries have established certification mechanisms designed to authenticate the origins of renewable energy and hydrogen production, which could prove instrumental in upholding the credibility and environmental sustainability of green hydrogen.

In addition, it is worth noting that each country has adopted its distinctive approach to innovation, research, and development, with each pursuing its distinct pilot projects. Nevertheless, it is pertinent to highlight that most of these countries currently lack explicit financial incentives aimed at stimulating and expediting green hydrogen development. This absence of financial incentives represents a potential area of emphasis for future policy initiatives, with the potential to further bolster the adoption of this environmentally friendly energy source. In summary, a global consensus is emerging regarding the potential of green hydrogen; however, there is an evident need for the establishment of legal frameworks and financial incentives to ensure consistent and sustainable progress across nations.

2.1. Strategies and Road Maps

Developing a roadmap and strategy for low-carbon hydrogen is pivotal in navigating the transition to a sustainable energy future. As well known, hydrogen, especially when produced through renewable sources or with carbon capture technology, holds immense potential as a clean energy carrier across various sectors. Crafting a comprehensive roadmap involves versatility encompassing technological advancements, policy frameworks, infrastructure development, and international collaboration.

Firstly, the roadmap must prioritise research and development to enhance the efficiency and scalability of low-carbon hydrogen production methods. Electrolysis powered by renewable energy sources such as wind or solar, alongside advancements in methane pyrolysis or biohydrogen production, are critical areas for innovation. Additionally, the integration of carbon capture and storage (CCS) technologies with hydrogen production from fossil fuels can substantially reduce emissions.

Strategies need to emphasise the establishment of a robust infrastructure to support the entire hydrogen value chain, including production, storage, transportation, and distribution. This involves the creation of hydrogen hubs, networks of production facilities, pipelines, and storage facilities. Encouraging investment in infrastructure and creating regulatory frameworks to facilitate private sector participation will be key components.

Furthermore, policy frameworks at national and international levels are essential to incentivise the adoption of low-carbon hydrogen. Supportive policies might include subsidies for renewable hydrogen production, carbon pricing mechanisms, mandates for hydrogen use in specific industries, and regulatory standards to promote safety and interoperability.

Collaboration among governments, industries, and research institutions globally is crucial. Initiatives like joint research and development programs, knowledge-sharing platforms, and standardisation efforts can accelerate progress and drive down costs.

The importance of such a roadmap and strategy lies in mitigating climate change by decarbonising hard-to-abate sectors like heavy industry, transportation, and heating. Low-carbon hydrogen serves as a versatile and clean energy carrier capable of reducing greenhouse gas emissions significantly. Embracing this strategy not only contributes to climate goals but also fosters economic growth, job creation, and energy security while ensuring a sustainable and resilient energy system for future generations.

For its part, the Mediterranean Region has proved to be on top of the situation, where 9 out of the 11 countries assessed in this study have stated that the country has developed a hydrogen strategy, roadmap or policy.

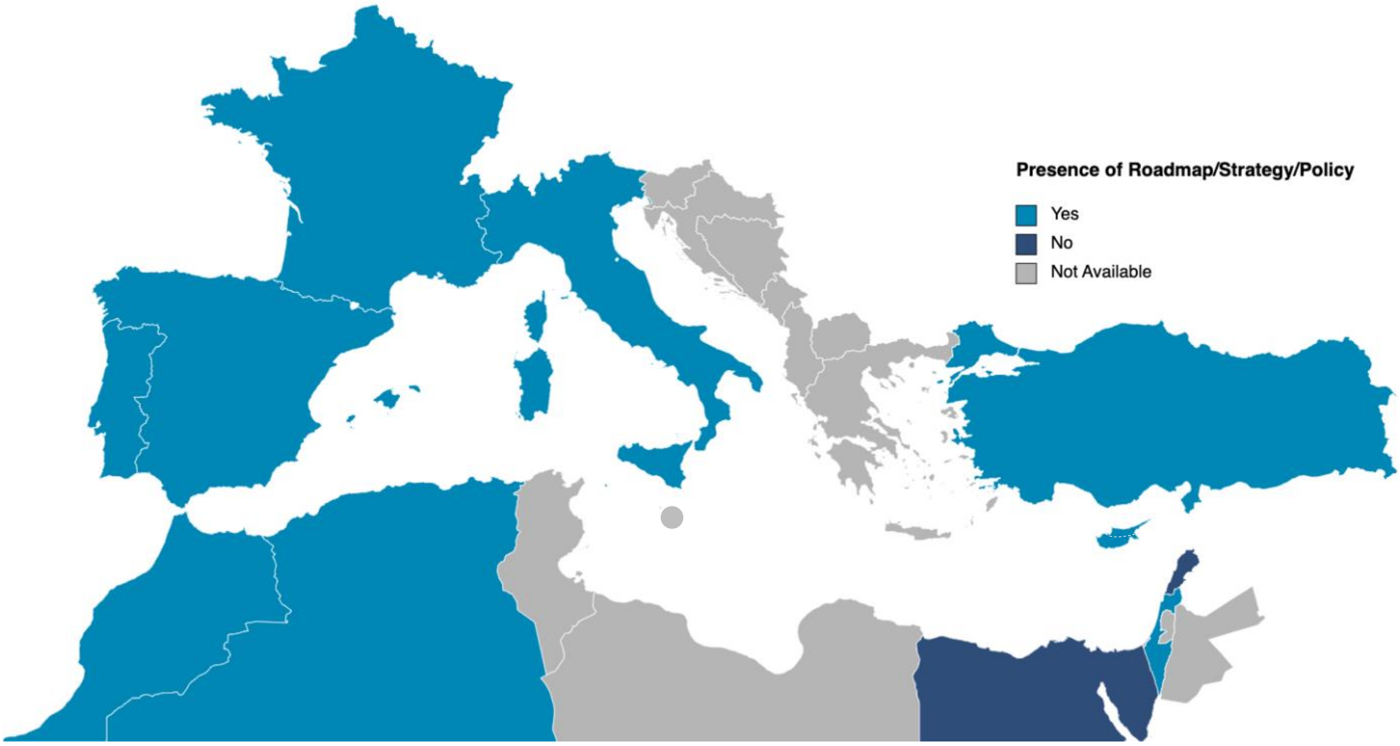

Figure 2 - Presence of Roadmap/Strategy/Policy on Hydrogen (Map by mapcharts.net)

Of the countries that have developed a strategy/roadmap, the majority have done so during the year 2020, where 4 of the 9 countries with a roadmap have done so by the end of the 2023. More statistics in that regard can be seen in Figure 3 below:

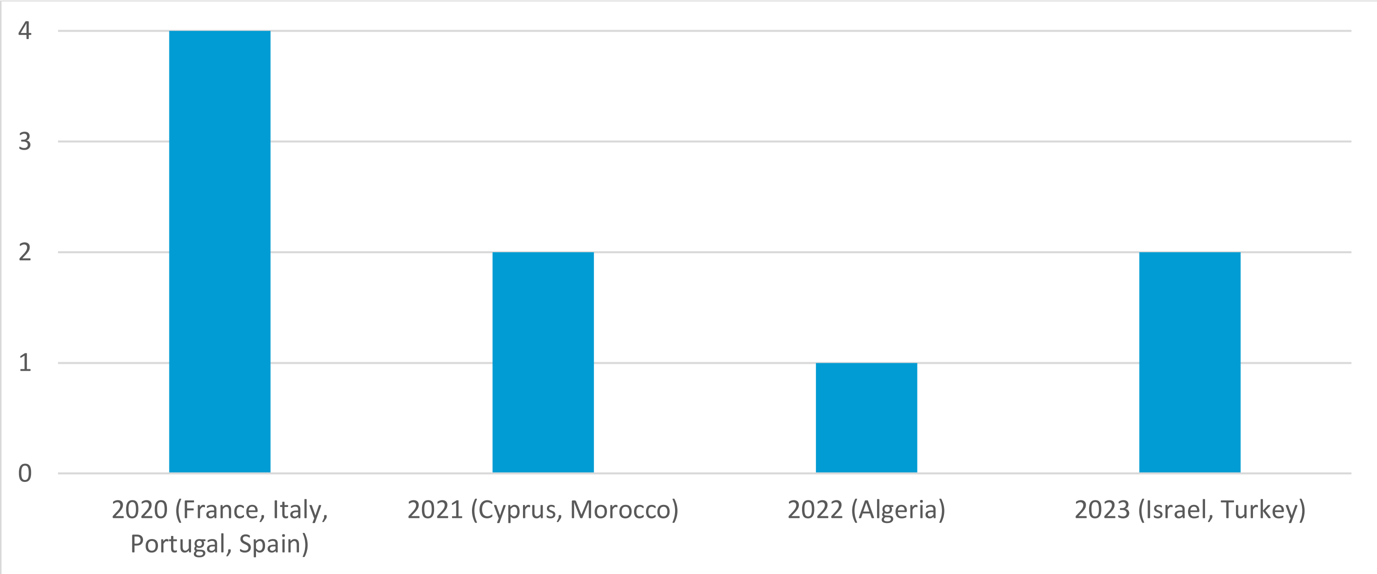

Figure 3 - Year of Development of Roadmap/Strategy

Table 1 below gives an insight into the names of the hydrogen strategies/roadmaps of the different countries in the region.

Table 1 - Name of the Roadmap/Strategy per Country

Country	Name of the Strategy
Algeria	Hydrogen Development Roadmap
Cyprus	National Hydrogen Strategy
Egypt	*Under Development*
France	National strategy for the development of low-carbon hydrogen
Israel	Hydrogen Strategy
Italy	Strategia Nazionale Idrogeno-Linee Guida Preliminari
Lebanon	*Under Development*
Morocco	Feuille de Route Hydrogène vert, Vecteur de transition énergétique et de croissance Durable «Green Hydrogen Roadmap »
Portugal	National Strategy for Hydrogen (EN-H2)
Spain	Draft National Energy and Climate Plan 2023 -2030
Türkiye	Hydrogen Technologies Strategy and Roadmap

In that regard, and to sink into more details of each country, **Algeria** positions itself as a key player in the hydrogen market, leveraging natural gas reserves, solar potential, and vast water resources. The country's phased roadmap emphasises grey, blue, and green hydrogen development, aiming to reduce fossil fuel reliance, diversify energy sources, and establish a hydrogen-based economy. The roadmap remains adaptable to evolving technologies and market dynamics.

Meanwhile, **Cyprus** outlines two hydrogen deployment scenarios: cautious and aggressive. The cautious approach foresees limited hydrogen usage by 2030, while the aggressive plan requires substantial investments and technological progress for widespread adoption by 2050. Sectors targeted include cement, ceramics, road transport, shipping, and aviation. Active policy interventions and investments are crucial, but uncertainties persist in technology and associated costs. Cyprus aims to position itself strategically amidst these scenarios, prioritising collaboration, innovation, and sustainable growth for a hydrogen-oriented future.

Egypt is in the process of formulating its strategy for hydrogen integration, aiming to align its energy sector with global trends and best practices. While specific details are yet to be disclosed, the nation's energy landscape, characterised by significant solar potential and ambitious renewable energy projects, indicates a promising foundation for potential hydrogen developments. Egypt's strategic roadmap is expected to emphasise technological advancements, research, and infrastructure to facilitate a seamless transition towards hydrogen integration within its energy sector.

In the **French** strategy, the development of low-carbon hydrogen technologies is seen as a means of accelerating the ecological transition. France has set three priorities in this strategy: decarbonize industry by developing a French electrolysis industry; develop heavy-duty mobility using low-carbon hydrogen; supporting research, innovation, and skills development to foster the uses of tomorrow.

Italy follows the National Integrated Energy and Climate Plan (PNIEC), where it positions green hydrogen as a key player in the country's industrial landscape by 2030. Anticipating up to 42% incorporation of green hydrogen in industries, Italy aligns its strategies with the EU's Hydrogen Strategy, identifying sectors ripe for competitive hydrogen implementation and outlining interventions to facilitate hydrogen's widespread utilisation. By focusing on specific sectors and setting ambitious targets, Italy aims to drive a significant reduction in carbon emissions while fostering innovation and sustainability within its industries.

As a member of the MED-GEM Network, **Lebanon** has embarked on its green hydrogen strategy, marking a pivotal phase in the country's decade-long energy transition journey. With a focus on aligning frameworks, policies, infrastructure, and financial mechanisms, Lebanon seeks to integrate renewable hydrogen into its energy landscape. By exploring and defining the necessary groundwork for sustainable energy adoption, Lebanon aims to position itself as a key player in the regional transition towards renewable energy sources, emphasising collaboration, innovation, and sustainable growth.

Morocco's green hydrogen roadmap outlines a comprehensive plan, envisioning the potential market and demand for green hydrogen and its derivatives by 2050. By estimating demand projections from various sectors, the country aims to drive technological innovation and cost reduction through extensive R&D and large-scale project deployment. The roadmap's structured action plan revolves around technological advancements, investment initiatives, and market development strategies. Morocco's approach prioritises creating a conducive environment for innovation, ensuring industry integration, and fostering both domestic and export markets for green hydrogen and its derivatives.

EN-H2 lays out **Portugal's** vision for hydrogen, outlining measures and targets for its integration across various sectors of the national economy. By promoting production and consumption and providing a short-, medium-, and long-term vision, EN-H2 aims to guide companies and project promoters. The plan intends to create necessary conditions for hydrogen's recognition and valorisation of the national market, emphasising legislative frameworks, safety standards, innovation, and financing. By setting specific targets for hydrogen incorporation and supporting various projects, Portugal seeks to establish itself as a leading player in the hydrogen economy, driving innovation, reducing carbon emissions, and ensuring sustainable growth.

Spain's Draft National Energy and Climate Plan encompasses a robust strategy focusing on renewable hydrogen adoption and integration. To achieve 12 GW of electrolysis capacity by 2030 and a substantial percentage of renewable fuels in industries, Spain is committed to reducing carbon emissions. The nation emphasises regulatory development, administrative simplification, and financial support for the renewable hydrogen value chain. By updating the "Spanish Hydrogen Roadmap," incentivising R&D, and promoting international cooperation, Spain aims to position itself as a frontrunner in renewable hydrogen technology and usage.

Türkiye’s strategic roadmap aims to create a robust domestic research program for hydrogen technology development. The nation sets ambitious targets, aiming to reduce green hydrogen production costs significantly by 2035 and substantially increase electrolyser capacity by 2053. This strategic vision underscores the importance of domestic technological advancements, emphasising cost efficiency and scaling up infrastructure to pave the way for widespread hydrogen integration. Türkiye's focus on technology development aligns with its ambition to become a key player in the global hydrogen market.

However, transitioning from the broader strategies and roadmaps for low-carbon hydrogen development to the specific legal frameworks within the Mediterranean region presents a nuanced progression in the pursuit of sustainable energy solutions. While the roadmaps elucidate the technological advancements, infrastructural needs, and policy directions crucial for fostering a low-carbon future, the focus shifts towards understanding the legal frameworks governing energy transitions within the diverse tapestry of Mediterranean countries.

2.2. Legal Bases for Low Carbon & Green Hydrogen Development

When discussing green hydrogen specifically, legal frameworks encompass national policies and regulations designed to support its production, distribution, and use. Countries in the Mediterranean region are increasingly acknowledging the potential of green hydrogen as a clean energy source, leading to the creation of specific laws and regulations aimed at facilitating its growth.

However, challenges persist in seamlessly integrating green hydrogen into existing energy systems within the region. Harmonising regulatory frameworks, addressing infrastructure gaps, and advancing technologies are crucial steps in fully realising the potential of green hydrogen across the Mediterranean countries.

In essence, the legal frameworks within the Mediterranean region underscore a shared commitment to foster the utilisation of green hydrogen as a fundamental component of sustainable energy strategies. Efforts focused on supportive policies and regulations highlight a collective recognition of green hydrogen's pivotal role in transitioning toward cleaner and more sustainable energy sources in the Mediterranean region.

Acknowledging the importance of having a legal framework in place dedicated to green hydrogen, it is noteworthy that it is a sector that needs more efforts to be put in place should the dream become a reality. Indeed, most of the countries assessed in the survey do not have a legal framework in place as of now, where only 2 of the 11 countries have stated that they have already developed a dedicated legal framework.

In that regard, in **France**, a segment in the Energy Code, Livre VIII, focuses on hydrogen regulations (Articles L811-1 to L851-2), covering production, traceability, distribution, storage, and sales. The legal framework is evolving pending European legislative reforms for gas and hydrogen markets. To accelerate low-carbon hydrogen production, the government initiated a support mechanism through a call for tenders governed by Energy Code articles L.811-1 to L.813-3. Decree no. 2023-854 complements this framework for specific hydrogen categories. The competitive tendering process involves candidate selection, dialogue with the Minister for Energy, and selection of eligible candidates. The Minister, alongside the French Agency for Ecological Transition (ADEME), manages this process, seeking opinions from the Energy Regulatory Commission.

Furthermore, further west in Europe, in **Portugal**, decree-Law no.60/2020, dated 17th August, introduces the mechanism for issuing guarantees of origin for low-carbon gases and gases of renewable origin, while also updating the energy targets for renewable sources. Directive no.17/2023, issued on 31st August, approves the manual of procedures for the Entity Issuing Guarantees of Origin. Additionally, Decree-Law no.62/2020, from 28th August, defines the organisation and operations of the National Gas System and its legal framework, aligning with Directive 2019/692. Meanwhile, Decree-Law no.84/2022, dated 9th December, sets targets for renewable energy consumption, partially incorporating provisions from Directive (EU) 2018/2001. Lastly, Ordinance no.15/2023, effective from 4th January, establishes the centralised purchasing system for biomethane and hydrogen produced through electrolysis from water using renewable energy sources.

Regarding the other 9 countries that currently do not have a legal framework dedicated to green hydrogen in place, **Algeria**, **Egypt**, **Italy**, **Lebanon**, **Morocco**, and **Türkiye** have stated that their framework is currently under development, however, each country is at a different stage given the alternate perspectives on some matters, particularities per country, as well as the priorities set.

Italy, even though there is no adopted policy in place, however, there is a draft programme being investigated and revised. Meanwhile in **Lebanon**, once the strategy is finalised, the development of a legal framework and legislation to produce hydrogen will go underway. In **Morocco**, the country is currently working on a 'Moroccan Offer' that encompasses the entire value chain of the green hydrogen sector. This includes the development of an appropriate framework to attract investors in renewable energy projects and other infrastructure related to the production, transportation, and storage of green hydrogen and its derivatives. In **Türkiye**, as included in the hydrogen roadmap, the current legislation for "production, transportation, storage and use of hydrogen "continues to be reviewed to ensure its resilience.

Even though not many legal frameworks are currently in place in that regard, it is comforting to know that countries that do not have a legal framework in place are already working hard to do so in the near future.

TABLE 2 below supplies detailed information regarding the key government bodies/entities responsible for spearheading hydrogen development initiatives, formulating policies, implementing regulations, conducting research, and fostering collaborations within the hydrogen industry. These entities play pivotal roles in orchestrating the roadmap for hydrogen development, ensuring alignment with national energy strategies, and promoting the integration of hydrogen technologies across various sectors.

Table 2 - Government Body responsible for the Development of Hydrogen

Country	Government Body
Algeria	Ministry of Energy and Mines
Cyprus	N.A.
Egypt	Ministry of electricity, ministry of petroleum and mineral resources
France	Ministries for policy making
Israel	ministry of energy for policy making
Italy	Ministry for Environment and Energy Security
Lebanon	Ministry of Energy and Water, Ministry of Environment, Ministry of Interior and Municipalities, Ministry of Industry, Ministry of Finance, Lebanese Customs Administration, MED-GEM Network
Morocco	Ministry of Energy Transition and Sustainable Development
Portugal	Energy Services Regulatory Authority, Directorate-General for Energy and Geology, National Entity for the Energy Sector, National Laboratory of Energy and Geology, Portuguese Environment Agency (APA), Institute of Mobility and Transport (IMT)
Spain	Ministry for Ecological Transition and Demographic Challenge
Türkiye	Turkish Energy, Nuclear and Mining Research Institute under the Ministry

2.3. Certification Mechanisms

Across different countries in the region, some have formulated distinct mechanisms and systems governing the certification of renewable energy and the production of hydrogen. These measures aim to promote transparency, confirm the origins of energy sources, and bolster the use of cleaner and greener energy alternatives. Each nation's approach showcases a unique set of regulations and mechanisms tailored to foster the adoption of renewable energy sources, paving the way for a more sustainable and environmentally conscious energy landscape.

Figure 4 below shows the status quo on the certification mechanisms per country.

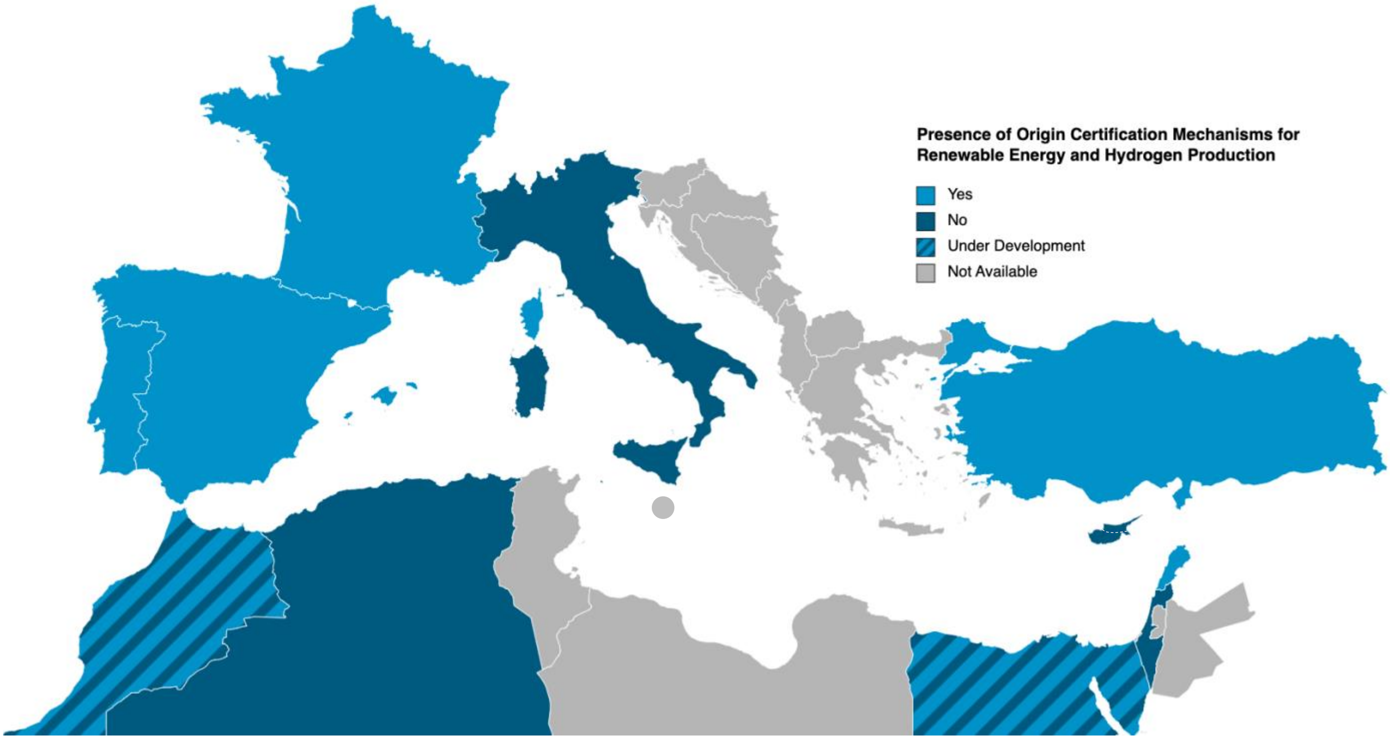

Figure 4 - Presence of Certification Mechanisms (Map by mapcharts.net)

France has introduced a comprehensive ordinance regarding hydrogen production and its associated mechanisms. This includes a "guarantee of origin" system for renewable or low-carbon hydrogen. Two mechanisms are outlined: one for when hydrogen is mixed with other gases, and another for when hydrogen isn't mixed with any other gas between the production and consumption stages. These guarantees will be managed by a designated body, handling issuance, transfer, monitoring, and the setup of a national register for hydrogen production guarantees. The implementing decree for these regulations is currently in progress.

Lebanon has received approval for issuing International Renewable Energy Certificates (I-REC) for electricity. The Lebanese Center for Energy Conservation is designated as the issuer for I-REC in Lebanon. However, as of the provided information, there's no certification mechanism available for hydrogen production in Lebanon.

In **Portugal's** new regime, gas producers of renewable origin must apply for guarantees of origin from EEGO for the gases they produce. These guarantees aim to demonstrate the origin of renewable gases to purchasers. There's an obligation for producers to contribute to the reliability of the system by installing monitoring systems for gas properties, ensuring certification of energy origin. Additionally, specific details must be included in guarantees of origin, such as raw materials used, production processes, CO2 emissions, and avoided CO2 emissions per kilogram produced, compared to fossil fuel production.

Spain's GO (Guarantee of Origin) system is managed by the Technical System Manager (TSM), Enagás GTS, through an online platform. The system involves various entities: responsible parties, account holders (producers, consumers, suppliers, traders), a measurement body, and an auditing entity ensuring information accuracy. The GO life cycle encompasses phases like expedition, transfer, and redemption, with different account holders participating in each phase.

Türkiye, aiming to promote renewable energy usage and protect the environment, introduced the Renewable Energy Source Guarantee Certificate Regulation (YEK-G) in the electricity market. This regulation ensures tracking, proof, and disclosure of electricity produced from renewable sources by licensed entities. It establishes a system enabling consumers to certify and access electrical energy derived from renewable sources.

Meanwhile in **Egypt** and **Morocco**, the status is that the mechanisms are still under development. However, it is noteworthy to say that in Morocco, Law No. 40.19, which amends Law No. 13.09 focusing on renewable energy development, as well as law 82.21 on auto-generation introduce the issuance of certificates of origin. These certificates of origin are a part of the procedural framework outlined within the legislation. The issuance procedures and issuing body will be detailed in a decree.

2.4. Contribution to R&D and Innovation for Hydrogen Development

Countries around the world, of which are in the Mediterranean region, are actively engaged in pioneering initiatives and collaborative endeavours to harness the potential of hydrogen technology, positioning it as a vital component in the transition towards renewable and clean energy sources.

Efforts to spearhead advancements in the green hydrogen sector are multifaceted and dynamic. Various collaborative projects are underway, often in partnership with leading companies specialised in hydrogen technology. These initiatives range from pilot projects exploring the integration of hydrogen in natural gas pipelines to solar energy storage implementations and the production of hydrogen-based substances like ammonia and green methanol. Leveraging insights gained from past endeavours, countries are strategically positioned to explore and cultivate various aspects of hydrogen technology, often involving dedicated research centres and educational institutions offering specialised programs in renewable energy, particularly focused on hydrogen and fuel cell technology.

Moreover, the commitment to advancing hydrogen technology is evident in the proliferation of pilot programs aimed at demonstrating and testing various hydrogen technologies, encompassing aspects of production, storage, and distribution. These initiatives signify a collective dedication to harnessing the potential of hydrogen as a clean and sustainable energy source, exemplified by projects aiming to establish hydrogen-powered facilities for various purposes across different regions. This collective momentum underscores a shared vision for a sustainable future powered by the transformative potential of green hydrogen.

For its part, the region has seen a diverse set of efforts being put in place.

Algeria is actively advancing its green hydrogen sector through collaborative projects focused on pilot initiatives not exceeding 10 MW in partnership with experienced companies in hydrogen technology. These projects encompass diverse areas, including an experimental loop of natural gas/hydrogen pipelines, solar energy storage for Sonatrach sites, and the production of ammonia and green methanol. Leveraging insights from prior similar projects through technology watch reports, Algeria is strategically positioning itself to explore and develop various aspects of hydrogen technology, emphasising research institutions like the Renewable Energy Development Center (CDER) and multiple universities offering programs in renewable energy, particularly focusing on hydrogen and fuel cells. Pilot programs scattered across the nation aim to demonstrate and test hydrogen technologies related to production, storage, and distribution, notably including plans for a hydrogen-powered fertiliser plant in Arzew, Oran, marking Algeria's commitment to advancing in the hydrogen sector.

The Ministry of Energy Commerce and Industry in **Cyprus**, using European Funds, completed a study to support the REPowerEU program's objectives. Specifically, the study aimed to develop the hydrogen market on the island and advance renewable energy initiatives.

France has launched strategic initiatives in line with its national hydrogen strategy. Two significant calls for projects were initiated in October 2020, aiming to enhance hydrogen-related components, systems, production, and transportation, as well as its applications in various sectors like transportation and energy supply. France's comprehensive hydrogen research programs, supported financially by France 2030, are managed by institutions like CEA and CNRS. Additional initiatives, such as funding for hydrogen-powered aircraft and trains, signify France's commitment to becoming a global leader in renewable and low-carbon hydrogen by 2030.

In **Italy**, there are hypotheses for financing hydrogen-related projects, but no final decisions have been made.

Lebanon's involvement in hydrogen development is limited due to the absence of a legal and strategic framework. However, the Lebanese government has expressed interest in promoting renewable energy, including hydrogen, as a potential energy carrier, aligning with its sustainability goals.

Morocco. Morocco has established a Green H2 Cluster. The primary objective of the Green H2 Cluster is to promote the hydrogen sector in Morocco by initiating, supporting, and coordinating innovative collaborative projects in the field of green hydrogen within the Kingdom of Morocco and abroad. This aims to encourage innovation and contribute to the emergence of a competitive hydrogen sector. Also, the kingdom is working on establishing a green hydrogen research platform called "Green H2A Platform." This initiative is spearheaded by IRESEN (Institut de Recherche en Énergie Solaire et en Énergies Nouvelles), Université

Mohammed VI Polytechnique (UM6P), and OCP Group. The platform will focus on R&D and innovation in green hydrogen and its applications, particularly in the "Power-To-X" (PtX) sector.

The National Strategy for Hydrogen in **Portugal** involves multiple initiatives. Notably, Floene, a gas distribution network operator, has implemented the "Green Pipeline Project" to test injecting green hydrogen into the natural gas network. This pilot project aims to gradually increase hydrogen's volume in the distribution network.

Spain's Hydrogen Roadmap emphasises R&D and innovation in the hydrogen economy. The plan includes developing large-capacity electrolysers, financing projects in the renewable hydrogen value chain, and reinforcing institutions dedicated to hydrogen research and development. Efforts also focus on technologies for recycling electrolysers and fuel cells and promoting hydrogen-based heat production technologies.

Türkiye has ongoing hydrogen village projects, aiming to mix hydrogen with natural gas for residential use and testing purposes. Supported by the Horizon Europe Program, the "HYSouthMarmara" project is Türkiye's first hydrogen valley, focused on green hydrogen production and derivatives. The project aims to create a valley dedicated to hydrogen production, storage, and consumption.

2.5. Policies and Regulatory Measures

Across diverse regions, a multitude of regulatory and policy measures have been implemented to ease the advancement of green hydrogen. These initiatives, tailored to incentivise production, fortify infrastructure, define safety protocols, and propel research within the growing sector, show a regional commitment to fostering hydrogen's potential as an essential clean energy source.

Most of the countries assessed in this study have stated that there are regulatory and/or policy measures to ensure effective and efficient development of Green Hydrogen Projects. More details on the countries' perspectives can be seen below:

Efforts in **Algeria** involve financial incentives to bridge the cost gap between green hydrogen and fossil fuels. These incentives include subsidies, loans, tax credits, or feed-in tariffs to support production, infrastructure, and consumption. Additionally, partnerships between producers and consumers will be carried out to benefit from the experience of pioneering companies in the field of hydrogen, meanwhile, Algeria is currently preparing a regulatory framework that define the standards, rules, and roles of different actors in the hydrogen value chain. Additionally, partnerships between producers and consumers aim to reduce hydrogen production costs through cooperative projects.

Egypt's approach depends on its role in the hydrogen market and its national strategy, considering aspects like development, production, export/import, infrastructure needs, and the mode of hydrogen development.

France emphasises a gradual regulatory framework adaptable to the evolving hydrogen market. The French strategy is based on a localized model close to consumption sites, and a prioritization of hydrogen uses for those that can only be decarbonized by this vector, particularly in industry and even heavy transport. Over the coming years, France will continue to support the deployment of domestic hydrogen production. Priority infrastructure development will focus on intra-hub networks, and their connection to storage infrastructures, to optimize the production, storage and use of hydrogen within these industrial hubs. They aim to establish legal certainty for investors, ensure safety and quality in production and distribution, and incentivise Research & Development (R&D).

Italy is engaged in pilot projects but lacks a comprehensive hydrogen production setup. Plans include the development of a regulatory framework compatible with EU and national legislation to facilitate connections and ensure safety.

Lebanon's strategy involves setting realistic renewable energy targets, offering financial incentives, stabilising the energy grid, establishing production standards, funding research, promoting collaborations, enforcing eco-friendly practices, and implementing monitoring systems for hydrogen development.

Morocco focuses on accelerating R&D, financing pilot projects, establishing regulatory frameworks, and upgrading the electricity grid to accommodate increased renewable energy demand.

Portugal aims for harmonisation in issuing certificates of guarantees of origin and ensuring hydrogen interoperability.

Spain plans a national legal framework compatible with EU legislation, guarantees of origin for renewable gases, quality and safety norms, and separate accounting for hydrogen network operators. R&D incentives are also highlighted.

Türkiye's focus areas involve adapting legislation for hydrogen across production, transportation, storage, and use. They aim to incentivise domestic components, develop traceability programs, promote R&D for national technologies, encourage partnerships, and initiate gradual decarbonisation via hydrogen blending in gas lines.

It is important to mention that at the EU level, the Decarbonisation Package in July 2024, sets rules and regulations for the development of the hydrogen sector that all Member States will have to apply.

2.6. Financial Incentives for Green Hydrogen Development

Financial incentives for green hydrogen production aim to stimulate the development of hydrogen derived from renewable sources. These incentives typically involve subsidies, grants, and investment support provided by governments, financial institutions, and specialised funds. These incentives tend to be designed to drive the adoption and competitiveness of green hydrogen in the global energy landscape.

Out of the countries studied in this report, a few countries, France, Portugal, Spain, and Israel, have implemented financial incentive programs and support mechanisms aimed at fostering the production, distribution, and utilisation of hydrogen-based solutions. These initiatives span multiple levels—ranging from European Union (EU) mechanisms, applied in all EU countries, to national strategies and regional programs—each tailored to encourage innovation, decarbonisation, and the establishment of robust hydrogen ecosystems.

Financial incentives in **France** predominantly span aid, subsidies, and investment grants, accessible at multiple levels—EU, national, and regional. At the European level, two key mechanisms provide funding and support for various projects. The first involves Projects of Common Interest (PCI) and Projects of Mutual Interest (PMI) facilitated by the Connecting Europe Facility, encompassing electrolysers and hydrogen transport and storage projects. France has submitted nine transport and storage projects and five electrolyser projects for consideration. The second mechanism, Important Projects of Common European Interest (IPCEI), aims to drive innovation across strategic industrial domains, such as the "IPCEI Hy2Tech" and "IPCEI Hy2Use" projects focusing on hydrogen technology and infrastructure, both receiving substantial funding.

Nationwide, France's national hydrogen strategy involves investment aid, exemplified by two significant calls for projects launched in October 2020. The first, a €350 million initiative titled "bricks and demonstrators," targets the enhancement of hydrogen-related components and systems. The second, a €275 million endeavour named "Territorial Hydrogen Ecosystems," aims to establish large-scale regional ecosystems for diverse hydrogen applications, jointly led by local authorities and industrial solution providers. Moreover, additional backing is provided through initiatives like "France Relance" and France 2030, supporting research in hydrogen-powered aircraft and the deployment of hydrogen trains across various regions.

At the regional level, exemplified by the Île-de-France region, specific calls for projects, such as the "Development of renewable electrical energy" and "Innovation and structuring of the hydrogen sector," offer subsidies and support for renewable hydrogen production, distribution, and the development of operational hydrogen distribution networks.

Portugal's support mechanisms encompass various programs and funds directed towards fostering renewable energy and environmental sustainability. Operational Program Sustainability and Efficiency in the Use of Resources (PO SEUR) finance projects dedicated to renewable energy production and distribution. The Innovation Support Fund (FAI) aids in technological development and investments related to renewable energy and energy efficiency. Additionally, the Environmental Fund provides non-repayable support for sustainable development aligned with national and European environmental commitments.

Under Portugal 2030, a key funding source for decarbonising the economy, the focus spans production, consumption of renewable gases, and the hydrogen sector. This includes initial support for production and infrastructure projects associated with hydrogen, followed by emphasis on decarbonisation within industrial and transport sectors. Furthermore, Portugal's Development Financial Institution (IFD) acts as a national development bank, supporting investments for decarbonisation efforts and combating climate change.

In **Spain**, financial aid, subsidies, and investment grants are available, notably within the framework of the "Plan for Recovery, Transformation, and Resilience" (PRTR). This plan encompasses incentives and support for projects concerning the renewable hydrogen value chain, including Important Projects of Common European Interest (IPCEI) focused on hydrogen initiatives.

On the other hand, although **Türkiye** are not sure of any incentive mechanism in practice, it is envisaged that some incentives may be put into effect within the framework of the "Türkiye Hydrogen Technologies Strategy and Road Map".

3

GREEN HYDROGEN DEVELOPMENT POTENTIAL

Focusing solely on renewable energy sources and their relationship with green hydrogen development, this chapter will shed some light on data related to renewable energy potential in terms of the irradiance, sunshine hours and wind speed. Furthermore, the chapter also showcase the renewable energy potential in MW per country assessed in this study.

3.1. Wind and Solar Energy Resources

As mentioned previously, renewable energy sources play a pivotal role in the quest for sustainable power generation, especially in regions like the Mediterranean, where abundant sunlight and consistent winds offer promising opportunities for solar and wind energy production. The relationship between renewable energy potential and green hydrogen production is a direct one.

In the Mediterranean region, solar energy is particularly abundant, with high levels of irradiance measured in kilowatt-hours per square meter (kWh/m²). Countries in this area experience ample sunshine hours, a measure of the duration of sunlight received yearly, enhancing the efficiency of solar panels and increasing the potential for solar power generation.

Wind energy, another pivotal renewable resource, relies on wind speed for electricity generation. Wind turbines convert kinetic energy from the wind into electrical power. Wind speed, often measured in meters per second (m/s), greatly influences the amount of energy a turbine can produce. Higher wind speeds result in greater power generation, highlighting the significance of wind resources in regions characterized by consistent and strong winds.

Below is a table showcasing selected countries in the Mediterranean region with their respective average annual solar irradiance, sunshine hours, and average wind speed, as reported by the regulatory authorities:

Table 3 - Wind and Energy Resources per Country

Country	Average Solar Irradiance	Number of Sunshine Hours	Wind Speed
Algeria	2263 kWh/m2	3600 hours	6 m/s
Cyprus	2000 kwh/m2	3400 hours	3,3 m/s
Lebanon	4900kWh/m2	N/A	5,67 m/s
Morocco	1862kWh/m2	3000 hours	9 m/s at 40 m elevation over 3500 km coastline
Portugal	1800kWh/m2	2200 to 3000 hours	N/A
Spain	1500kWh/m2	2500 hours	6,64 m/s

These statistics highlight the varying potential for solar and wind energy generation across these Mediterranean countries. While the countries show differing levels of solar irradiance and sunshine hours, they all present opportunities for significant solar power production. Additionally, their varied wind speeds, though not as high as in some other regions, still offer considerable potential for wind energy development.

Integrating data on solar irradiance, sunshine hours, and wind speed into energy planning is crucial for maximizing the use of renewable resources in the Mediterranean region. These insights empower policymakers and energy stakeholders to strategically deploy solar panels and wind turbines in locations with best conditions, thereby accelerating the shift towards sustainable and eco-friendly energy solutions. Harnessing the power of renewable resources, including the production of green hydrogen, holds immense promise for the Mediterranean countries in their journey towards a cleaner and greener energy landscape.

Other parts in the Mediterranean also surveyed in this study have some potential, however regulatory authorities of some of the countries in this study, such as GASREG (Egypt), CRE (France), NGA (Israel), ARERA (Italy), and EMRA (Türkiye) do not have such data.

3.2. Renewable Energy Potentials

Transitioning from discussing the renewable energy potential in the Mediterranean region, the focus now shifts to the existing capacity and potential for renewable energy sources across specific countries in this area. Evaluating the renewable energy landscape, including solar, wind, hydroelectric, and biomass sources, supplies valuable insights into each country's commitment and progress toward a sustainable energy future.

Countries in the Mediterranean region have been investing in solar energy infrastructure, with some nations showcasing substantial solar photovoltaic (PV) capacity. Spain, for instance, has emerged as a leader in solar energy deployment, boasting a significant installed solar capacity. Many countries have recognised the potential of solar energy as a viable and clean power source, contributing significantly to their renewable energy portfolios.

Wind energy has been another focal point for renewable energy development in the Mediterranean region. Türkiye, with its extensive coastline and favourable wind conditions, has made considerable advancements in wind energy capacity. Spain, too, has been harnessing its wind resources, investing in wind farms that contribute substantially to the national electricity grid.

The region's topography and natural landscape have endowed several Mediterranean countries with hydroelectric power potential. Some countries have recognised the reliability and flexibility of hydroelectricity, using it as a stable renewable energy source to complement other intermittent renewables like solar and wind.

Furthermore, the use of biomass, including agricultural residues and organic waste, as a renewable energy source has been gaining attention in various Mediterranean countries. While biomass contributes to a smaller portion of the overall renewable energy mix, its sustainable nature and potential for reducing waste make it an integral part of the region's renewable energy strategy.

Even though some countries currently have substantial installed capacities for renewable energy sources, the question remains whether they will be able to sustain and expand these capacities to support the future incorporation of green hydrogen production.

Different countries in the region have conducted thorough assessments of their future renewable energy potential and have set ambitious goals for the years to come. These plans often include significant investments in infrastructure, technological advancements, and policy frameworks to ensure that their renewable energy grids can handle the additional demand from green hydrogen production.

A summary of the potentials in some of the countries in the region can be seen below. It is noteworthy to reiterate that the figures demonstrate the gross potential as set by the countries or as per their roadmaps/strategies.

Algeria has stated that with the current electricity infrastructure, the country would be able to support up to an installed solar capacity of 13,5 GW and 1 GW of wind.

Lebanon on the other hand has claimed that the country can potentially have up to 182 GW in terms of installed capacity of solar, 6,23 GW installed capacity of wind, 0,47GW of hydroelectric and 0,013 GW of Biomass.

Morocco boasts significant renewable energy potential, with more than 25 GW of onshore wind capacity and more than 250 GW offshore. Additionally, the country's solar energy potential exceeds 20 GW.

Portugal goals for 2030 show that the country would like to drastically increase its installed solar capacity to 20,4 GW, and 12,4 GW in installed wind capacity. The country also aims to have an installed hydroelectric capacity of 8,1 GW.

Spain has calculated their capacity ceiling for 2050, where the figures are as follows: Concentrated solar thermal at 2738,8 GW, solar photovoltaic at 1202,9 GW, wind at 1080,2 GW, hydroelectric at 18.8 GW and Biomass at 15,2 GW.

Meanwhile, **Cyprus** does not have an estimate in terms of the potential capacity that can be installed, however, stated that there is unlimited potential for solar and wind energy assuming there are no area or financial investment constraints. Meanwhile, for hydroelectric energy production, there appear to be significant barriers.

Like the previous sub-chapter, other countries in the Mediterranean also surveyed in this study have some potential, however, regulatory authorities of some of the countries in this study, such as GASREG (Egypt), CRE (France), NGA (Israel), ARERA (Italy), and EMRA (Türkiye) do not have such data.

4

HYDROGEN PRODUCTION AND APPLICATIONS

4.1. Hydrogen Production

4.1.1. Current Efforts

This sub-chapter turns its focus toward an examination of the distinct efforts embedded within the various countries in terms of hydrogen production, regardless of the source of production.

From the northern shore to the southern one, and spanning the eastern and western boundaries, countries currently producing hydrogen showcase some particularities, in terms of the means used to produce the hydrogen. Through this section, the endeavours by country will be uncovered highlighting the interplay between geographical advantages, technological innovations, and collaborative ventures that define the current landscape of hydrogen production across the Mediterranean nations. This closer inspection will offer a comprehensive understanding of the collective efforts and individual contributions shaping the region's pivotal role in advancing the global agenda for a sustainable energy future.

Of the countries that provided their response to the questionnaire, 6 are currently considered hydrogen-producing countries, as seen in the figure 5 below:

Figure 5 - Status of Hydrogen Production (Map by mapcharts.net)

Among the methods incorporated to produce hydrogen is through petrochemical processes, such as in **Egypt**, indicating a reliance on hydrocarbon feedstocks. However, the precise production schemes and methods for hydrogen extraction are yet to be fully defined, as the country is currently in the process of formulating its hydrogen strategy, which to date remains under development.

Similarly, **Portugal** relies on refinery processes fuelled by natural gas, highlighting a commitment to conventional methods of hydrogen production. In 2018, the country produced approximately 0.65 metric tons of hydrogen per year through this process. This signifies Portugal's existing contribution to hydrogen production within the region, primarily driven by refinery operations.

France and **Spain**, on the other hand, currently employ a dual approach for hydrogen production, utilising Steam Methane Reforming (SMR) with natural gas as a source of energy, alongside electrolysis powered by electricity. This dual strategy reflects a balance between traditional and emerging technologies, giving evidence that both countries are putting strenuous efforts to integrate sustainable practices into their hydrogen production, emphasizing a transition towards cleaner and more environmentally friendly energy sources.

Furthermore, countries like **Italy**, **France** and **Spain** are producing hydrogen (about 0.8 Mt/y each). However, it is noteworthy y to mention that this hydrogen is not considered as green hydrogen; it is mostly hydrogen produced via steam reforming.

4.1.2. Future Green Hydrogen Efforts

The global drive for sustainable energy solutions has encouraged ambitious goals for green hydrogen production, showcasing a collective commitment to decreasing carbon emissions and embracing cleaner energy sources.

Ranging from ambitious capacity expansion plans to focused cost-efficiency initiatives, these targets collectively underscore the significance of green hydrogen as a central component in the worldwide shift towards cleaner energy. Appreciating the differences and unique approaches embedded in these production goals sheds light on the multifaceted landscape of Mediterranean green hydrogen initiatives. With that being said, a majority of the countries in the region that have been assessed in this study have plans to produce green hydrogen in the future; a representation of those countries can be seen in Figure 6 below:

Figure 6 - Status of Future Green Hydrogen Production (Map by mapcharts.net)

Algeria sets its sights on a significant output range of 30-40 TWh, positioning itself as a potential key player in the green hydrogen landscape. Meanwhile, **Egypt's** calculation that 1 tonne of hydrogen generates approximately 33 MWh emphasizes the energy potential inherent in hydrogen production and consumption. **France's** ambitious national strategy aims to deploy 6.5 GW of electrolysis capacity by 2030, translating to an impressive 600 kt/year of carbon-free hydrogen—a pivotal step towards reducing carbon emissions. **Italy** envisions a dual approach: producing 10 million tons of green hydrogen domestically and importing an equivalent amount by 2030, which are targets set at the EU level. To achieve this, Italy plans to harness 10 TWh of solar energy specifically for electrolysis by the end of the decade.

Conversely, **Morocco's** approach, outlined in its Green Hydrogen Roadmap, appears more fluid with an estimation of the overall green hydrogen demand and the necessary capacity based on potential scenarios, emphasising adaptability and responsiveness to evolving needs.

Türkiye, through its Hydrogen Technologies Strategy and Road Map, foresees a rapid escalation in green hydrogen adoption across crucial sectors like transportation, petrochemicals, iron and steel, fertilizer, and cement. Notably, Türkiye has set an ambitious target to substantially reduce the cost of green hydrogen production—planning to achieve costs below 2.4 US dollars per kilogram by 2035 and further decrease it to below 1.2 US dollars per kilogram by 2053. These targets underscore a steadfast commitment to technological advancements and cost efficiency, signalling a long-term vision for sustainable hydrogen-based solutions in Türkiye's energy landscape.

In addition, **Portugal** has a target of 120 GWh/year for the production of hydrogen derived from water electrolysis from renewable sources.

In terms of the presence of infrastructures that can support the transportation of hydrogen to feed the energy systems, a majority of the countries are still yet to implement changes in that regard.

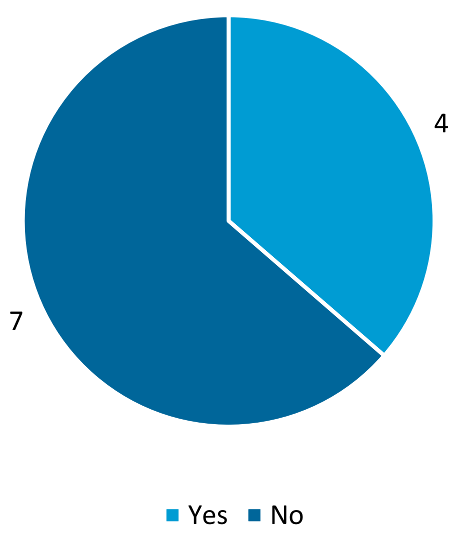

Figure 7 - Presence of Infrastructure in Place to Transport Hydrogen

The 4 countries that stated that they have an infrastructure in place to transport hydrogen are France, Italy, Portugal, and Spain.

France has established local pipelines primarily within industrial clusters to facilitate the transportation of hydrogen, indicating a localized approach to its distribution and usage.

Italy possesses a significant network of gas transmission pipelines capable of transporting hydrogen when blended with gas. However, the exact percentage of infrastructure adapted for hydrogen transportation remains undisclosed. Plans are in place to gather this information starting from 2024. Notably, the primary Italian Transmission System Operator (TSO) is undertaking the "South H2 corridor" project in collaboration with Austrian and German TSOs. This project, situated within the European Hydrogen Backbone, aims to create a network linking potential renewable hydrogen production sites in North Africa and southern Italy to the EU. It involves adapting existing Italian gas infrastructures and constructing new sections to enable hydrogen transportation. The project has been proposed as a Project of Common Interest, seeking access to funds from the Connecting Europe Facility. Several other Central and Eastern European Union Member States have expressed interest in linking to the South H2 corridor, potentially expanding its reach. The corridor aims to connect Italy to Germany via Austria and could potentially utilize pipelines like the Tunisian Pipeline (“TTPC”) and Trans Mediterranean Pipeline (“TMPC”) to access renewable resources in North Africa, aligning to create an Italian transport backbone dedicated to meeting European hydrogen demand.

Portugal incorporates hydrogen by blending it with natural gas and utilizes the existing natural gas infrastructure, including pipelines and storage facilities, for its transportation and distribution.

Spain's approach involves the compression of hydrogen and its transportation through natural gas pipelines, indicating a dual method of distribution involving compressed hydrogen and blending with natural gas for transportation purposes.

However, it is noteworthy to say that there are some ongoing developments and prospects in some countries regarding the issue. For example, in **Egypt**, there is an ongoing development initiative concerning hydrogen transportation infrastructure. The specific details of this infrastructure are currently being formulated and implemented. Similarly, **Morocco's** hydrogen transportation infrastructure status is unspecified, with no detailed information available currently. Meanwhile, In **Lebanon**, there is an absence of infrastructure specifically designed for the supply and export of hydrogen. Further investigation is required in subsequent planning stages to develop a strategic infrastructure strategy.

The countries of the region have had their unique responses regarding the most promising technology for transporting Hydrogen. The assessed countries' responses in that regard revolved around liquification, pipelines and through ammonia. Even though some countries use hydrogen, it appears that they might not have a clear view regarding the most interesting way to transport hydrogen, as the current methods are already satisfactory, such as in the case of **Portugal** and **Spain**. The schematic shown in Figure 8 below shows what the assessed countries believe is the most promising transport technology for Hydrogen.

In the pursuit of viable technologies for transporting hydrogen, the different countries in the region are exploring various methods based on their unique infrastructural capabilities, cost considerations, and safety factors.

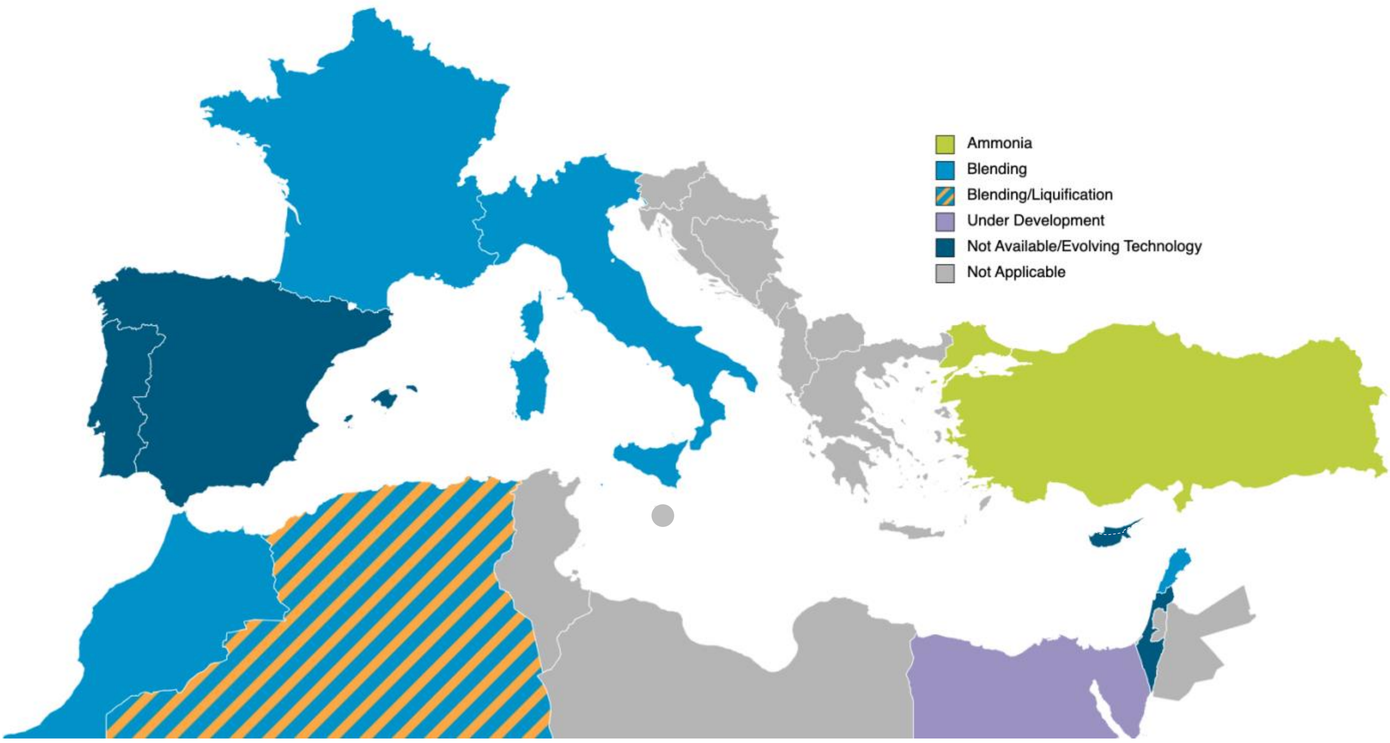

Figure 8 - Most Promising Technology to Transport and Use Hydrogen per Country (Map by mapchatrs.net)

Algeria identifies liquid terminal transport as the most promising avenue, despite the associated high costs, which appears to be a major barrier. Meanwhile, the potential for blending hydrogen with natural gas and ammonia within pipelines is also being considered. In that regard, it is noteworthy to mention that there are plans for a gas pipeline project, which would connect **Italy** with **Algeria** with a capacity of between 8-10 bcm per annum. Said project will extend to 837 km, of which 560 km offshore across the Mediterranean, and it would be able to transport natural gas, hydrogen, and ammonia.

France leans towards utilizing pipelines to blend hydrogen with natural gas. Similarly, **Italy** is exploring the prospect of blending hydrogen with gas, while **Lebanon** is eyeing pipeline infrastructure for transit. In **Morocco**, the determination of the most promising transport technology for hydrogen hinges on multiple variables such as specific use cases, distances, available infrastructure, and safety parameters. Countries equipped with well-established gas transportation infrastructures may find blending hydrogen with gas as an optimal solution.

Türkiye, on the other hand, has conducted studies indicating that transporting hydrogen via ammonia could be cost-effective. Moreover, there are plans to establish a hydrogen network in Europe specifically for transporting hydrogen, and Türkiye's initial priority seems to be injecting hydrogen into the natural gas transmission system. Future steps will likely align with developments in Europe, shaping Türkiye's approach to hydrogen transport based on emerging advancements in the field.

Meanwhile, **Egypt's** initiatives for hydrogen transport are still in the developmental phase.

4.2. Hydrogen Applications

The Mediterranean region stands at the forefront of harnessing hydrogen's potential across various industries, with 8 countries: Algeria, Egypt, France, Israel, Morocco, Portugal, Spain, and Türkiye, actively exploring its diverse applications. From bolstering petrochemical and refining sectors to revolutionising fertilizer production and transportation, these countries are navigating the evolving landscape of hydrogen utilisation. While each nation exhibits a unique focus and utilisation pattern, there remains an overarching commitment to shaping hydrogen strategies that optimise production scales, market scenarios, and off-take contracts, both domestically and potentially for international export. Amidst this exploration, an intricate tapestry of hydrogen's role in industrial and economic landscapes is being woven, promising transformative advancements across the Mediterranean region's key sectors.

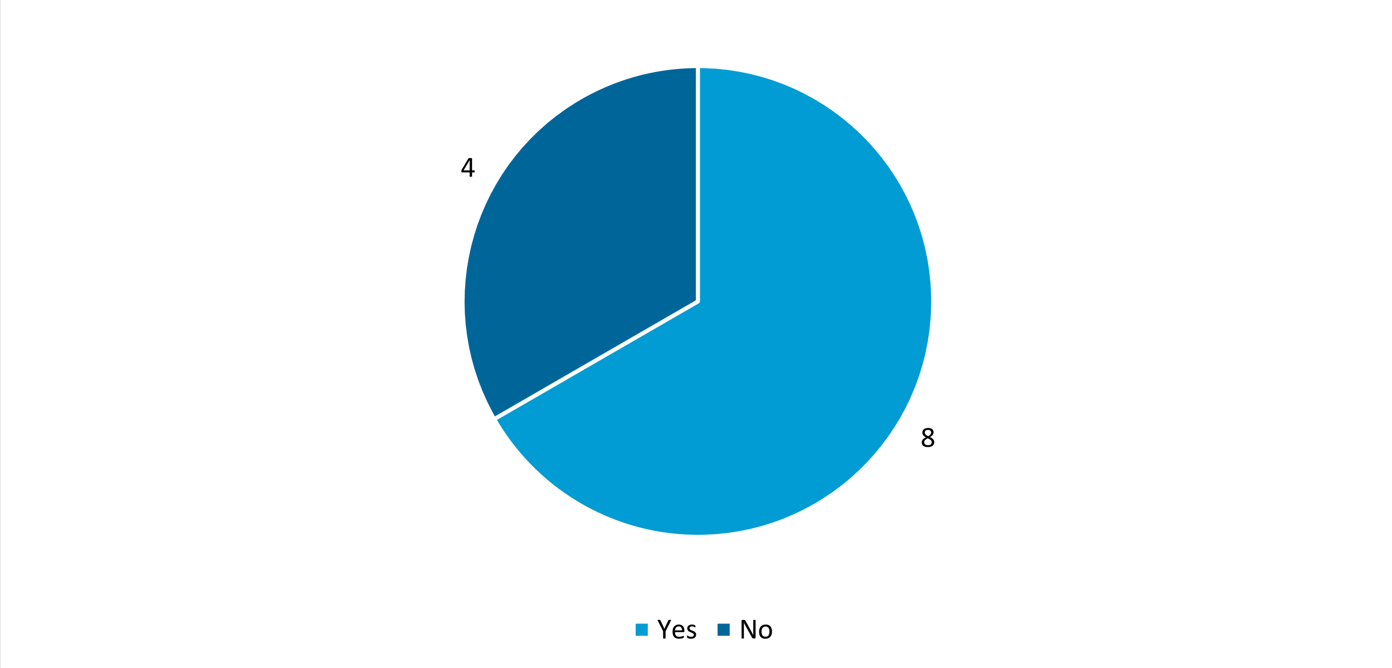

Figure 9 - Current Presence of Hydrogen Applications

Egypt is focusing on applications in petrochemicals and the iron industry, as well as ammonia and fertiliser production. However, the specifics of these applications for achieving economies of scale are pending clarification within the ongoing development of Egypt's hydrogen strategy. This strategy aims to define the market scenarios, production scales, and off-take contracts, both domestic and for potential export, to optimise the utilisation of hydrogen.

France has historically employed hydrogen for the desulphurisation of petroleum fuels, accounting for approximately 60% of its usage. Around 25% is utilised in ammonia synthesis, primarily for fertiliser production, while an additional 10% serves various chemical applications. France's annual hydrogen consumption stands at an estimated 900,000 tonnes, primarily within the oil and chemical industries. Future applications will focus on heavy-mobility transport and industrial sectors that are difficult to decarbonize by other means.

Israel, while mentioned in the context of refining, lacks detailed information about the extent or specific applications of hydrogen utilisation within its industries.

Morocco possesses a significant potential market for green hydrogen application. The OCP Group, which manages the world's largest phosphate reserves and is a leading global producer and exporter of phosphate fertilizers, aims to replace imported traditionally produced ammonia with green ammonia produced from green hydrogen.

In **Portugal**, the refining sector prominently employs hydrogen, particularly in the hydrocracking unit of heavy diesel at the Sines refinery complex. However, specific details regarding other potential applications of hydrogen within Portugal are currently unavailable.

Spain's use of hydrogen is not extensively documented by CNMC (National Commission of Markets and Competition). The information regarding its use in the refining sector, other industrial applications such as chemicals and fertilisers, as well as its potential application in heavy transport, remains unavailable as per CNMC records.

Türkiye is also among the countries that utilise hydrogen in various forms.

5

DRIVERS AND BARRIERS FOR GREEN HYDROGEN DEVELOPMENT

The surge in interest surrounding green hydrogen stems from its compelling potential to address critical environmental concerns while revolutionising the energy sector. A primary driver propelling its advancement is its inherent sustainability, derived from the use of renewable energy sources in its production process. The increasing urgency to mitigate climate change and reduce carbon emissions has spurred widespread recognition of green hydrogen as a key solution in achieving these goals. Additionally, the versatility of green hydrogen as a clean energy carrier, suitable for various sectors such as transportation, industry, and power generation, has garnered significant attention from governments, industries, and investors worldwide.

However, despite this enthusiasm, several challenges stand in the path of its widespread implementation. Technical complexities, cost-intensive production methods, infrastructural inadequacies, and regulatory uncertainties present large barriers, demanding thorough examination and strategic interventions.

This chapter aims to dissect these drivers propelling the growth of green hydrogen and the barriers that impede its seamless integration. By dissecting these factors, it aims to offer insights crucial for informed decision-making and strategic planning. Through an understanding of these dynamics, stakeholders can chart a path toward leveraging the potential of green hydrogen while effectively navigating the obstacles impeding its adoption. Ultimately, this exploration serves as a foundational guide, empowering stakeholders to navigate and optimise the transformative potential of green hydrogen within the evolving energy landscape.

5.1. Drivers for Green Hydrogen Development

The drivers for green hydrogen development were classified in the questionnaire drafted. These drivers were taken from prior surveys and discussions carried out by MEDREG's General Assembly as well as during meetings of the GAS WG, where on numerous occasions the advantages of developing the sector were mentioned.

The drivers assessed in this study include the following:

<u>Economic Growth:</u> The pursuit of green hydrogen aligns closely with fostering economic growth by creating new industries, generating job opportunities, and stimulating innovation. Investments in green hydrogen infrastructure, technology development, and associated supply chains can catalyse economic activities, spurring growth in both established and emerging markets. Furthermore, the adoption of green hydrogen technologies often leads to increased productivity and competitiveness, driving economic prosperity through the establishment of a sustainable energy ecosystem.

<u>Export Incomes:</u> Green hydrogen presents a promising avenue for countries to diversify their energy portfolios and capitalise on export opportunities. Nations blessed with ample renewable resources can use their surplus energy production for green hydrogen generation, positioning themselves as key exporters in the global energy market. Exporting green hydrogen or its derivative products not only contributes to national revenue but also sets up long-term partnerships, bolstering international trade relations while reducing reliance on conventional fossil fuel exports.

Industry Decarbonisation: The imperative to reduce carbon emissions across industries has propelled the interest in green hydrogen as a means of decarbonising industrial processes. Many industries, particularly those with high carbon footprints like steel, cement, and chemicals, are exploring the integration of green hydrogen as a clean energy feedstock or fuel. By substituting conventional fossil fuels with green hydrogen, these sectors can significantly cut down their carbon emissions, aligning with sustainability goals and regulatory requirements while maintaining operational continuity.

Energy Security: Green hydrogen is perceived as a key player in enhancing energy security by diversifying energy sources and reducing dependence on finite fossil fuels, which are subject to geopolitical uncertainties. The ability to produce hydrogen domestically using renewable resources offers a more resilient energy supply chain, reducing vulnerability to geopolitical disruptions and price fluctuations in the global energy market. By promoting self-sufficiency in energy production, green hydrogen contributes to a more secure and stable energy landscape for nations aiming to reduce reliance on imported fuels.

Figure 10 below shows the representation of the distribution the significance of each of the above drivers as perceived by the countries assessed in this study:

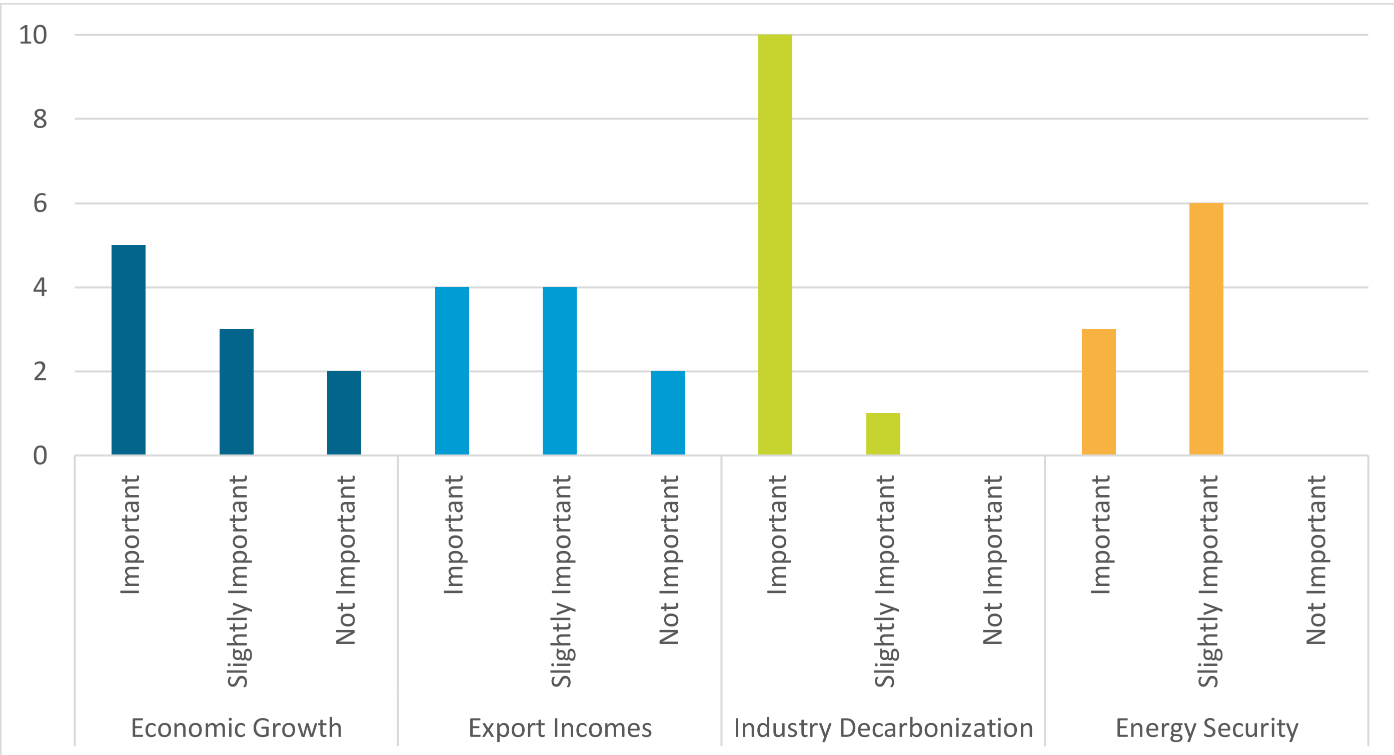

Figure 10 - Importance of Drivers for Developing Green Hydrogen

The data reveals a nuanced perspective on the drivers for developing green hydrogen in the analysed country. Economic growth appears as a paramount factor, with a significant weight assigned to its importance, where 5 of the 11 countries were given in that regard. This underscores a clear recognition of the potential economic benefits associated with the development of green hydrogen.

Export incomes also hold considerable significance, with a balanced distribution across the importance spectrum, reflecting an awareness of the role green hydrogen can play in enhancing the country's export revenue.

The standout driver, however, is industry decarbonisation, receiving an overwhelmingly high importance rating of 10 out of 11. This underscores a strong commitment to reducing carbon emissions within the industrial sector, aligning with global efforts to mitigate climate change.

Energy security is recognised as a driver, though to a lesser extent, with a moderate importance rating. The interesting aspect in that regard is that in a similar study assessing the importance of security of natural gas supply, energy security is the driver that was hailed as the factor of utmost priority, followed by Energy Affordability, with the last place in terms of significance going to climate change.

5.2. Barriers for Green Hydrogen Development

Like the drivers, the barriers for green hydrogen development indicated in the questionnaire drafted, were taken from the conclusions and outcomes of the previous meetings and workshops held by MEDREG. In almost all occasions the needs for finance and the lack of a hydrogen market are always discussed, and these are among the barriers chosen to be assessed in this study.

The full set of barriers studied are as follows:

High Cost: One of the primary barriers hindering the widespread adoption of green hydrogen is its currently high production cost compared to conventional hydrogen derived from fossil fuels. The expense is mainly attributed to the energy-intensive process involved in producing hydrogen through electrolysis powered by renewable sources. Additionally, costs associated with infrastructure development, technology optimisation, and scale-up further contribute to the overall high cost, limiting its competitiveness against conventional alternatives.

Lack of Access to Affordable Financing: Access to affordable financing stays a significant challenge for scaling up green hydrogen projects. The substantial upfront investment needed for infrastructure development, technology deployment, and research and development efforts often surpasses the financial abilities of many entities, including governments, industries, and investors. Although could be compared to the above aforementioned high costs, the lack of clear and favourable financing mechanisms or incentives tailored specifically for green hydrogen projects poses a barrier, deterring potential investors and impeding the development of a robust green hydrogen market. Political and geopolitical factors also play a role in the lack of financial incentives. A lack of clear and supportive policies and regulations can create uncertainty for investors. Additionally, international cooperation is essential for the development of a global green hydrogen economy, but geopolitical tensions and trade disputes can hinder progress. The supply chain for critical components, such as electrolyzers and hydrogen storage tanks, is still developing, leading to potential supply bottlenecks and cost fluctuations. Moreover, the future demand for green hydrogen is subject to various uncertainties, including evolving energy policies, technological advancements, and economic conditions. This market uncertainty can deter potential investors and hinder the development of a robust green hydrogen market.

Lack of Market: The absence of a well-established and mature market for green hydrogen hampers its widespread adoption. A lack of clear regulatory frameworks, standards, and policies supporting the production, distribution, and utilisation of green hydrogen impedes market development. Additionally, the relatively limited demand from end-users across various sectors, coupled with the lack of established supply chains and infrastructure, restricts the growth of a viable market ecosystem necessary for the proliferation of green hydrogen. However, lack of market can also be viewed as a consequence rather than a barrier given the context.

Environmental Constraints: While green hydrogen is lauded for its environmental benefits, certain environmental constraints pose challenges to its production and adoption. The large land and resource requirements for renewable energy generation, such as solar or wind power used in electrolysis, might raise concerns about habitat disruption or land-use conflicts. Moreover, the lifecycle analysis of green hydrogen production, including factors such as water usage and material sourcing for infrastructure, needs careful consideration to ensure it still is environmentally sustainable throughout its entire value chain. Striking a balance poses a significant challenge in its widespread adoption.

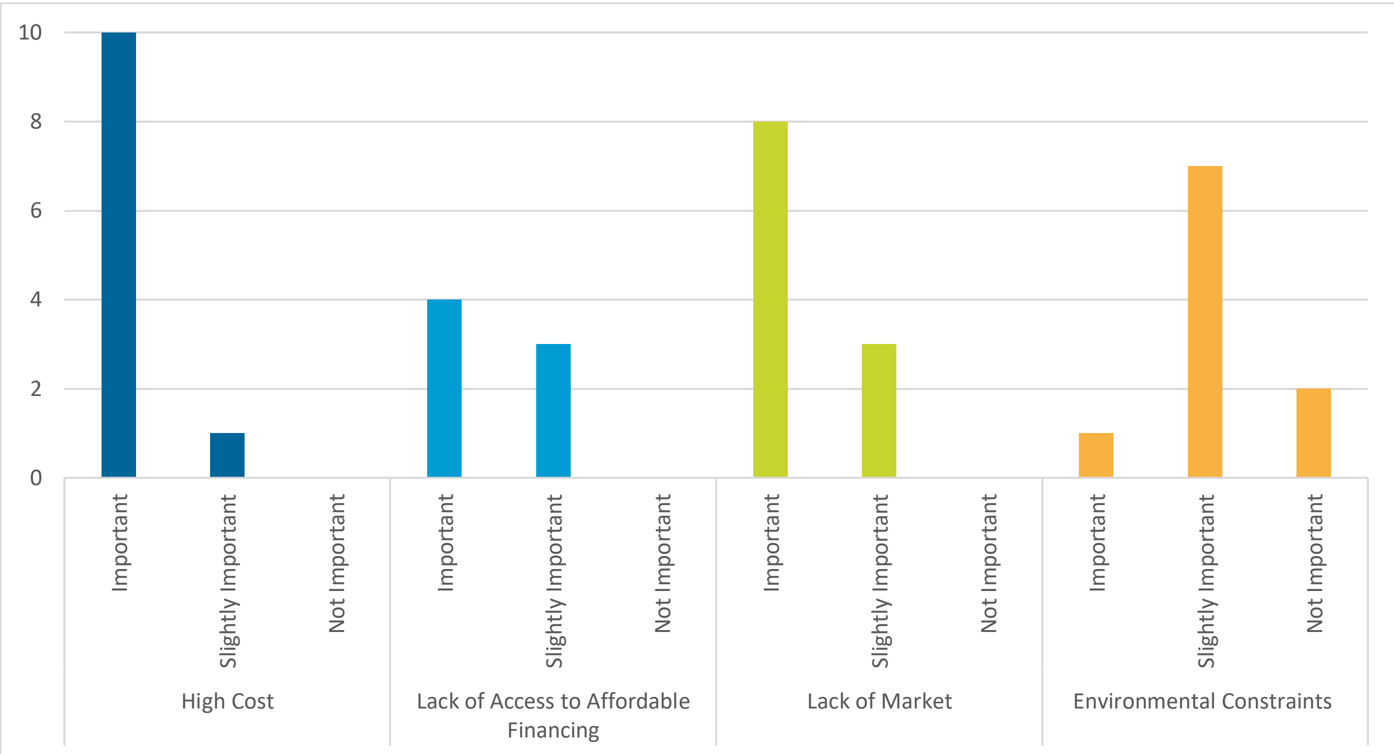

Figure 11 - Barriers for Developing Green Hydrogen

The data illustrates a comprehensive view of the barriers influencing the development of green hydrogen. High cost emerges as the most substantial impediment, garnering a significant importance rating of 10. This suggests a recognition of the financial challenges associated with green hydrogen production, emphasising the need for cost-effective solutions to drive widespread adoption.

The lack of access to affordable financing follows closely, with an importance rating of 8, highlighting the financial constraints that may hinder the development of green hydrogen projects.

Furthermore, the lack of a market is identified as a barrier, though to a slightly lesser extent. The importance rating of 6 indicates a perceived need for the creation and expansion of markets that can support the uptake of green hydrogen.

Environmental constraints, surprisingly, are considered less significant as a barrier, with one country highlighting that it is an important barrier. This could suggest a belief that environmental considerations, while relevant, are not the primary hindrance to the development of green hydrogen. In summary, the data underscores the critical role of economic factors and financing accessibility as primary barriers, emphasising the importance of addressing these challenges to foster the growth of the green hydrogen sector.

6
CONCLUSION

CONCLUSION

Given the numerous advantages of hydrogen, a strategy or a roadmap is a great asset to have to define national and international objectives regarding hydrogen, its production, and its uses. Prioritising research and development in the field is thus key to enhance efficiency and sustainability of hydrogen production methods, along with making infrastructure more reliable and efficient. On this note, encouraging investment in infrastructure by creating a transparent framework and creating supportive policies for investment, along with regulatory standards to promote work safety in these areas might prove beneficial in the long run.

Collaboration among governments, research institutions and industries can be effective, especially by promoting initiatives like joint research programs and standardisation guidelines. These can all contribute to accelerating the process while also driving down foreseen costs. In that regard, creating common policies and adopting the same international standard could be a driving factor in mitigating and limiting said costs. Common policies might also prove to be helpful in speeding up the process, facilitating investments, and helping the formation of a common international market. MEDREG could help smoothen the process by acting as intermediary between countries and creating common grounds for research and development.

As more and more Mediterranean countries acknowledge hydrogen as a potential clean energy source and a promising alternative to fossil fuels, a common legal framework across multiple countries might be necessary in the near future, a challenge that regulators in the region can tackle through collaborative efforts. Nowadays, challenges persist in integrating green hydrogen into existing energy systems. This also implies the opportunity to develop a shared commitment to use green hydrogen and making sure the energy used to create hydrogen also comes from clean energy sources.

Across different countries in the region, not all have a certification mechanism to check whether hydrogen produced derives from clean energy sources. Certificates that are widely recognised can help form a common international market while guaranteeing checks on the production of hydrogen, thus helping the widespread use of the goods.

Countries in the Mediterranean region are actively engaged in pioneering initiatives and collaborative endeavours to harness the potential of hydrogen technology, positioning it as a vital component in the transition towards renewable and clean energy sources.

Albeit numerous collaborative projects are underway, often in partnership with leading companies specialised in hydrogen technology, these efforts often lack funding to bear fruit.

To improve research and development of more advanced hydrogen production methods, financial backing from the government and campaigns to raise awareness can be beneficial to attract investments at a national and international level, something already underway as proven by the numerous pilot programs aimed at demonstrating and testing various hydrogen technologies, encompassing aspects of production, storage, and distribution.

To achieve stable green hydrogen production in a short period, several patterns can be classified as “barriers to entry” for investors that have to be tackled. Investing in hydrogen nowadays is a risky endeavour due to lack of demand, thus lack of market, high costs, and lack of access to affordable financing, mostly represented by the two points mentioned above.

Lack of demand is mainly considered as a lack of market, due to low incentives for consumers to buy hydrogen or hydrogen-fuelled products.

A way to tackle this issue is to create well-designed incentives for encouraging users to modify their consumption via mechanisms that can ensure that hydrogen products are more appealing to the consumer, hence, reducing the barriers for hydrogen to enter the market, creating a condition where green hydrogen alternatives are seen as viable solution to more traditional energy sources.

Another way might be promoting green hydrogen, besides funding research and development, by creating transparent regulations to check the quality and security of products/services using hydrogen as an energy source, thus facilitating investment through the partial elimination of legal barriers to entry. Some countries in the region have already implemented some form of incentives, operating at different levels, by introducing subsidies, loans, tax credits, or feed-in tariffs, although those policies are limited to the national level or a specific area and prove to be insufficient to fully close the cost gap between green hydrogen and other fuels.

Considering the current green hydrogen production and the objectives set by the producing countries, creating a standard of quality and production alongside common legal frameworks and roadmap sharing can help in reaching the objectives faster, alongside creating a niche for hydrogen as a competitive alternative to fossil fuels.

It's also key to highlight the importance of developing new assets based on the needs of the energy system and choosing the most cost-efficient solutions in consideration of the different scenarios. Costs need to be allocated in a transparent to those who want to invest in the sector, avoiding cross-subsidization and eliminating barriers to entry.

Finally, fostering continuous knowledge exchange and sharing experiences among countries in the region is crucial. It is important to note that there isn't a one-size-fits-all solution. Nevertheless, encouraging regulatory authorities to draw lessons from each other's successes and challenges can significantly enhance capacities and capabilities. MEDREG's collaborative framework plays a pivotal role in guiding the way forward.

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