

Demonstration of an H₂ value chain in the energy-intensive industry in Türkiye using the example of kilns in the ceramic industry

Final Report

The International Hydrogen Ramp-up Programme (H2Uppp) of the German Federal Ministry for Economic Affairs and Climate Action (BMWK) promotes projects and market development for green hydrogen in selected developing and emerging countries as part of the German National Hydrogen Strategy.

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Abbreviations

CBAM	Carbon Border Adjustment Mechanism
TENMAK	Turkish Energy, Nuclear and Mineral Research Agency
PESTLE	Political, Economic, Technological, Environmental, Legal
UNFCCC	United Nations Framework Convention on Climate Change
SDGs	Sustainable Development Goals
MDGs	Millennium Development Goals
THSR	Turkish Hydrogen Technologies Strategy and Roadmap
UK	United Kingdom
CO ₂	Carbon Dioxide
EMRA	Energy Market Regulatory Authority
TÜBİTAK	The Scientific and Technological Research Council of Türkiye
RFNBOs	Renewable Fuels of Non-Biological Origin
GHG	Green House Gas
EU	European Union
IED	Industrial Emissions Directive
BMWK	German Federal Department of Economic Affairs and Climate Protection
CfD	Contracts for Difference
BMBF	Federal Ministry of Education and Research
NOW GmbH	The National Organization for Hydrogen and Fuel Cell Technology
BMZ	The German Federal Ministry for Economic Cooperation and Development
EED	Energy Efficiency Directive
TurSEFF	Türkiye Sustainable Energy Financing Program
EBRD	European Bank for Reconstruction and Development

1 Executive Summary

The Turkish ceramic industry boasts a rich history and a strong presence in the global market. Renowned for its high-quality products and competitive edge, the sector faces a dynamic environment shaped by various external forces. This study specifically focuses on the potential of hydrogen as a fuel source in ceramic production processes. Hydrogen offers a promising avenue for reducing the industry's environmental footprint and aligning with global sustainability trends. The study provides a comprehensive analysis of the potential for H2/Power-to-X (PtX) Production in the Ceramic Industry Sector in Türkiye, with a focus on the regulatory environment.

In this study, the regulatory environment was compared with Europe and Germany to define clearly the necessary steps to be taken. The EU and Germany have established detailed legal frameworks governing green hydrogen energy, encompassing production, storage, distribution, and end-user applications. In contrast, Turkish legislation currently lacks specific regulations for hydrogen energy. While the country prioritizes renewable energy sources and energy efficiency, a dedicated hydrogen energy policy is still under development. The recently published Türkiye Hydrogen Technologies Strategy and Roadmap outlines the goal of increasing green hydrogen use but lacks concrete steps for establishing a legal framework.

There is no binding regulation on any aspect of green hydrogen energy in Türkiye, including production, storage, distribution, or end-user applications. The current Energy Efficiency Law and Electricity Market Law do not comprehensively address hydrogen energy. Regulations for safety, environmental impact, licensing, incentives, and dispute resolution are entirely missing for hydrogen energy. The current legal framework does not support the development of hydrogen transportation and storage infrastructure.

The report recommends introducing a framework law for hydrogen energy in Türkiye. This law should define different hydrogen types (grey, blue, green) and production methods. The framework law should address safety and environmental considerations throughout the hydrogen life cycle, from production to end-use. It should define licensing and permitting procedures for hydrogen production, storage, and transportation companies. The framework law needs to establish mechanisms for financial incentives, including tax reductions, subsidies, and support for research and development activities.

The report emphasizes the importance of aligning Turkish regulations with international standards and fostering international cooperation in hydrogen energy. Specific recommendations for regulating hydrogen transportation (pipelines, compressed tanks) and storage (safety standards, licensing) are provided. The framework law should address the safe use of hydrogen by end-users in various sectors. It should establish technical compatibility standards for hydrogen infrastructure and consumer protection mechanisms.

A clear legal framework will encourage investments in hydrogen energy production, storage, and infrastructure development in Türkiye. It will promote the safe and sustainable use of hydrogen energy across various sectors, contributing to the country's energy transition goals. Aligning with international standards will facilitate technology transfer and cooperation with other countries in the field of hydrogen energy.

The report calls for urgent action to establish a comprehensive legal framework for green hydrogen energy. In coordination with relevant stakeholders, the Ministry of Energy and Natural Resources should lead the development of this framework law. The framework law should be designed to be future-proof and adaptable to evolving technologies and best practices in the global hydrogen energy landscape.

2 Introduction

This report provides a comprehensive analysis of the potential for green H₂/Power-to-X (PtX) Production in the Ceramic Industry Sector in Türkiye, with a focus on the regulatory environment.

The report has been developed through a comprehensive approach, blending extensive desk research with insightful field studies. A crucial component of this process involved conducting meetings with key institutions directly involved in the subject matter. These face-to-face interactions were held with esteemed organizations such as the Ministry of Trade on 27th February 2024, the Ministry of Energy and Natural Resources on 28th February 2024, TENMAK on 1st March 2024 and EMRA on 21st of March. By engaging with these stakeholders, we were able to gather valuable insights and ensure the accuracy and relevance of the report's findings.

The report thoroughly examines the regulatory landscape surrounding green hydrogen production and usage within the Turkish ceramic industry. Our analysis encompasses various dimensions, beginning with a PESTLE analysis to evaluate the political, economic, technological, environmental, and legal factors shaping the regulatory context.

Through benchmarking studies comparing Türkiye and Germany, the report aims to glean insights into legislative and regulatory environments, identifying areas of convergence and disparity. The report delves into critical aspects of green hydrogen and its role in facilitating the transition towards sustainable energy practices within the benchmarking analysis. It also explores the intricacies of financing green hydrogen projects, tax regimes, and incentives designed to foster investment in renewable energy initiatives. Moreover, analysis extends to the realm of technology and innovation, as well as market regulations, trade agreements, and collaborations pertinent to the hydrogen sector, highlighting opportunities for strategic partnerships and international cooperation.

In preparing the regulatory path, the report delineates the scope of the regulatory environment in Türkiye, conducting stakeholder analyses to understand perspectives and concerns. The stakeholder analysis outlines various associations, equipment suppliers, hydrogen suppliers, and financial institutions involved in the hydrogen energy sector. It ranks these organizations based on their influence and interest, helping to identify key stakeholders.

Through legislative and regulatory risk assessments, coupled with the formulation of a road map table and checklist, the report aims to provide a structured approach to regulatory compliance and risk mitigation.

Finally, findings and recommendations encapsulate the culmination of our analysis, offering actionable insights to policymakers, industry stakeholders, and regulatory bodies. By synthesizing our research and observations, we endeavour to contribute to advancing regulatory frameworks conducive to sustainable green hydrogen utilization within the Turkish ceramic industry.

3 Framework Analysis: H₂/PtX Production & Usage in Turkish Ceramic Industry - Regulatory Context

3.1 PESTLE Analysis

The Turkish ceramic industry boasts a rich history and a strong presence in the global market. Renowned for its high-quality products and competitive edge, the sector faces a dynamic environment shaped by various external forces. This PESTLE analysis delves into the critical political, economic, social, technological, environmental, and legal factors impacting the industry's current state and future trajectory.

This study specifically focuses on the potential of hydrogen as a fuel source in ceramic production processes. Green hydrogen offers a promising avenue for reducing the industry's environmental footprint and aligning with global sustainability trends.

By examining these crucial PESTLE factors, this analysis aims to provide valuable insights for stakeholders within the Turkish ceramic industry. It will identify strategic opportunities, highlight potential disruptions, and aid in navigating the path towards a more sustainable and resilient future.

3.1.1 Political Factors

In recent years, Türkiye has embarked on a transformative journey towards green transition, driven by political commitments to address environmental challenges and promote sustainable development. As a signatory to key international agreements and frameworks, including the United Nations Framework Convention on Climate Change and the Paris Agreement, Türkiye has demonstrated its willingness to participate in global efforts to combat climate change. Moreover, Türkiye's engagement with initiatives such as the European Green Deal reflects its recognition of the importance of aligning national policies with international standards for environmental sustainability. This journey is characterized by Türkiye's proactive stance in integrating green policies into its political agenda, as evidenced by its endorsement of the Sustainable Development Goals and efforts to integrate principles of sustainable development into national strategies. By navigating the complex interplay between environmental protection, economic development, and social equity, Türkiye is poised to emerge as a leader in the region's transition towards a more sustainable and resilient future.

In this part of the analysis, the political aspects of the green transition are covered internationally and nationally. Moreover, national and regional strategies/actions for hydrogen technologies, production, storage and transportation are summarized.

International Level Policies:

In the face of mounting environmental challenges and the urgent need for sustainable development, international cooperation has played a pivotal role in shaping policies and frameworks to address these issues. This journey towards sustainability and green transition has been marked by significant milestones embodied in major international policy steps. Each step represents a concerted effort by the global community to tackle environmental degradation, mitigate climate change, and promote sustainable development. Delving deeper into these milestones provides valuable insights into their goals, mechanisms, and implications, underscoring their collective impact on global sustainability efforts' trajectory.

Stockholm Declaration (1972):

The Stockholm Declaration emerged from the United Nations Conference on the Human Environment, the first major conference of its kind to focus on environmental issues at the global level. It recognized the interdependence of human well-being and environmental health, emphasizing the need for sustainable development strategies that balance economic growth with environmental protection. The declaration established principles for international environmental governance, including the precautionary principle, which advocates for preventive action in the face of environmental risks. Türkiye became a State Party to this Convention signed by 179 states on the 12th of January 2010, after signing and executing it on 23rd of May 2001.

Brundtland Report (1987):

The Brundtland Report, officially titled "Our Common Future," was produced by the World Commission on Environment and Development, chaired by Gro Harlem Brundtland. It popularized the concept of sustainable development, defining it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The report highlighted the interconnectedness of social, economic, and environmental issues, calling for integrated approaches to development that address poverty, inequality, and environmental degradation simultaneously. Türkiye welcomed the Brundtland Report and recognized the importance of sustainable development. Since then, Türkiye has taken steps to integrate the principles of sustainable development into its national policies and development plans, aiming to balance economic growth with environmental protection and social equity.

United Nations Framework Convention on Climate Change (UNFCCC) (1992):

The UNFCCC is an international treaty to stabilise greenhouse gas concentrations in the atmosphere to prevent dangerous anthropogenic interference with the climate system. It established a framework for international cooperation on climate change, including the commitment to reduce greenhouse gas emissions and adapt to the impacts of climate change. The convention has facilitated ongoing negotiations and agreements on climate action, serving as the foundation for subsequent agreements such as the Kyoto Protocol and the Paris Agreement. Türkiye is a party to the UNFCCC and actively participates in its meetings and negotiations. Türkiye has submitted several national communications and greenhouse gas inventories to the UNFCCC Secretariat, demonstrating its commitment to fulfilling its obligations under the convention.

Kyoto Protocol (1997):

The Kyoto Protocol is an international treaty linked to the UNFCCC, which sets binding emission reduction targets for developed countries. It introduced flexible mechanisms such as emissions trading and clean development projects to facilitate cost-effective emissions reductions and promote sustainable development. The protocol represented the first concerted effort by the international community to address climate change through legally binding commitments, although the lack of participation from major emitters limited its effectiveness. While Türkiye is a party to the Kyoto Protocol, it was classified as a non-Annex I country, which means it was not legally bound to reduce its greenhouse gas emissions under the protocol. However, Türkiye has implemented various measures to mitigate climate change and improve energy efficiency.

Millennium Development Goals (2000):

The Millennium Development Goals (MDGs) were eight international development goals established by the United Nations to address poverty, hunger, disease, gender inequality, and environmental degradation. While the MDGs did not specifically focus on environmental sustainability, they included environmental conservation and biodiversity targets, highlighting the importance of environmental stability in achieving broader development objectives. The MDGs galvanized global efforts to address poverty and improve human development outcomes, laying the groundwork for the subsequent adoption of the Sustainable Development Goals (SDGs). Türkiye endorsed the Millennium Declaration and committed to achieving the Millennium Development Goals (MDGs), including those related to environmental sustainability. Türkiye implemented various initiatives to address poverty, improve access to clean water and sanitation, and protect biodiversity, contributing to the achievement of the MDGs.

Paris Agreement (2015):

The Paris Agreement is a landmark international treaty under the UNFCCC, which aims to strengthen the global response to climate change by keeping global temperature rise well below 2 °C above pre-industrial levels and pursuing efforts to limit it to 1.5 °C. It represents a collective commitment by nearly every country worldwide to undertake ambitious climate action, including setting nationally determined contributions (NDCs) to reduce greenhouse gas emissions. The agreement also includes provisions for adaptation to the impacts of climate change, climate finance, technology transfer, and capacity-building support for developing countries. Türkiye signed the Paris Agreement in 2016 and ratified it in 2016. As a party to the agreement, Türkiye has committed to contributing to global efforts to limit global warming and adapt to climate change impacts. Türkiye's nationally determined contribution (NDC) includes targets for reducing emissions intensity and increasing the share of renewable energy in its energy mix.

2030 Agenda for Sustainable Development (2015):

The 2030 Agenda for Sustainable Development is a universal call to action adopted by all United Nations Member States, which includes 17 Sustainable Development Goals (SDGs) and 169 targets to address the world's most pressing challenges. The SDGs cover many issues, including poverty, hunger, health, education, gender equality, clean water and sanitation, affordable and clean energy, climate action, and sustainable cities and communities. The 2030 Agenda emphasizes the interconnectedness of social, economic, and environmental issues, recognizing that sustainable development cannot be

achieved without addressing all three dimensions simultaneously. Türkiye has endorsed the 2030 Agenda for Sustainable Development and has integrated the Sustainable Development Goals (SDGs) into its national development plans and strategies. The Turkish government has taken steps to align its policies and programs with the SDGs, addressing issues such as poverty reduction, gender equality, and environmental sustainability.

European Green Deal (2019):

The European Green Deal is a comprehensive policy framework introduced by the European Commission to guide the European Union's transition to a sustainable, low-carbon economy. It encompasses a wide range of initiatives across various sectors, including energy, transportation, agriculture, and industry, to achieve climate neutrality by 2050. The European Green Deal aims to transform the EU economy into a circular and resource-efficient one, while also addressing social inequalities and promoting economic growth. Türkiye, as a candidate country for EU membership, closely monitors and engages with the European Green Deal. While not formally part of the European Union, Türkiye has expressed interest in aligning its environmental policies with EU standards and has cooperated with the EU on various environmental initiatives.

REPowerEU Plan (2022):

The REPowerEU plan, introduced by the European Commission, aims to rapidly reduce Europe's reliance on Russian fossil fuels while advancing the green transition. This plan is a response to the disruptions caused by Russia's invasion of Ukraine, which highlighted the need to address both energy security and the climate crisis. By prioritizing renewable energy and diversifying energy sources, Europe can rapidly phase out its dependency on Russian fossil fuels. The plan aligns with public sentiment, as 85% of Europeans support reducing dependency on Russian gas and oil to support Ukraine.

To achieve these goals, the REPowerEU plan emphasizes four main actions:

- ✓ Diversifying our energy supply: Finding alternative ways to ensure energy supply and securing affordable energy supplies.
- ✓ Increasing our gas storage: This action aims to ensure that Europeans have access to affordable energy by enhancing gas storage capacity.
- ✓ Saving energy: Reaching an agreement for reducing gas demand across the EU to promote energy efficiency and conservation.
- ✓ Investing in renewables: Promoting massive investment in renewable energy to accelerate the transition to clean and sustainable energy sources

National Level:

Türkiye has been actively pursuing policies aimed at green transformation, aligning with its geographical vulnerability to climate change and recognizing the importance of addressing environmental challenges. The country's efforts in combating climate change and promoting sustainability are rooted in its national realities, focusing on green growth and curbing emissions trends in line with its status as a developing nation.

The commitment to tackling climate change is evident in various strategic documents, including the Development Plan of 2019 and the Presidential Annual Program of 2021, which outline measures and initiatives aimed at addressing climate-related issues.

The New Economic Program (2021-2023) emphasizes sustainable growth and the production and exportation of value-added products. Under the "Current Account Balance" section, there is a specific focus on adapting Türkiye's exports to the European Green Deal within the scope of the Türkiye-EU Customs Union.

The Economy Reform Package announced in March 2021 aims to support green transformation in various sectors. Initiatives include the establishment of green Industrial Zones, preparing a national circular economy action plan, supporting R&D activities to develop green technologies, and strengthening green financing mechanisms.

The International Direct Investment Strategy (2021-2023) underscores the importance of aligning Türkiye's business environment and regulatory framework with Sustainable Development Goals and the European Green Deal to maintain and enhance competitiveness in international trade and investment.

The Ministry of Industry and Technology's implementation of the 2023 Industry and Technology Strategy emphasizes adopting a green production approach, modernization of infrastructure and operations in Industrial Zones, and promoting clean production investments.

The transportation sector is also targeted for green transformation, as evidenced by the Smart Transportation Systems Strategy and Action Plan (2020-2023), which aims to reduce emissions by integrating efficient, environmentally friendly, and smart transportation systems across all modes of transportation.

The National Energy Plan (2023) is a comprehensive roadmap for the energy sector, considering key factors such as policy preferences, net-zero emission constraints, and projections for 2035-2053, focusing on sustainable energy development.

In summary, Türkiye's green transformation policies encompass various initiatives across various sectors, reflecting a holistic approach to addressing environmental challenges and promoting sustainable development in alignment with national and international priorities.

International Centre for Hydrogen Energy Technologies (UNIDO-ICHET):

UNIDO-ICHET, or the International Centre for Hydrogen Energy Technologies, was a significant initiative focused on advancing hydrogen energy research and development. Established in October 2003 in İstanbul. It marked a collaborative effort between the United Nations Industrial Development Organization (UNIDO) and the Turkish Ministry of Energy and Natural Resources. The project was solidified through a Trust Fund Agreement signed in Vienna, Austria.

UNIDO-ICHET became operational in 2004 and played a crucial role in promoting hydrogen energy technologies for a period of eight years. The Government of Türkiye played a crucial role in supporting this initiative by committing a substantial sum of USD 40 million to fund the initial five years of operation. On the other hand, UNIDO shouldered the responsibility of managing the entire project, ensuring its smooth functioning and achieving its goals.

UNIDO-ICHET's operations concluded in December 2012.

Green Hydrogen Strategy of Türkiye:

The Turkish government has formulated a comprehensive plan, the Turkish Hydrogen Technologies Strategy and Roadmap (THSR), to position itself as a leader in developing and deploying hydrogen technologies. This strategic initiative recognizes the growing global trend towards hydrogen as a clean energy source and outlines a four-part approach to achieve its goals.

Firstly, the THSR seeks to enhance the role of hydrogen in Türkiye's national energy mix. This includes progressively integrating hydrogen into various sectors like transportation, industrial processes, and power generation. This diversification is expected to contribute to a more sustainable and secure energy landscape for the nation.

Secondly, the strategy emphasizes fostering a competitive domestic hydrogen industry. This focus on indigenous development aims to stimulate economic activity and job creation within this new technology sector. A robust domestic industry would ensure Türkiye's long-term competitiveness in the global hydrogen market.

Thirdly, the THSR recognizes the potential of hydrogen technologies to be a catalyst for economic growth. By fostering innovation and attracting investments, the strategy aims to generate new employment opportunities and contribute to overall economic prosperity in Türkiye.

Finally, the THSR aims to mitigate climate change by reducing greenhouse gas emissions. The large-scale adoption of hydrogen, a clean-burning fuel, is expected to contribute significantly to Türkiye's environmental sustainability goals.

In conclusion, the Turkish Hydrogen Technologies Strategy and Roadmap represents a significant commitment by the Turkish government to embrace hydrogen as a transformative energy source. The successful implementation of this comprehensive plan holds the potential to propel Türkiye towards a cleaner, more sustainable, and economically prosperous future.

Regional Level:

In June 2021, the Izmir Development Agency prepared the Izmir Hydrogen Strategy as part of the BEST for Energy Project. This document explores the potential of hydrogen as a clean energy source for the region. It analyzes hydrogen's properties, potential energy, mobility, and industry applications, along with clean production technologies and infrastructure needs. The strategy emphasizes domestic technology development and assesses the viability of hydrogen in the Turkish context, with a specific focus on Izmir. It provides policy recommendations at a national level and investment suggestions for regional development in Izmir.

3.1.2 Economical Factors

The global ceramic industry focusing on the sanitary equipment market is projected to reach USD 70.3 billion by 2027, growing at a CAGR of 4.8%¹. Leading players like Kohler (US), Toto (Japan), Roca (Spain), Ideal Standard (UK), and Villeroy & Boch (Germany) dominate the landscape.

Dominating the Market: China

China reigns supreme in terms of production volume, capturing over half of the global market share due to its massive production capacity and economies of scale². Government support further bolsters their export capabilities. However, concerns regarding quality perception in some segments and high overall energy usage within the industry remain challenges.

Emerging Competitors:

Türkiye positions itself strategically, offering a compelling balance between cost and quality compared to Europe. This, coupled with a skilled workforce and established infrastructure, makes them strong exporters³. Fluctuations in exchange rates and limited brand recognition in some international markets pose hurdles to their continued growth.

India boasts a robust domestic market fueled by rising disposable incomes and urbanization. The market is expected to reach USD 5.2 billion by 2025⁴. While a skilled workforce fuels production, dependence on imports for high-end technology and infrastructural limitations hinder further advancement.

Other Notable Players:

North America, with a market size of USD 12.5 billion in 2022⁵, houses established brands renowned for their strong brand recognition and focus on innovative, high-quality products. Southeast Asia, particularly Vietnam and Thailand, is emerging as

¹ Grand View Research. (2023, January 11). Ceramic Sanitary Ware Market Size, Report 2022-2027.

² Mordor Intelligence. (2023, January). Ceramic Sanitary Ware Market - Size, Share & Industry Trends Analysis.

³ Statista. (2023, January 18). Market size of bathroom and sanitary ceramics in Türkiye in 2022.

⁴ Allied Market Research. (2022, December 21).

⁵ Grand View Research. (2023, September 12). Bathroom Fixtures Market Size, Report 2022-2027.

a significant player due to low labour costs and increasing production capacity, offering a cost advantage and harboring significant growth potential.

Market Segmentation and Distribution Channels:

The market is segmented based on product type (toilets, bidets, washbasins, urinals - with the global toilet market expected to reach USD 25.4 billion by 2027⁶, material (ceramic, acrylic, stone), and distribution channels (retail stores, online platforms, home improvement projects).

Online platforms are gaining traction globally, with China showcasing a solid online presence. Established retail networks remain important, particularly in Europe and North America. Home improvement projects are relevant in specific regions and for premium products.

Regulations and Sustainability:

Government regulations vary across regions, impacting production standards, environmental considerations, and product safety. Stringent regulations in Europe, while driving higher production costs, ensure high quality and environmental consciousness. Other regions like China and India are gradually adopting stricter regulations.

Europe leads the green transition by implementing stringent regulations and focusing on renewable energy sources in production. While other regions are moving towards greener practices by adopting energy-efficient equipment and cleaner technologies, significant advancements are still necessary, especially for high-volume producers like China.

A Dynamic Landscape:

The global ceramic industry market presents a diverse landscape with distinct regional players. Concerns about quality and sustainability challenge China's dominance in production volume. The rise of emerging players like Türkiye and India, coupled with Europe's focus on innovation and sustainability, paints a dynamic picture. The ability to adapt to changing consumer preferences, embrace sustainable practices, and invest in innovation will be key differentiators for success in this evolving market.

Table 1 Comparison of Ceramic Industry Market: Global Landscape

Comparison of Ceramic Sanitary Equipment Market: Global Landscape						
Parameter	China	Türkiye	Europe	India	North America	Southeast Asia (Vietnam, Thailand)
Positioning Decision	Low-cost, high-volume production	Cost-competitive, export-oriented	Premium, high-quality, innovative	Domestic market focus, growing export potential	Established brands, innovation focus	Emerging players, cost advantage
Market Segments	Budget-friendly, mass market	Mid-range, budget-friendly, growing premium	High-end, design-oriented, niche markets	Budget-friendly, mid-range, emerging premium	Mid-range, high-end	Budget-friendly, mid-range

⁶ Grand View Research. (2023, January 10). Toilets Market Size, Report 2022-2027.

Strengths	Largest manufacturing base, economies of scale, government support	Cost advantage, skilled workforce, established infrastructure	Brand recognition, technological advancements, sustainability focus, stringent quality standards	Large domestic market, growing disposable incomes, skilled workforce	Established brands, innovation focus	Lower production costs, growth potential
Weaknesses	Lower quality perception, limited innovation, environmental concerns	Fluctuating exchange rates, rising costs, limited brand recognition	Higher production costs, limited brand recognition in some regions	Reliance on imports for high-end technology, infrastructure limitations	Limited production volume compared to other regions	Emerging market, brand recognition challenges
Distribution Channels	Strong online presence, focus on direct-to-consumer sales	Established distribution networks, focus on both retail and online channels	Focus on established retail partnerships, growing online presence	Growing online presence, established retail networks	Established retail networks, growing online presence	Growing online presence, established retail networks in major economies
Government Regulations	Less stringent regulations	Focus on improving production standards and environmental regulations	Stringent environmental regulations and product safety standards	Evolving regulations, increasing focus on sustainability	Established regulations	Evolving regulations, increasing focus on quality and safety
Growth Potential	Targeting premium segment and innovation, expanding into international markets	Strengthening brand recognition and premium offerings, focusing on niche markets and innovative technologies	Expanding online presence and exploring emerging markets	Expanding production capacity, focusing on premium segment and exports, improving technological advancements	Maintaining brand recognition, exploring niche markets, focusing on sustainability	Expanding production capacity, targeting export markets, improving quality standards

Source: Consultants' opinions based on references

Economic Factors Affecting Ceramic Industry in Türkiye:

We can observe 2 significant economic impacts of the current economic policy of Türkiye on the ceramic industry.

1) Economic Environment:

Türkiye's economic environment, while presenting challenges, also offers opportunities for the ceramic industry to grow and thrive through innovation, strategic marketing, and operational efficiency.

Türkiye's Dynamic Market: Türkiye's evolving economic landscape presents unique opportunities for the ceramic industry. The government's focus on stimulating growth can lead to increased infrastructure investment, creating demand for construction materials like ceramic tiles. Additionally, a weaker Turkish Lira can make Turkish exports more competitive in the global market, boosting sales for ceramic producers.

Innovation and Efficiency: The need to navigate rising costs can incentivize the ceramic industry to embrace innovation and efficiency-enhancing measures. This can involve investment in new technologies that optimize production processes and reduce reliance on expensive materials or energy sources. Additionally, streamlining operations and focusing on cost-effectiveness can improve profit margins.

Evolving Consumer Preferences: Shifting consumer preferences towards domestic products due to inflation can present an opportunity for the Turkish ceramic industry. By emphasizing high-quality, locally-produced ceramics at competitive prices, Turkish companies can capture a larger share of the domestic market.

Targeting Export Markets: Focusing on exports allows Turkish ceramic producers to benefit from a weaker Turkish Lira. By strategically targeting overseas markets with strong demand for affordable, high-quality ceramics, companies can expand their customer base and mitigate reliance on the domestic market.

2) EU Carbon Border Adjustment Mechanism (CBAM):

The CBAM is a proposed policy designed to address carbon leakage concerns within the EU. Carbon leakage is when stricter environmental regulations in the EU incentivize businesses to relocate production to regions with less stringent regulations. This can lead to a net increase in global carbon emissions, undermining the EU's environmental goals.

CBAM functions by imposing a carbon price on certain imported goods. This aims to level the playing field for EU producers who are subject to stricter carbon pricing policies within the EU Emissions Trading System (EU ETS). The ultimate goal is to ensure that imported goods compete on the basis of factors other than environmental regulations.

A carbon border adjustment mechanism will be introduced for aluminium, cement, electricity, fertiliser, iron, and steel products by 2026. In the transformation period (from 2023 to the end of 2025), product importers in the included industries will be obliged to report emissions without paying any tax. It will be put into practice by 2026. The ceramic sector is not included. It's foreseen for CBAM to be reviewed in 2025. According to recent developments, the Commission may expand CBAM'S scope to more sectors and/or indirect emissions by 2026. This means that at least some of the ceramic industry sectors may be included in the CBAM system by 2026.

Turkish Ceramics Federation has studied the effects of EU Carbon Border Adjustment Mechanism on Ceramic Product Sectors. Calculated emission allocation cost rates are about 07 % of the sale price for CBA 50 Euro and Scope 1 emissions in Ceramic Tile Products and 4 % of the sale price for CBA 50 Euro and Scope 1 emissions in Ceramic Industry. In the case of being included in the scope, costs arising from electricity consumption and additional costs are not included in this calculation. This becomes more of an issue for foreign trade. It can be seen that this situation is the most significant risk in this market, which makes up half of Türkiye's export every year.

The Turkish ceramic industry exerts a multifaceted influence on the country's social landscape. On the positive side, it serves as a significant source of employment, bolstering local economies in regions where ceramic production thrives. This can be particularly impactful in areas with limited job opportunities, providing a crucial source of income and stability for communities. Furthermore, the industry plays a vital role in preserving Türkiye's rich heritage of ceramic craftsmanship. By sustaining these traditional skills and passing them down through generations, the industry ensures the continuation of a unique cultural expression.

However, the social impact of the ceramic industry is not without its drawbacks. Concerns about worker safety and exposure to harmful dust within some ceramic factories have been raised. Additionally, air and water pollution generated by production

facilities can pose health risks for residents in surrounding communities. These negative externalities necessitate a focus on improving production practices to ensure the well-being of both workers and the surrounding populace.

The industry acknowledges these environmental concerns and actively seeks solutions for a more sustainable future. Advancements in waste management and the implementation of energy-efficient technologies are crucial steps in mitigating the environmental impact of ceramic production.

Additionally, the European Union's Carbon Border Adjustment Mechanism (CBAM) is poised to impact the Turkish ceramic industry in Türkiye significantly. While the primary focus is on environmental and economic consequences, the social effects of CBAM also warrant careful consideration. The potential social implications of CBAM for the Turkish ceramic industry can be highlighted in both positive and negative aspects.

Positive Social Effects

Green Job Creation: The transition to cleaner production technologies mandated by CBAM could create new job opportunities in the "green sector." This sector encompasses a wide range of fields, such as renewable energy, pollution control technologies, and the development of energy-efficient machinery (International Labour Organization, 2021). As the industry invests in cleaner technologies to comply with CBAM, there will be a demand for skilled professionals in these areas. This shift presents an opportunity to create new employment opportunities in the region, potentially offsetting some job losses in traditional sectors.

Improved Working Conditions: A move towards cleaner production processes often leads to improved air quality and overall working conditions within factories. Dust, fumes, and other pollutants associated with traditional ceramic production methods can be significantly reduced through the adoption of cleaner technologies (European Commission, 2021). This can positively impact the health and well-being of workers in the industry, creating a safer and healthier work environment.

Negative Social Effects:

Job Losses in the Short Term: The transition to cleaner technologies often involves some automation or process redesign. This can lead to job losses in certain segments of the workforce, particularly those involved in traditional, labour-intensive production methods (Meidani et al., 2022). Workers with specific skillsets honed for older processes might find themselves needing to adapt or retrain.

Impact on Livelihoods: Job losses in the ceramic industry can have a ripple effect on local communities in Türkiye. Families who depend on the industry for income could face financial hardship if their primary source of income is disrupted. This can lead to social instability and strain on social safety nets (Gopalakrishnan et al., 2023).

The social effects of CBAM on the Turkish ceramic industry can be multifaceted. While there are potential challenges, such as job losses, there are also opportunities for creating new green jobs and improving working conditions. By implementing effective social safety nets, retraining programs, and a well-defined just transition strategy, the Turkish government and industry stakeholders can navigate the potential challenges and ensure a sustainable future for the industry, its workforce, and the surrounding communities. A proactive approach that considers the social dimension alongside the environmental and economic aspects of CBAM will be crucial for a successful transition towards a greener ceramic industry.

3.1.3 Technological Factors

In the realm of sustainable energy and industrial innovation, the emergence of green hydrogen holds immense promise, particularly within the ceramic industry, where its applications are poised to revolutionize traditional production processes. This section delves into the technological facets, exploring the opportunities, challenges, and transformative potential embedded within the intersection of green hydrogen production and its integration into ceramic manufacturing processes.

Technology analysis on green hydrogen utilization in the ceramic industry includes:

- classification and listing of green hydrogen energy technologies and equipment,
- the state-of-the-art and development points for each technology,
- challenges for each technology,
- comparisons between alternative technologies.

Green Hydrogen Production Technologies: Electrolysers:

In the ceramic industry, where environmental sustainability and energy efficiency are paramount concerns, the adoption of green hydrogen production methods holds significant promise for transforming manufacturing processes. Green hydrogen, produced through electrolysis powered by renewable energy sources, presents a clean and sustainable alternative to conventional fossil fuel-based energy sources in ceramic production. As the industry seeks to reduce carbon emissions and enhance operational sustainability, the selection of the most suitable electrolyzer technology becomes crucial. Proton Exchange Membrane (PEM), Alkaline, Anion Exchange Membrane (AEM), and Solid Oxide Electrolysis (SOE) technologies, are compared to provide insights into the optimal choice of electrolyzer technology for green hydrogen production within the ceramic manufacturing sector. By examining factors such as efficiency, reliability, cost-effectiveness, and compatibility with existing infrastructure, this analysis aims to empower ceramic industry stakeholders with the knowledge needed to advance towards a sustainable, hydrogen-based future. A comparison of PEM, Alkaline, AEM and SOE Electrolysis technology is given in **Fehler! Verweisquelle konnte nicht gefunden werden.2**.

Table 2 Comparison of Electrolysis Technology

Specification	PEM	Alkaline	AEM	SOE
Maturity	Commercial	Commercial	Commercial	Early Commercial
Working fluid	Distilled water	High concentration Solution	Distilled water or Low concentration solution	Steam
Electrolyte	Solid polymer	Aqueous solution 10-40% KOH/NaOH	Solid polymer	Solid ceramic
Charger carrier	H ⁺	OH ⁻	OH ⁻	O ²⁻
Anode material	Pt; Ir; Ru	Ni	Ni-based alloy	LSMYSZ; CaTiO ₃
Cathode material	Pt; Pt=C	Ni alloys	Ni, Ni-Fe, NiFe ₂ O ₄	Nicermet
Cell voltage	1.80 2.40 V	1.80 2.40 V	~ 1.85 V	0.95 1.30 V
Current density	0.6-2 A/cm ²	0.2 0.4 A/cm ²	0.1-0.5 A/cm ²	0.3 1 A/cm ²
Temperature, °C	70-90	65-100	50-70	650-1000
Operation pressure, bar	15-30	2-10	Up to 35	<30
Efficiency, HHV	67-84%	62-82%	-	~90%
Startup duration	< 15 minutes	15 minutes	-	> 60 minutes
Stack lifetime	<40,000 hr	<90,000 hr	>10,000hr	<40,000 hr
Energy consumption, kWh/Nm ³	4.5-7.5	4.5-7	~ 4.8	2.5-3.5
Estimated cost by 2050.	\$750/kWch	\$600/kWch	-	\$200/kWch
Advantages	Compact and simple design. Fast response and startup. High hydrogen purity.	Low capital cost. Stable and well-established. No use of noble material.	A mixture of the advantages of PEM and AWE. Suitable for load fluctuation. Cheap components.	It can be used as a fuel cell. High efficiency. Due to the absence of noble material, the capital cost is

Specification	PEM	Alkaline	AEM	SOE
				low.

Source: A review of water electrolysis-based systems for hydrogen production using hybrid/solar/wind energy systems Mohamed Nasser^{1,2} · Tamer F. Megahed^{3,4} · Shinichi Ookawara⁵ · Hamdy Hassan^{1,6}

The comparison of electrolyser technologies for green hydrogen production reveals distinct advantages and considerations among alkaline, PEM (Proton Exchange Membrane), AEM (Anion Exchange Membrane), and solid oxide electrolyzers. While alkaline electrolyzers historically boast the lowest installed costs, PEM electrolyzers offer a smaller footprint and higher current density. Although relatively new, AEM electrolyzers show promise in competitive installed costs and potentially similar footprint reductions. Solid oxide electrolyzers lead to electrical efficiency. Despite the commercial availability of alkaline and PEM electrolyzers, AEM technology is emerging, requiring further development for widespread adoption. In navigating the choice for green hydrogen production, understanding the nuanced differences between these technologies is essential for informed decision-making in advancing sustainable energy solutions.

Installed Cost: Alkaline electrolyzers have traditionally had the lowest installed cost. PEM electrolyzers may have a higher installed cost compared to alkaline, but this may vary depending on the specific implementation. AEM electrolyzers are relatively new but may offer competitive installed costs compared to PEM and alkaline electrolysis.

Footprint: PEM electrolyzers have a smaller footprint compared to alkaline electrolyzers, and AEM electrolyzers might also have a similar advantage. A reduced stack footprint of around 60% for PEM compared to alkaline translates into a 20%-24% reduction in the facility footprint. AEM may offer a similar reduction in footprint compared to alkaline.

Current Density and Output Pressure: PEM electrolyzers typically have higher current density and output pressure compared to alkaline electrolyzers. AEM electrolyzers might offer similar advantages due to their membrane characteristics.

Commercial Availability: Alkaline and PEM electrolyzers are already commercialized and widely used. AEM electrolyzers are a newer technology and may still be in the development or early commercialization stages, although they are gaining attention for their potential advantages.

In summary, AEM electrolyzers are a newer technology with potential competitive advantages in terms of cost, footprint, and possibly efficiency compared to alkaline and PEM electrolyzers. However, further development and commercialization may be needed to realize these advantages fully and compete with established technologies.

In accordance with the "Green Hydrogen Cost Reduction: Scaling Up Electrolyzers" report by IRENA, in 2020, Alkaline electrolysis operates at pressures below 30 bar, while PEM and AEM systems function under pressures below 70 bar and 35 bar, respectively. Solid Oxide Electrolysis Cells (SOEC) maintain pressures under 10 bar. However, by 2050, all technologies are projected to experience significant pressure increases, surpassing 70 bar for Alkaline, PEM, and AEM, and exceeding 20 bar for SOEC. Lifetime projections for 2020 indicate 60,000 hours for Alkaline, 50,000-80,000 thousand hours for PEM, over 5,000 hours for AEM, and less than 20,000 hours for SOEC. By 2050, lifetimes are expected to stabilize, with Alkaline and AEM lasting 100,000 hours, PEM ranging from 100,000 – 120,000 hours, and SOEC at 80,000 hours. Capital costs for large stacks in 2020 are 270 USD/kWel for Alkaline and 400 USD/kWel for PEM, while AEM and SOEC lack specified data. 2050 significant cost reductions are anticipated, with Alkaline, PEM, and AEM systems projected to cost less than 100 USD/kWel, and SOEC slightly higher at below 200 USD/kWel. Capital cost ranges for entire systems (>10 MW) in 2020 are between 500-1,000 USD/kWel for Alkaline and 700-1,400 USD/kWel for PEM, with AEM and SOEC not specified. By 2050, all technologies are expected to witness considerable reductions, with costs below 200 USD/kWel, except for SOEC, which may range slightly higher at below 300 USD/kWel.

Hydrogen Storage Technologies:

H₂ has a high gravimetric energy density of 120 MJ/kg, approximately 3 times that of gasoline and approximately 2.5 times that of natural gas. On the other hand, the volumetric energy density of H₂ is quite low compared to other energy vectors. Hydrogen is the lightest element in the universe and occupies high volumes at atmospheric pressure, so its density must be

increased in order for H₂ to be stored and transported efficiently. Hydrogen can be stored in gaseous form by compressing to high pressures, in liquid phase at cryogenic temperatures, or in solid form by physical or chemical adsorption in metal hydride materials. The usage area and economic suitability is considered when deciding on the storage method. The H₂ density at atmospheric pressure is 0.090 kg/m³, while the H₂ density is 42 kg/m³ at 700bar, and is 71 kg/m³ at 1013bar and in liquid form (@ -253 °C).⁷

The most widely used H₂ storage method is physical storage in gaseous form at high pressures such as 350-700bar. The H₂ storage capacity depends on the volume and working pressure of the tank. This storage method offers high H₂ filling-releasing rates and does not require energy for release. On the other hand, compressing H₂ to high pressures consumes up to 18% of the lower heating value of H₂. Pressurized storage tanks must withstand high operating pressures; the tank material must be light, low-cost, and resistant to H₂ embrittlement. There are four types of storage tanks used for H₂ storage. Type-1 storage tanks are made of metallic materials, generally steel or aluminium alloy, and are the most economical option. H₂ is generally stored at 180-200bar. These tanks have very low gravimetric energy density and store only about 1% H₂ by weight. In Type-2 tanks, the cylindrical part of the metallic liner is wrapped with fibre resin composite. It has a higher cost but is lighter by 30-40% compared to Type-1. In Type-3 tanks, the metallic liner is completely wrapped with fibre resin composite. Type-4 tanks are made of polymer liner, generally high-density polyethylene (HDPE), completely wrapped with fibre resin composite. Type-3 and Type-4 tanks have higher gravimetric capacity and are used to store H₂ at higher pressures, such as 700bar.⁸ In addition, studies continue on Type-5 tanks made entirely of composite materials.

Hydrogen can be liquefied by cooling to cryogenic temperatures (-253 °C). Although the volumetric energy density of liquid hydrogen is high compared to the gas phase, hydrogen liquefaction is a very energy-intensive process with high thermal losses. Additionally, well-insulated cryogenic vessels, which are quite expensive, are needed to prevent boil-off losses. The energy consumption of the liquefaction process is approximately 30-40% of the net heating value of hydrogen.⁹

Material-based storage is an alternative to physical H₂ storage in gas and liquid form. Storing hydrogen in solid metal compounds through physical or chemical adsorption is considered a solution to increase volumetric energy density. Metal hydrides, metal-organic and covalent-organic frameworks (MOF and COF) are used for this purpose. This method is generally used only in stationary applications due to its high weight and unsuitability for H₂ transportation and mobile applications.

A comparison of compressed gas, liquid, cryo-compressed, metal hydride, complex hydride, physical adsorbent and liquid organic carrier hydrogen storage methods is given in Table 3.

Table 3 Comparison of various hydrogen storage methods

Storage method	Hydrogen content (wt% H ₂)	Volumetric density (g/L)	Volumetric energy density (MJ/L)
Compression			
1 bar, RT	100	0.0814a	0.01
350 bar, RT	100	24.5b	2.94
700 bar, RT	100	41.4b	4.97
700 bar, RT, (incl. Type IV tank)	5.7	40.8	4.9
Liquid hydrogen			
1 bar, -253 °C	100	70.8	8.5
1 bar, -253 °C (incl. tank)	14	51	6.12

⁷ Sabancı University Istanbul International Center for Energy and Climate (IICEC), Türkiye Yeşil Hidrojen Geleceği 2023

⁸ Muhammad R. Usman, Hydrogen storage methods: Review and current status, <https://doi.org/10.1016/j.rser.2022.112743>

⁹ : IEA. Hydrogen production and storage: R&D priorities and gaps. Paris: IEA; 2006. <https://www.iea.org/reports/hydrogen-production-and-storage>

Storage method	Hydrogen content (wt% H ₂)	Volumetric density (g/L)	Volumetric energy density (MJ/L)
Cryo-compression			
350 bar, -253 °C	100	80	9.6
Metal hydrides			
MgH ₂	7.6	110	13.2
FeTiH ₂	1.89	114	13.7
Complex hydrides			
NaAlH ₄	7.5	80	9.6
Physical adsorbents			
Activated carbon @77 K and 30–60 bar	5.0	38.5	2.4
Zeolite (NaX) @77 K and 40 bar ^c	2.55	20	2.4
MoF (MOF-210) @77 K and 80 bar	7.9	25.8	3.1
Liquid hydrogen organic carriers			
Methylcyclohexane/toluene	6.2	47.3	5.68
perhydro-benzyltoluene/ benzyltoluene	6.2	56.0	6.72
^a Calculated from ideal gas law. ^b Calculated from the standard form of the Peng-Robinson equation. ^c Assuming the same density as activated carbon.			

Source: IEA

The table below compares the different physical and chemical hydrogen storage methods, but the compressed gas storage method comes to the forefront when considering applications in the ceramics sector. The comparative characteristics of type-I, II, III, IV and type-V tanks that can temporarily store hydrogen in an equalization tank before processing or physically bringing hydrogen to the plant from another location are given in the table below.

Table 4 Classification of pressure vessels

	Pressure Vessels				
	Type 1	Type 2	Type 3	Type 4	Type 5
Components	All metal construction	Steel Vessel with Glass fibre composite	Full composite overwrap with Metal (Aluminum) liner	Full Carbon-fibre or Carbon-glass composite with HDPE liner and metallic boss	Full composite without liner
Structural Load	Metal body withstands the whole load	Steel and composite materials share the load equally	The composite structure bears the most load, and the metal liner takes only about 5% mechanical load	Composite material carries the load	Composite material carries the load
Storage Pressure	Up to 50 MPa	Highest pressure tolerance	Typically, around 45 MPa and showed problems for 70 MPa	Up to 100 MPa	Under development
Gravimetric Density	~1wt%	<2.1 wt%	<4.2 wt%	4.4%-5.7%	Under development
Weight	Relatively weight is high	30 40% less than Type 1	Around half the weight of Type II	Lighter than Type III	It has the potential to be the lightest
Cost (Differs with application)	83 USD/kg	86 USD/kg	700 USD/kg	633 USD/kg	Under development

Source: Journal of Natural Gas Science and Engineering

Hydrogen Infrastructure: Pipelines

When discussing the transportation of hydrogen gas, it is essential to consider the infrastructure that facilitates its distribution from production sites to end-users. Among the critical components of this infrastructure are hydrogen pipelines, which serve as conduits for transporting hydrogen gas over long distances. Two primary types of hydrogen pipelines are often distinguished: dedicated and rededicated pipelines.

Dedicated pipelines for hydrogen are purpose-built systems designed specifically for the transportation of hydrogen gas. These pipelines are constructed with materials and specifications tailored to the unique properties of hydrogen, including its potential for embrittlement and its low density. Operators can optimize their design and maintenance practices by dedicating pipelines exclusively to hydrogen transport to ensure the safe and efficient delivery of hydrogen to its intended destinations¹⁰.

In contrast, **rededicated pipelines** represent a repurposing of existing pipeline infrastructure to accommodate hydrogen transportation. This process involves thoroughly cleaning, testing, and potentially retrofitting the pipeline to meet hydrogen transportation's safety and compatibility requirements. Rededicated pipelines offer a cost-effective means of expanding hydrogen distribution networks by leveraging existing infrastructure, albeit with careful consideration of compatibility and integrity issue.¹¹

Dedicated and rededicated pipelines play pivotal roles in enabling hydrogen's widespread adoption as a clean energy carrier. By providing reliable pathways for hydrogen transportation, these pipelines support various applications, including industrial processes, transportation fuels, and power generation. However, ensuring the integrity and safety of hydrogen pipelines remains paramount, requiring adherence to stringent design standards, regular maintenance practices, and robust monitoring and inspection protocols.

Hydrogen infrastructure development, particularly the establishment of robust piping and fitting systems, plays a pivotal role in facilitating the integration of hydrogen blending into natural gas for the ceramic sector¹². As the industry transitions towards greener practices, blending hydrogen into natural gas presents a compelling avenue to reduce carbon emissions while enhancing energy efficiency. However, this transition necessitates the adaptation of existing infrastructure to accommodate the unique properties of hydrogen, which includes addressing potential challenges such as hydrogen embrittlement and permeation. Therefore, the design and deployment of hydrogen-compatible piping and fitting systems emerge as critical components in ensuring hydrogen-blended natural gas's safe and efficient distribution within ceramic manufacturing facilities.

In recent years, materials science and engineering advancements have led to the development of innovative piping and fitting solutions tailored specifically for hydrogen applications¹³. High-strength materials such as advanced polymers, composite materials, and corrosion-resistant alloys are being employed to mitigate the risks associated with hydrogen-induced degradation and ensure the integrity of the infrastructure over its operational lifespan. Furthermore, the integration of smart monitoring and control technologies enables real-time assessment of pipeline integrity and performance, enhancing safety and reliability in hydrogen distribution networks.

Moreover, regulatory frameworks and industry standards play a significant role in shaping the deployment of hydrogen infrastructure. Compliance with stringent safety regulations and adherence to established standards such as ISO 19880 and

¹⁰ International Journal of Hydrogen Energy, vol. 45, no. 3, pp. 289-302, 2021

¹¹ Renewable and Sustainable Energy Reviews, vol. 82, pp. 1889-1901, 2018

¹² Muhammad R. Usman, Hydrogen storage methods: Review and current status, <https://doi.org/10.1016/j.rser.2022.112743>

¹³ <https://doi.org/10.1016/j.jngse.2022.104843>

ASME B31.12 are paramount to ensure the safe operation of hydrogen piping and fitting systems.¹⁴ Collaboration between industry stakeholders, research institutions, and regulatory bodies also fosters knowledge sharing and promotes best practices in hydrogen infrastructure development.

Hydrogen pipelines are not a novel technology for transporting H₂ molecules over long distances. In fact, one of the earliest systems was established in 1938 and has since been expanded and remains operational in the Rhine-Ruhr area of Germany, connecting 25 chemical and petrochemical plants over a combined distance of 875 km. Typically, the decision to utilize pipelines over alternative methods, such as road transport in tanks, is driven by economic factors, owing to their capacity to supply substantial volumes of hydrogen to intended consumption points reliably. However, while economic considerations also apply to natural gas pipelines, it's important to note that their transmission infrastructure is significantly more extensive than that of hydrogen, with the total length of natural gas pipelines estimated to be approximately 555 times longer.¹⁵

A key factor contributing to the limited development and use of hydrogen pipelines is their current role in delivering hydrogen from production sites to specific sectors, such as oil refining or the petrochemical industry. These sectors primarily utilize hydrogen as a feedstock to manufacture complex products rather than as a standalone commodity. Consequently, while the average existing hydrogen pipeline transports around 13.5 GW of energy over distances of up to 100 km, the largest and longest H₂ projects can deliver 20-30 GW across 500 kilometres. Additionally, the vast majority of hydrogen delivered through these pipelines, similar to global production, is 'grey' as it is synthesized from fossil fuels. This highlights the necessity to transition to green hydrogen towards a net-zero carbon paradigm.¹⁶

In Türkiye, efforts led by GAZBİR-GAZMER are underway to explore the use of hydrogen blended with natural gas. In the "Doğalgaz Sektörü Hidrojene Geçişte Yol Haritası Önerileri -Roadmap Suggestions for Transitioning the Natural Gas Sector to Hydrogen," published by GAZBİR-GAZMER and cleangas Türkiye in 2021, recommendations regarding technical compatibility studies were provided. It was highlighted that the transportation and domestic use of hydrogen through pipelines pose significant technical and safety challenges. Hydrogen is prone to leakage, can cause embrittlement of metal pipes, and may require different chemical additives and odorants compared to those used for natural gas. Therefore, comprehensive testing and compatibility studies are necessary to integrate hydrogen into distribution networks.

According to the report, hydrogen can be blended with natural gas up to a maximum of 20% without requiring significant modifications to the natural gas infrastructure. However, issues such as the potential brittleness of steel pipes due to hydrogen and the compatibility of household equipment require detailed testing and adaptation efforts. Additionally, measurement, monitoring, and efficiency studies should be conducted for hydrogen storage in natural gas storage facilities.

Tests are being conducted at the Clean Energy Center in Konya to ensure the compatibility of industrial appliances with hydrogen. However, long-term results of these tests are awaited. Furthermore, risks and safety measures associated with the use of hydrogen in steel pipelines must be considered. In the process of integrating hydrogen into distribution networks, natural gas equipment manufacturers in Türkiye need to develop equipment compatible with hydrogen concentrations and make technical adjustments to existing equipment. In this context, detailed studies and collaborations are essential for the transportation and domestic use of hydrogen through pipelines.^{17 18}

¹⁴ American Society of Mechanical Engineers (ASME), ASME B31.12-2019, "Hydrogen Piping and Pipelines," ASME, New York, NY, 2019

¹⁵ Hydrogen pipelines vs. HVDC lines: Should we transfer green molecules or electrons?, The Oxford Institute for Energy Studies, November 2023

¹⁶ Hydrogen pipelines vs. HVDC lines: Should we transfer green molecules or electrons?, The Oxford Institute for Energy Studies, November 2023

¹⁷ Doğalgaz Sektörü Hidrojene Geçişte Yol Haritası Önerileri -Roadmap Suggestions for Transitioning the Natural Gas Sector to Hydrogen, GAZBİR-GAZMER & cleangas Türkiye, 2021

¹⁸ Türkiye'de Yeşil Hidrojenin Üretilip Doğal Gaza Karıştırılması Çalışmaları; GAZBİR-GAZMER, Hidrojen Teknolojileri Derneği, Yıldız Teknik Üniversitesi, cleangas Türkiye, 2021

The comprehensive analysis of hydrogen pipelines underscores their pivotal role in facilitating hydrogen gas distribution, which is crucial for its integration into various sectors. These pipelines, including both dedicated and repurposed infrastructures, represent the backbone of hydrogen transportation networks, ensuring reliable and efficient delivery from production sites to end-users.

With dedicated pipelines purposefully designed for hydrogen transport and rededicated pipelines leveraging existing infrastructure, the industry is poised for significant expansion. These pipelines enable the widespread adoption of hydrogen as a clean energy carrier and present cost-effective solutions for scaling up distribution networks.

As the ceramic sector transitions towards greener practices, the integration of hydrogen blending into natural gas holds promise for reducing carbon emissions while enhancing energy efficiency. However, this transition necessitates the adaptation of existing infrastructure to accommodate the unique properties of hydrogen, underscoring the importance of hydrogen-compatible piping and fitting systems.

Advancements in materials science and engineering, coupled with smart monitoring technologies, drive innovation in pipeline design, enhancing safety and reliability in hydrogen distribution networks. Moreover, regulatory frameworks and industry standards play a critical role in ensuring the safe operation of hydrogen infrastructure, fostering collaboration among stakeholders to promote best practices.

Despite the technical challenges and costs associated with hydrogen pipeline development, the progress is promising, with initiatives like the European Hydrogen Backbone leading the way. This ambitious project aims to establish an interconnected network of hydrogen pipelines across Europe, facilitating the transition to a sustainable, low-carbon energy system. Türkiye is also following these ambitious targets for green hydrogen transition.

In summary, hydrogen pipelines are integral to the advancement of hydrogen infrastructure, enabling the widespread adoption of hydrogen as a clean energy solution. The industry is poised to overcome challenges and pave the way for a greener future through collaboration, innovation, and adherence to safety standards.

Gas Mixture Technologies – Hydrogen Blending into Natural Gas

Environmental sustainability and reducing carbon emissions have become a significant priority in the energy sector today. In this context, the integration of hydrogen into the natural gas infrastructure stands out as a promising strategy for low-carbon energy production.

The HyDeploy project in the UK aims to reduce carbon emissions by blending hydrogen into the natural gas network, with the UK Government aiming to achieve net zero carbon emissions by 2050.¹⁹ Similarly, the Fort Saskatchewan Hydrogen Blending Project, led by ATCO in Alberta, started in October 2022 and integrated a mixture of natural gas containing 5% hydrogen into a portion of the Fort Saskatchewan natural gas distribution system. This step enabled approximately 2,100 customers to safely heat their homes and businesses with hydrogen-blended natural gas, meeting their energy needs.²⁰

Another sustainability strategy in the UK is the H21 project, an industrial initiative to research the future hydrogen transportability in the gas infrastructure. Considering that 83% of homes in the country use natural gas for heating and cooking, the project examines the potential of safely transporting hydrogen through the existing gas network.²¹

In the same vein of innovation, the HyBlend project, initiated by the U.S. Department of Energy to support the H2@Scale vision, targets addressing technical barriers to hydrogen blending in natural gas pipelines. The project includes research on

¹⁹ www.hydeploy.co.uk

²⁰ <https://gas.atco.com/en-ca/community/projects/fort-saskatchewan-hydrogen-blending-project.html>

²¹ <https://h21.green/projects/>

material compatibility, technical-economic analysis, and the development of publicly available tools to assess the opportunities, costs, and risks of blending hydrogen.²²

On the other hand, France pursues the GRHYD project among a series of initiatives, aiming to utilize hydrogen produced from renewable energy sources by blending it with natural gas for various applications after conversion.²³

Like France's GRHYD project, the Hydrogen Park South Australia (HyPSA) project in South Australia aims to convert surplus renewable energy into hydrogen and blend it with natural gas for a wide range of applications. By blending up to 5% renewable hydrogen into natural gas, the project aims to meet the energy needs of many homes.²⁴

Among ongoing efforts, the hydrogen blending project conducted by Enbridge Gas and Cummins Inc. in Ontario, Canada, aims to green energy consumption by adding clean hydrogen to the natural gas system. Blending hydrogen with existing natural gas reduces greenhouse gas emissions while maintaining energy costs, reliability, and safety. This project aims to contribute to Ontario's net-zero emission goal by reducing 117 tons of carbon dioxide (CO₂) emissions annually and leading clean energy transformation in Ontario.²⁵

The Hy4Heat project addresses technical, safety, and compliance aspects of replacing natural gas with hydrogen in residential and commercial buildings in the UK.²⁶

The Hydrogen Injection in the Gas Grid project demonstrates the transportability of up to 15% hydrogen in transmission and distribution networks. Test results show that the system does not have more hydrogen leakage compared to natural gas and that tested components can handle hydrogen without significant changes in hydrogen concentrations.²⁷

EN-H2 is Portugal's national hydrogen strategy to contribute to national and EU decarbonization goals. It aims to introduce hydrogen as a sustainable foundation in the energy sector and integrate it as part of the decarbonization economy transition.²⁸

The Hyready-DNV Project is a collaborative industry project aiming to create practical guidelines for adding hydrogen to the natural gas infrastructure. By addressing the integration of hydrogen into the natural gas network, this project guides network managers in this area.²⁹

Table 5 Hydrogen blending projects currently underway

No.	Project	Country	Blended Hydrogen [%]
1	HyDeploy	UK	20%
2	Fort Saskatchewan Hydrogen Blending Project	Canada	5%
3	H21	UK	100%
4	Hyblend	US	-
5	GRHYD	France	20%
6	Snam	Italy	10%
7	HyPSA	Australia	5%

²² <https://www.energy.gov/eere/fuelcells/hyblend-opportunities-hydrogen-blending-natural-gas-pipelines>

²³ <https://www.engie.com/en/businesses/gas/hydrogen/power-to-gas/the-grhyd-demonstration-project>

²⁴ <https://research.csiro.au/hyresource/hydrogen-park-south-australia/>

²⁵ <https://www.cummins.com/news/releases/2022/01/13/enbridge-gas-announces-launch-first-its-kind-hydrogen-blending-project>

²⁶ <https://www.hy4heat.info/>

²⁷ <https://en.energinet.dk/about-our-reports/reports/hydrogen-into-the-gas-grid/>

²⁸ <https://gh2.org/countries/portugal>

²⁹ <https://www.dnv.com/article/hyready-219355>

8	Enbridge and Cummins	Canada	2%
9	Hy4Heat	UK	100%
10	Hydrogen injection in the gas grid	Denmark	15%
11	Cleongas Türkiye	Türkiye	20%
12	EN-H2 (Portugal National Hydrogen Strategy)	Portugal	15%
13	Hyready-DNV Project	Norway	N/A

Source; Hydrogen firing: UK's Lucideon works with the ceramic industry on hydrogen firing trials

In the report published by Shura Energy Transition Center and Bilkent Energy Policy Research Center, considering hydrogen supply-demand equilibrium, it is stated that Türkiye has an annual green hydrogen export potential of 1.5 to 1.9 Mt in 2050, and that this export can be achieved by blending hydrogen into natural gas pipelines or via ship transportation by converting hydrogen into ammonia. The most suitable option for exporting green hydrogen through the gas network is the Trans Anatolian Natural Gas Pipeline (TANAP), the international pipeline passing through Türkiye. According to the statements of TANAP officials, up to 20% hydrogen blending is possible in pipelines without requiring any additional investment/modifications. This allows 0.2 Mt of green hydrogen to be transported through international pipelines, equivalent to approx. 10% of the total export potential of 1.9 Mt/year. TANAP pipeline has two exit points in Türkiye, one in Eskişehir province and the other in the Thrace region. Green hydrogen blending into the pipeline can be achieved by extending a dedicated hydrogen pipeline to Eskişehir or Thrace, by Direct mixing of green hydrogen injected into the domestic gas network to be transported by TANAP, or by installing electrolyzers at TANAP exit points and mixing directly.

Hydrogen Burner Technologies:

Within the hydrogen transition framework, hydrogen combustion applications play a significant role in high-carbon sectors when electrification is not applicable. The ceramic industry heavily relies on natural gas combustion for thermal energy, contributing to CO₂ emissions and climate change concerns. With current technologies nearing maturity, achieving emission reduction targets requires radical changes in energy sources. European initiatives highlight hydrogen, mainly green hydrogen produced via water electrolysis with renewable electricity. Hydrogen can substitute or supplement natural gas in ceramics, offering low or zero CO₂ emissions. However, its technical immaturity necessitates thorough assessments of its impact on physicochemical reactions, equipment materials, process variables, and emissions.³⁰

Utilization of combustion applications in both thermo-electric power generation, which relies on internal combustion engines including gas turbines and piston engines, and hard-to-abate industries necessitate high-temperature kilns and furnaces. In this section, hydrogen combustion technology, the combustion properties of hydrogen, and new-generation kilns will be discussed, and examples of newly developed kilns for use in the ceramic industry will be given.

Table 6 Main characteristics of natural gas and hydrogen

Parameters	H2	Natural gas
Composition considered	100%	90% methane 7.5% ethane 1.5% propane 0.4% butane 0.6% N ₂
HV (kWh/Nm³)	2997	10,617
Gas density (kg/Nm³)	0.0899	0.7955
Flammability range (% vol.)	4-75 (Air)	5-15 (Air)

³⁰ Hydrogen Combustion: Features and Barriers to its Exploitation in the Energy Transition, Eugenio Giacomazzi et al, 2023

Parameters	H2	Natural gas
	4-94 (Oxygen)	5-61 (Oxygen)
Laminar flame velocity (cm/s)	270 (Air)	35 (Air)
	290 (Oxygen)	330 (Oxygen)
Adiabatic flame T (2C)	2,045 (Air)	1,875 (Air)
	2,805 (Oxygen)	2,780 (Oxygen)
Flame visibility	No	Yes

Source: Hydrogen Combustion: Features and Barriers to its Exploitation in the Energy Transition, Eugenio Giacomazzi, Guido Troiani et al. 2023

A comparison of natural gas and hydrogen is needed for theoretical investigation of the combustion of natural gas and hydrogen. In the ceramic sector, hydrogen could be used to substitute natural gas in current processes. The above table outlines the fuel properties of both gases. Hydrogen combustion offers a notable advantage over fossil fuels as it produces no CO₂ emissions, as depicted in the combustion reactions detailed in the table below. However, it's noteworthy that hydrogen-air combustion can lead to higher thermal NO_x emissions due to its elevated flame temperature, which becomes critical beyond temperatures of around 1400°C. NO_x emissions are subject to regulatory limits in environmental authorizations, varying depending on the process stage.³¹

Table 7 Combustion reactions of hydrogen with air

Combustion Reactions	Stoichiometry Ratio
$\text{H}_2 (\text{g}) + 0,5.(\text{O}_2 (\text{g}) + 3,76.\text{N}_2 (\text{g})) \rightarrow \text{H}_2\text{O}(\text{g}) + 1,88. \text{N}_2 (\text{g})$	Volumetric 2.38 Nm ³ air/Nm ³ H ₂
$\text{H}_2 (\text{g}) + 8.(\text{O}_2 (\text{g}) + 26,5.\text{N}_2 (\text{g})) \rightarrow 9.\text{H}_2\text{O}(\text{g}) + 26,5. \text{N}_2 (\text{g})$	Mass 34.5 kg air/kgH ₂

Source: Combustion of hydrogen-natural gas mixtures applied to the cooking of ceramic products: emissions and flame properties, S. Ferrer Et Al 2022

For a certain burner, two gases are considered interchangeable if they exhibit the same combustion characteristics in terms of flame behaviour and heat flow under identical supply conditions (pressure and temperature). The Wobbe index, used to compare the energy equivalence of gaseous fuels with different compositions, is a critical parameter to assess the interchangeability of combustible gases. When two fuel gases have identical Wobbe index values, they can be utilized in the same burner without changing the working conditions. While deviations in the Wobbe index of up to 5% do not require modifications in the burner, higher variations necessitate equipment adjustments or even replacements.³² The table below shows the calorific value and Wobbe indices per unit volume for different hydrogen-natural gas mixtures.

Considering that variations in the Wobbe index of up to 5% can be tolerated, adding up to 20 vol.% hydrogens to natural gas will be compatible with existing burners and combustion systems, as seen in the Below table.

Table 8 LHV, HHV, Wobbe Index values and their variation for different H2-Natural Gas mixtures

Natural gas (vol.%)	Hydrogen (vol.%)	LHV (kWh/Nm ³)	HHV (kWh/Nm ³)	Wobbe Index (kWh/Nm ³)	%Variation in Wobbe Index
100	0	10.62	11.78	54.16	-
90	10	9.85	10.96	52.76	2.57
80	20	9.09	10.13	51.36	5.17
70	30	8.33	9.31	49.95	7.77

³¹ Combustion of hydrogen-natural gas mixtures applied to the cooking of ceramic products: emissions and flame properties, S. Ferrer*, E. Monfort*, R. Pereira**, J. Viduna**, J. Montolio*, A. Mezquita*, J. Vedrí, Air Products, 2022

³² Combustion of hydrogen-natural gas mixtures applied to the cooking of ceramic products: emissions and flame properties, S. Ferrer Et Al 2022

60	40	7.57	8.49	48.56	10.34
50	50	6.81	7.66	47.20	12.84
40	60	6.04	6.84	45.95	15.16
30	70	5.28	6.01	44.88	17.12
20	80	4.52	5.19	44.25	18.30
10	90	3.76	4.37	44.65	17.55
0	100	3.00	3.54	48.36	10.71

Source: Combustion of hydrogen-natural gas mixtures applied to the cooking of ceramic products: emissions and flame properties, S. Ferrer Et Al 2022

There are ongoing studies on developing new furnaces or furnace operating conditions to reduce NO_x emissions in furnaces burning natural gas mixed with hydrogen or 100% hydrogen. One OF THE examples in Türkiye is The hydrogen-enriched natural gas combustion experiments carried out for a ceramic kiln, including burners, which operates in the city of Usak by Usak Ceramic Industry Co. Ltd.

3.1.4 Environmental Factors

The Turkish ceramic industry, a vital part of the nation's economy, has experienced substantial growth and success in recent decades. Despite its significant contributions to the country's economic prosperity, the industry's operations are not devoid of environmental implications. This part of the report aims to deeply examine the environmental challenges posed by the ceramic industry, with a particular emphasis on the production of ceramic tiles, while also shedding light on the ongoing efforts to shift towards more sustainable practices.

Air and Greenhouse Gas Emissions:

One of the most significant environmental concerns linked to the Turkish ceramic industry is its heavy reliance on fossil fuels during crucial stages of production, such as firing and drying. Burning these fuels results in the emission of harmful air pollutants and greenhouse gases, primarily carbon dioxide (CO₂). According to research conducted by Türkmen and colleagues (2021), CO₂ emissions from the ceramic industry can make up an astonishing 92.1% of the industry's total environmental impact. This substantial contribution to greenhouse gases significantly exacerbates climate change, a global issue of critical importance due to its far-reaching and potentially devastating effects. Furthermore, the release of other harmful pollutants such as nitrogen oxides (NO_x) and sulfur oxides (SO_x) can lead to a drastic decline in air quality, posing risks to human health and causing detrimental effects to local ecosystems.

Water Pollution:

The process of ceramic production is notably water-intensive. Large quantities of water are used for numerous purposes throughout the production process, including the processing of materials, cleaning, and operation of equipment. While some facilities may be equipped with wastewater treatment plants, improper management of effluent can pose a significant risk to water resources. Untreated wastewater often contains dangerous chemicals, suspended solids, and organic matter. Discharging such effluent into water systems can wreak havoc on aquatic ecosystems, contaminate potable water sources, and negatively impact biodiversity.

Land Degradation and Raw Material Extraction:

The extraction of raw materials, specifically clay which is indispensable for ceramic production, disrupts natural landscapes. Mining activities can lead to the loss of habitats for different species of flora and fauna, disrupt natural drainage patterns causing water body contamination, and contribute to soil erosion. The subsequent transportation of these raw materials to production facilities further expands the industry's environmental footprint. The dust generated during the extraction and transportation processes can also negatively impact air quality in the surrounding areas.

Chemical Releases:

The ceramic industry's production process often involves using certain chemicals that pose significant environmental and health risks. Two such chemicals that are of particular concern are chromium and mercury. Improper handling or accidental spills during production can release these chemicals into the environment, contaminating the air and soil. Exposure to chromium can lead to respiratory issues and skin irritation, while mercury, a potent neurotoxin, can have harmful effects on the human nervous system. Moreover, these chemicals can bioaccumulate in the food chain, posing a long-term threat to both wildlife and human health.

The Path Towards Sustainability:

Despite the environmental challenges that have been outlined above, there are encouraging signs of positive developments within the Turkish ceramic industry, illustrating a growing commitment towards sustainability. There are ongoing research efforts aimed at identifying and implementing cleaner production technologies. These technologies aim to reduce energy consumption during the firing and drying stages, thereby minimizing the emission of greenhouse gases and air pollution. Examples of these technologies include using more efficient kilns, adopting alternative fuel sources such as natural gas, and exploring waste heat recovery systems.

Life Cycle Assessment (LCA):

A vital step towards achieving sustainable ceramic production involves understanding the environmental impact at every stage of the product life cycle. LCA studies are being conducted to assess the environmental burden associated with each stage, from raw material extraction and processing to the final disposal of the product. By identifying the areas within the life cycle that have the greatest environmental impact, manufacturers can target interventions and implement strategies for improvement. Sustainable Practices: An increasing number of Turkish ceramic manufacturers are embracing sustainable practices in an effort to minimize their environmental footprint. Waste recycling programs play an integral role in reducing the demand for new raw materials and diverting waste from landfills. The exploration and adoption of renewable energy sources such as solar and wind power can significantly reduce the industry's reliance on fossil fuels, thereby decreasing greenhouse gas emissions. Additionally, implementing water conservation measures and investment in efficient wastewater treatment systems can help reduce water usage and protect water resources.

The Turkish ceramic industry is at a critical juncture. It faces a vital choice: to prioritize short-term economic benefits at the expense of the environment, or to embrace sustainable practices that ensure long-term viability and environmental protection. Research and development efforts focused on cleaner production technologies, life cycle assessment, and the adoption of sustainable practices offer a promising path forward. By transitioning towards a more environmentally responsible approach, the Turkish ceramic industry can continue to be a significant contributor to the economy while safeguarding the environment for future generations.

3.1.5 Legal Factors

Türkiye has set ambitious goals for itself in the clean energy sector, aiming to reduce greenhouse gas emissions and promote sustainability. This is reflected in its legislative framework, which includes several key laws and regulations. This part of the report explores this framework, examining how it supports the use of clean energy in general and delves specifically into the current and future regulations surrounding hydrogen as a clean energy source.

General Legal Framework:

Türkiye's legislative framework for energy and environmental policies encompasses several key laws and regulations aimed at promoting sustainability and combating climate change:

1. The Climate Change Law (Drafted) sets out to regulate greenhouse gas emissions reduction and climate change adaptation in alignment with Türkiye's green development vision and net zero emission target.
2. The Energy Efficiency Law (No. 5627) and related regulations, including the Regulation on Thermal Insulation in Buildings, the Regulation on Increasing Efficiency in the Use of Energy Resources and Energy, and the Regulation on Energy Performance in Buildings, focus on enhancing energy efficiency across various sectors and promoting the utilization of renewable energy resources.
3. The Law on the Utilization of Renewable Energy Resources for Electricity Generation (No. 5346) aims to expand the use of renewable energy sources for electricity generation, reduce greenhouse gas emissions, and foster economic development.
4. The Communiqué on Environmentally Friendly Design Requirements For Solid Fuel Space Heaters ensures environmentally sound practices in the heating sector, contributing to overall sustainability goals.
5. The Electricity Market Law (No. 6446) establishes a transparent electric energy market to provide electricity to consumers efficiently, sustainably, and cheaply while ensuring independent regulation and supervision.
6. The Regulation on the Operation of Carbon Markets (Drafted) lays out principles and procedures for establishing and operating carbon markets to encourage the cost-effective reduction of greenhouse gas emissions.

Clean Energy in General:

The Climate Change Law, currently in draft form, aims to regulate greenhouse gas emissions reduction and climate change adaptation, aligning with Türkiye's green development vision and net zero emission target. This law mandates the Ministry of Energy and Natural Resources to maximize the utilization of renewable energy resources, including technologies like green hydrogen and carbon capture, utilization, and storage.

Several regulations, such as the Energy Efficiency Law and regulations on building thermal insulation and energy performance, complement this effort by promoting energy efficiency and renewable energy utilization across various sectors. These regulations focus on enhancing energy efficiency in production, distribution, and consumption stages and improving awareness and utilization of renewable energy resources.

Additionally, the Law on the Utilization of Renewable Energy Resources for Electricity Generation emphasizes expanding renewable energy usage to reduce greenhouse gas emissions and protect the environment while fostering economic development. Moreover, the Communiqué on Environmentally Friendly Design Requirements for Solid Fuel Space Heaters ensures environmentally sound practices in the heating sector, contributing to overall sustainability goals.

Hydrogen as a Vector of Clean Energy:

In Türkiye, the definition of clean energy resources is outlined in Law Number 5346, also known as the Renewables Law. This law mandates that obtaining an electricity generation license from the Energy Market Regulatory Authority (EMRA) is necessary for electricity generation in the Turkish market.

Currently, Türkiye's legislative framework for producing and utilising hydrogen energy is still in its infancy. Although there is a recognition of the potential of hydrogen as a clean energy source and steps are being taken towards its development, the country is still in the initial stages of establishing foundational aspects like production and storage.

However, potential investors and companies interested in hydrogen face challenges due to the absence of a specific legal framework. They encounter bureaucratic hurdles during the permitting and licensing process.

Flexibility, coordination, and speed emerge as crucial factors for hydrogen production permitting in industries. Currently, processes lack predictability, leading to an expectation for streamlined regulations that would expedite project realization efficiently within a shorter timeframe.

Regarding **market regulations**, the legal landscape in Türkiye has not yet been fully formed. As hydrogen needs to be regulated as a tradable good, discussions are underway with government agencies and independent administrative authorities about a framework that would allow hydrogen trading. Once this framework is established, various authorizations related to the hydrogen market are expected to fall under the jurisdiction of the stock exchange or EMRA (the Energy Market Regulatory Authority), the market regulatory authority.

In terms of **economic and financial regulations**, Türkiye doesn't currently have a dedicated set of rules specifically for hydrogen energy. However, it's likely that financial incentives such as grants, subsidies, tax reductions, or loan guarantees will be provided in the near future to stimulate investments in hydrogen production, storage, and infrastructure development. On top of this, discussions are ongoing with government agencies about financial opportunities for pilot projects involving the use of hydrogen energy. The Ministry of Trade is considering the establishment of carbon pricing schemes or emissions trading systems to incentivise the production of low-carbon hydrogen.

When it comes to **licensing and permitting**, Türkiye currently lacks a comprehensive set of laws and regulations establishing specific licensing and permitting requirements for activities related to hydrogen energy, including production, storage, transportation, and utilization. It is anticipated that once a framework law on hydrogen is established, the state structure will follow developments towards end-use sector integration. EMRA, which also regulates electric vehicle charging stations, is closely monitoring the use of hydrogen energy in fuel cells in the automotive sector.

Lastly, in the area of **research and development support and funding**, Türkiye does not have a dedicated law focused solely on hydrogen energy. However, organizations such as TENMAK and The Scientific and Technological Research Council of Türkiye (TÜBİTAK) continue to work on the development of hydrogen technologies. The Ministry of Industry and Technology is also focusing on this issue.

In conclusion, while Türkiye's legislative situation regarding hydrogen energy is still in its early stages, there are clear signs that the government recognises the potential of hydrogen and is taking steps towards its development.

Table 9 Prioritized Factors in PESTLE Analysis

POLITICAL FACTORS	ECONOMICAL FACTORS	TECHNOLOGICAL FACTORS	ENVIRONMENTAL FACTORS	LEGAL FACTORS
Factor Prioritization	Factor Prioritization	Factor Prioritization	Factor Prioritization	Factor Prioritization
1. International commitments and alignment with the European Green Deal: These commitments create pressure for action and open doors for trade and investment.	1. Economic Climate: The current economic climate in Türkiye presents challenges. Consider including a contingency plan to address potential disruptions caused by inflation or currency fluctuations. This directly impacts production costs and consumer demand.	1. Feasibility: The economic feasibility of hydrogen blending in natural gas infrastructure projects is still evolving. Careful planning, cost optimization strategies, and a supportive regulatory environment are crucial for successful implementation. Electrolysis technology advancements is required for efficiency and the lowering of the cost of green hydrogen production.	1. Air and Greenhouse Gas Emissions: CO2 emissions are a primary global concern (climate change). NOx and SOx have significant negative impacts on local air quality and ecosystems.	1. Absence of a Framework Law for Hydrogen: Establish a foundation for hydrogen production, storage, utilization, and market regulations are crucial.
2. Domestic policies promoting green transformation: These policies provide a supportive environment for the project and demonstrate government commitment.	2. EU Carbon Border Adjustment Mechanism (CBAM): This poses a significant risk due to potential carbon pricing on exports.	2. Cost of Hydrogen Production: This is a critical factor determining the economic viability of blending. Efforts should focus on advancements in electrolysis technology and securing cost-effective renewable energy sources. Advocating for carbon pricing policies creates a stronger economic case for hydrogen blending	2. Water Pollution: Contamination of water resources can have severe consequences for human health, aquatic life, and overall environmental well-being	2. Streamline Permitting Processes: Design and Implementing the permitting process is vital for the implementation of the projects. Reducing bureaucratic hurdles will ensure predictability for hydrogen project approvals.
3. Support for R&D and domestic hydrogen industry: This ensures long-term sustainability and competitiveness.	3. Global market competition: Competitiveness requires strategic pricing and brand recognition.	3. Retrofitting Costs of Existing Infrastructure: Optimizing pipeline modifications and minimizing upfront costs are crucial for project approval.	3. Chemical Releases: The health risks associated with chromium and mercury necessitate responsible management and potential substitution with safer alternatives.	3. Finalize Market Regulations: Establish a framework for hydrogen trading under EMRA or the stock exchange.

Source: Consultants' opinions based on references

3.2 Benchmarking Study – Türkiye-Germany

3.2.1 Legislations and Regulatory Environment

3.2.1.1 Hydrogen Policies

The European energy and climate policy landscape is undergoing significant changes, driven by the European Green Deal presented in late 2019. The Green Deal focuses on decarbonization, reflecting a stronger commitment to climate issues. The European Climate Law, adopted in June 2021, enforces binding targets for net-zero greenhouse gas emissions by 2050 and a 55% reduction by 2030.

The evolution of the German energy system is closely intertwined with a wider transformation occurring in the European energy scenario. Member states within the European Union have set ambitious energy and climate goals for 2030 and beyond, with the objective of ensuring supply security, competitiveness, and climate protection throughout Europe. The Integrated National Energy and Climate Plan (NECP) has been introduced as an innovative monitoring tool at the EU level, aimed at facilitating the achievement of European energy and climate targets. In 2018, each EU member state presented an initial NECP to the EU Commission.

Table 10 Insights of Strategies

Key Sectors	Germany Hydrogen Strategy	Priority	Key Sectors	Türkiye Hydrogen Technology Strategy and Road Map	Priority
Industries	Iron and Steel	High-priority/Short-term	Industries	Iron and Steel	High Priority/Long Term
	Chemicals	High-priority/Short-term		Chemical (methanol, ammonia, sodium borohydride, etc.) production	High Priority/Long Term
	Refineries	High-priority/Short-term		Petrochemistry and chemistry	High Priority/Medium Term
	Other industry segments include: Wood, Textiles, Transport Equipment Manufacturing, Food & Beverage, & Ceramic & Glass	High-priority/Short-term		Fertilizer	High Priority/Medium Term
Transport	Passenger Vehicles	Low-priority	Transport (No Distinction)	Cement	High Priority/Medium Term
	Medium- and Heavy-duty	High-priority/Short-term		Glass and ceramics	High Priority/Medium Term
	Buses/Rail	High-priority/Short-term			High Priority/Medium Term
	Maritime/Aviation	Long-term Goal (>2030)			

Source: Developed by the Consultant

In comparing Germany and Türkiye's hydrogen strategies, both countries strongly emphasise key sectors, outlining priority areas for hydrogen deployment. Germany's strategy places high priority on the Iron and Steel, Chemicals, Refineries, and various other industries in the short term, signaling an urgent focus on these sectors. In contrast, Türkiye's Hydrogen Technology Strategy and Road Map target the Iron and Steel and Chemical (including methanol, ammonia, and sodium borohydride production), industries as high-priority, but with a long-term perspective. Additionally, Türkiye extends its focus to sectors like Petrochemistry and Chemistry, Fertilizer, Cement, Glass, and Ceramics, categorizing them as high-priority with medium-term goals. The transport sector is addressed differently, with Germany designating Passenger Vehicles as low-priority and Medium- and Heavy-duty vehicles, Buses/Rail in the short term, while Türkiye places Transport under a general high-priority category with no specific distinctions.

Table 11 : Analysis of Strategies

Goals and Focus	Similarities	Main Differences	Approach to industry	Focus on Specific Technologies	Hydrogen Source:
Ambitious goals: Both countries have set ambitious targets for hydrogen development. Germany aims for 10 GW of electrolyzer capacity by 2030 and 70 GW by 2053, while Türkiye plans for 2 GW in 2030, 5 GW in 2035, and 70 GW by 2053.	Emphasise on decarbonization : Both aim to use hydrogen to reduce carbon emissions in industry, transportation, and other sectors.	Current stage: Germany is significantly ahead with a more developed hydrogen strategy, and concrete measures are already in place. Türkiye is still in the early stages of developing its hydrogen strategy.	Germany: Focuses on domestic hydrogen production through large-scale expansion of renewables and electrolyzers. Additionally, they plan to develop an import strategy to meet the remaining demand.	Germany: Emphasizes developing and producing domestic electrolyzers.	Germany: Plans to combine domestic production with imports to meet demand.
Focus on green hydrogen: Both strategies prioritize the production of green hydrogen using renewable energy sources.	Both aim for carbon reduction in the industry: Germany and Türkiye see hydrogen as a key element in decarbonizing their industrial sectors.	Germany's approach is more comprehensive and action-oriented, while the Turkish strategy needs further development.	Türkiye: Details on industry involvement are not mentioned in the provided information.	Türkiye: It focuses on R&D for producing electrolyzers and fuel cells, utilizing boron resources for storage, and adapting natural gas infrastructure for hydrogen.	Türkiye: Prioritizes domestic production from renewable energy sources and investigates production from lignite, organic waste, and natural gas. There is an emphasis on localization and Nationalization.

Source: Developed by the Consultant

3.2.1.2 Existing Legislations and Regulations

In recent years, the global energy landscape has witnessed a paradigm shift towards sustainable and renewable sources, with hydrogen emerging as a key player in achieving ambitious climate goals. Within the European Union (“EU”), a comprehensive legislative framework has been established to promote the development and utilization of hydrogen energy. Similarly, Germany has enacted detailed and pragmatic legislation, reflecting its commitment to leveraging hydrogen as a cornerstone of its energy transition strategy. Additionally, Türkiye has demonstrated a keen interest in harnessing the potential of hydrogen and is actively preparing its legislative framework to facilitate its integration into the energy sector.

Below is a table encompassing the primary parameters delineated in our project, strategically designed to elucidate legislative procedures comprehensively. This classification system categorises the legislation according to these parameters, facilitating

an in-depth comprehension of the regulatory frameworks about hydrogen energy within each jurisdiction. The table presented below offers an extensive comparison of the prevailing legislative stances concerning hydrogen energy within the EU, Germany and Türkiye. This comparative analysis aims to elucidate the distinctive legal frameworks shaping their individual trajectories towards embracing hydrogen as a pivotal component of their energy strategies. Subsequently, a comprehensive explanation of the legislative landscape is discussed in the table.

Table 12 Overview of Legislation in EU and Germany

Major Parameters	EU	Germany
Production and Manufacturing Regulations - National and International Standards	1.The Delegated Regulation on Additionality 2.The Delegated Regulation on GHG Savings 3.The Proposal For Regulation On The Internal Markets For Hydrogen COM(2021) 804 4.The Renewable Energy Directive 5. Proposal For A Directive Of The European Parliament And Of The Council On Common Rules For The Internal Markets In Renewable And Natural Gases And In Hydrogen (standards) 6.The Communication on the European Hydrogen Bank (COM/2023/156) 7. EU Emission Trading System 8. Net-Zero Industry Act (Manufacturing) 9. The European Hydrogen Bank (manufacturing)	1.The German National Hydrogen Strategy (Nationale Wasserstoffstrategie - NWS) 2.The German National Energy and Climate Plan (NECP) 3.The Renewable Energy Act (Erneuerbare Energien Gesetz-EEG) 4. Greenhouse Gas Emissions Trading Act (Treibhausgas-Emissionshandelsgesetz-TEHG) 5. Federal Immission Control Act (Bundes-Immissionsschutzgesetz) 6.İzin Gerektiren Tesislere İlişkin Yönetmelik (4. BlmSchV) 7.The Renewable Energy Act (EEG-Erneuerbare Energien Gesetz) 8. The Renewable Energy Directive II
Storage and Transportation Regulations	1. Regulation Of The European Parliament And Of The Council On The Internal Markets For Renewable And Natural Gases And For Hydrogen And Regulation (Eu) 2017/1938 (storage) 2. Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions - The Sustainable and Smart Mobility Strategy (transportation) 3. The Renewable Energy Directive 4.The Clean Hydrogen Partnership	1.TEN-E Regulation (EU) 2022/869 of the European Parliament and of the Council of 30 May 2022 on guidelines for trans-European energy infrastructure 2. The German 2023 Market Reform Plan Monitoring Report "The power plant list of the Federal Network Agency" (Die Bundesnetzagentur - BNetzA) 3.The Renewable Energy Act (EEG-Erneuerbare Energien Gesetz) 4. The Gas Network Access Ordinance (Gasnetzzugangsverordnung - GasNZV) 5.The German Technical and Scientific Association for Gas and Water Technical

	5.TEN-E Regulation (EU) 2022/869 of the European Parliament and of the Council of 30 May 2022 on guidelines for trans-European energy infrastructure. 6.RePowerEU (transportation)	Rules (Deutsche Vereinigung des Gas- und Wasserfachs - DVGW) 6. Association of the Supra-regional Gas Transmission Grid Operators Rules (Vereinigung der Fernleitungsnetzbetreiber im Gasbereich e.V.- FNB Gas)
Hydrogen Quality Standards - National and International	1. Directive Of The European Parliament And Of The Council On Common Rules For The Internal Markets In Renewable And Natural Gases And In Hydrogen	1.EU standardisations (CEN, ISO, IEC, national standardisation institutions) 2.BMWK
Security and Safety Standards and Regulations	1. The Renewable Energy Directive 2. SEVESO Directive (Directive 2012/18/EU) 3.The Agreement concerning the International Carriage of Dangerous Goods by Road ("ADR") 4. Regulations concerning the International Carriage of Dangerous Goods by Rail ("RID") 5. The European Committee for Standardization ("CEN") 6. The International Organization for Standardization ("ISO") 7. The International Electrotechnical Commission ("IEC")	1.EU standardisations (CEN, ISO, IEC, national standardisation institutions)
Environmental Regulations	1. A Hydrogen Strategy For A Climate-Neutral Europe (COM/2020/301) 2. The European Clean Hydrogen Alliance 3. The Communication on the European Hydrogen Bank (COM/2023/156) 4. The Green Deal 5. Fit for 55 6.The EU's Carbon Border Adjustment Mechanism (CBAM) 7. Revision of the Gas Directive 2009/73/EC and Gas Regulation (EC) No 715/2009 : the Hydrogen and gas markets decarbonisation package	1. Environmental Impact Assessment Act (Gesetz über die Umweltverträglichkeitsprüfung (UVPG)) 2. The German Emergency Climate Protection Program 3. German Federal Emission Control Act (BImSchG-Bundesimmissionsschutzgesetz)

End-Use Sector Integration	1. Energy Efficiency Directive	1. Energy Efficiency Directive (Energieeffizienzrichtlinie - EED)
	2. The Renewable Energy Directive	2. The Renewable Energy Directive II

Source: Developed by the Consultant

Examining Germany's benchmark legal framework for hydrogen energy is crucial for understanding Türkiye's needs in this sector. The table below highlights the gaps in Türkiye's current approach, like the lack of a central hydrogen law. It emphasizes the importance of streamlining regulations and focusing on key areas like permitting to attract investment and develop a robust hydrogen economy.

Please note that due to differences in the legal systems of Germany and Türkiye, existing laws and ordinances specified for Germany have been kept separate, while in Türkiye, primary and complementary laws and regulations corresponding to these relevant laws and ordinances have been collectively drafted.

Explanation of Columns:

- ✓ Name of the Law: Title of the German Law/Ordinance.
- ✓ Authority: The German government ministry responsible for the law.
- ✓ Brief of Legislation: A concise explanation of the law's purpose.
- ✓ Implementation Field: The law applies to the stages of the hydrogen value chain (production, transport, storage, or end-use).
- ✓ Turkish Equivalent Law: Existing Turkish law addressing a similar area (if applicable). If not, a possible Turkish law for future inclusion is suggested.
- ✓ Authority: The Turkish government ministry is responsible for the equivalent law (if applicable).

Table 13 Comparison of Legislation Germany and Türkiye

Name of the Law	Authority	BRIEF OF LEGISLATION	Turkish Equivalent Law (In case of absence, possible law to be included)	Authority
Climate Change Act	Federal Government	The legal framework for hydrogen energy in Germany is still evolving. The government actively pursues further amendments to legislation and regulations to streamline permitting processes and support the development of a comprehensive hydrogen economy. Please note that the legal framework for hydrogen energy in Germany is not governed by a single act but rather by a combination of existing legislation that has been adapted to address the specific needs of hydrogen As outlined in the Federal Climate Change Act, Germany is committed to achieving climate neutrality by 2045. Hydrogen and its derivatives, including gaseous or liquid energy carriers derived from green hydrogen, are poised to assume a significant role in facilitating the transition to climate neutrality, especially within energy-intensive industries.	The Climate Change Law (Drafted)	Presidency / EMRA (Republic of Türkiye Energy Market Regulatory Authority)
Energy Industry Act (EnWG) amended in March 2023	BMWK - Federal Ministry for Economic Affairs and Climate Action of Germany	The Act defines the framework conditions for a secure, affordable, consumer-friendly and environmentally friendly energy supply. Also, regulations were introduced to establish a hydrogen core network in Germany, coupled with a substantial enhancement of the competencies granted to the Federal Network Agency (BNetzA) in overseeing the regulation of gas and electricity grids. Through the establishment of a legal framework for a hydrogen core network.	Energy Efficiency Law (No. 5627)	Presidency / Ministry of Environment, Urbanisation and Climate Change
			Regulation on Thermal Insulation in Buildings	Ministry of Environment, Urbanisation and Climate Change
			Regulation on Increasing Efficiency in the Use of Energy Resources and Energy	Ministry of Energy and Natural Resources

			Regulation on Energy Performance in Buildings	Ministry of Environment, Urbanisation and Climate Change
Renewable Energy Sources Act 2021 (EEG 2021)- From 1.1.2023: Renewable Energy Sources Act 2023 (EEG 2023)	BMWK - Federal Ministry for Economic Affairs and Climate Action of Germany	The legislation aims to foster the advancement of technologies in generating electricity from renewable sources and to attain reductions in costs.	Law on the Utilisation of Renewable Energy Resources for Electricity Generation (No. 5346)	Ministry of Energy and Natural Resources
Combined Heat and Power Act (KWKG 2020) - From 1.1.2023: Combined Heat and Power Act 2023 (KWKG 2023)	BMWK - Federal Ministry for Economic Affairs and Climate Action of Germany	The Act increases electricity generation from CHP plants in the interests of saving energy and protecting the environment and climate.	Communiqué On Environmentally Friendly Design Requirements For Solid Fuel Space Heaters	Ministry of Industry and Technology
Energy Financing Act (EnFG)	BMWK - Federal Ministry for Economic Affairs and Climate Action of Germany	It is designed to provide financial support and incentives for projects related to energy production, efficiency, and renewable energy sources. It aims to facilitate the implementation of sustainable energy projects and contribute to the country's energy transition goals. A complete exemption from the levies is provided for the electricity required to produce green hydrogen.	Energy Efficiency Law (No. 5627) (and related regulations)	Mentioned above
			Electricity Market Law (No. 6446)	Ministry of Energy and Natural Resources/ EMRA
Federal Immission Control Act (BImSchG)	BMUV - Federal Ministry for Environment, Nature Conservation and Nuclear Safety	The law aims to safeguard humans, animals, plants, soil, water, the atmosphere, and cultural and material assets from detrimental environmental influences. It extends its applicability to the transport sector, specifically emphasising the relevance of hydrogen and RFNBO concerning potential offsets against the GHG quota.	Regulation on the Operation of Carbon Markets (Drafted)	EMRA/ Ministry of Trade/ Ministry of Energy and Natural Resources
Coal-fired Power Generation Termination Act (KVBG)	BMWK - Federal Ministry for Economic Affairs and Climate Action of Germany	The law aims to phase out coal-fired power generation in Germany through measures like tenders and mandated reduction paths. It also explores options for converting hard coal plants to hydrogen with relevant subsidy programs.	—	—

Coal Regions Investment Act (InvKG)	BMWK - Federal Ministry for Economic Affairs and Climate Action of Germany	To strengthen the automotive sector and decarbonize energy generation in the lignite regions, hydrogen is one of the technologies mentioned in the guiding principles outlined.	–	–
Wind Energy at Sea Act (WindSeeG)	BMWK - Federal Ministry for Economic Affairs and Climate Action of Germany	Concerning hydrogen, the Act encompasses the planning and approval processes for hydrogen pipelines. Conversely, distinct provisions are outlined for "other energy production areas," specifically addressing the electrolysis of hydrogen using offshore wind turbine-generated electricity.	–	–
LNG Acceleration Act (LNGG)	BMWK - Federal Ministry for Economic Affairs and Climate Action of Germany	The legislation aims to ensure the national energy supply by swiftly incorporating liquefied natural gas into the transmission network. Starting in 2044, continued operation approval for plants should only be granted if they operate with climate-neutral hydrogen.	Natural Gas Market Law (No. 4646) and Natural Gas Market Internal Installation Regulation	Ministry of Energy and Natural Resources/ EMRA
Greenhouse Gas Emissions Trading Act (TEHG)	BMUV - Federal Ministry for Environment, Nature Conservation and Nuclear Safety	The Act implements Directive 2003/87/EC and creates the legal basis required for a functioning European emissions trading system at the national level.	The Climate Change Law (Drafted) / Regulation on the Operation of Carbon Markets (Drafted)	Ministry of Trade/ EMRA
Fuel Emissions Trading Act (BEHG)	BMUV - Federal Ministry for Environment, Nature Conservation and Nuclear Safety	This legislation aims to establish the foundation for trading certificates related to fuel emissions and to guarantee the pricing of these emissions, specifically for those not covered by the EU emissions trading system.	Regulation on Exhaust Gas Emission Control	Ministry of Environment, Urbanisation and Climate Change/ Ministry of Transport and Infrastructure
			Regulation on Control of Industrial Air Pollution	Ministry of Environment, Urbanisation and Climate Change
Energy Tax Act (EnergieStG)	BFM - Federal Ministry of Finance	The Energy Tax Act governs the taxation of energy products in the Federal Republic of Germany. Apart from the taxation provisions applicable to specific energy products, the act also includes guidelines for tax exemption under specific conditions.	Tax Law (No. 193)	Ministry of Treasury and Finance
			Law on the Utilisation of Renewable Energy Resources for Electricity Generation (No. 5346)	Ministry of Energy and Natural Resources
			Electricity Market Law (No. 6446)	Ministry of Energy and Natural Resources/ EMRA

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			The Climate Change Law (Drafted) / Regulation on the Operation of Carbon Markets (Drafted)	Ministry of Trade/ EMRA
Technical regulations/worksheets for the gas and water industry	DVGW - German Technical and Scientific Association for Gas and Water" (Deutscher Verein des Gas- und Wasserfaches)	German Technical and Scientific Association for Gas and Water (Deutscher Verein des Gas- und Wasserfaches e.V.), develops technical regulations and worksheets for the gas and water industry in Germany. These documents, often referred to as DVGW rules, serve as industry standards and guidelines to ensure the safety, quality, and efficiency of gas and water-related processes and systems.	—	—
Name of the Law	Authority		Turkish Equivalent Ordinance	Authority
Hydrogen Network Charges Ordinance (WasserstoffNEV)	BMWK - Federal Ministry for Economic Affairs and Climate Action of Germany		-	-
Gas Network Charges Ordinance (GasNEV)	BMWK - Federal Ministry for Economic Affairs and Climate Action of Germany		Regulation on Natural Gas Market Tariff	EMRA/ Ministry of Energy and Natural Resources
			Regulation on Organised Wholesale Natural Gas Sales Market and Natural Gas Market Internal Installation Regulation	
			Natural Gas Market Transmission Network Operation Regulation	
Gas Network Access Ordinance (GasNZV)	BMWK - Federal Ministry for Economic Affairs and Climate Action of Germany		Natural Gas Market Tariff Board Decisions (from EMRA Board)	EMRA/ Ministry of Energy and Natural Resources
Renewable Energies Ordinance (EEV)	BMWK - Federal Ministry for Economic Affairs and Climate Action of Germany		Regulation on Certification and Support of Renewable Energy Resources	EMRA/ Ministry of Energy and Natural Resources
Proof of Origin and Regional Proof of Origin Implementing Ordinance (HkRNDV)	BMWK - Federal Ministry for Economic Affairs and Climate Action of Germany			
Ordinance on installations requiring approval (4th BImSchV)	BMUV - Federal Ministry for Environment, Nature Conservation and Nuclear Safety		Environmental Law (No. 2872)	

		Regulation on Environmental Impact Assessment	Ministry of Environment, Urbanisation and Climate Change
		Regulation on Environmental Permits and Licences	
		Regulation on Combating Air Pollution	
		Regulation on Water Pollution Control	
		Regulation on Waste Management	
Ordinance on small and medium-sized combustion plants (1. BImSchV)	BMUV - Federal Ministry for Environment, Nature Conservation and Nuclear Safety	Regulation on Water Pollution Control	Ministry of Environment, Urbanisation and Climate Change
Ordinance on the quality and labelling of fuels and combustibles (10th BImSchV)	BMUV - Federal Ministry for Environment, Nature Conservation and Nuclear Safety	Regulation on Exhaust Gas Emission Control and Natural Gas Market Internal Installation Regulation	Ministry of Environment, Urbanisation and Climate Change
Major Accidents Ordinance (12th BImSchV)	Federal Government	Regulation On The Control Of Pollution Caused By Hazardous Substances In Water And Its Environment	Ministry of Environment, Urbanisation and Climate Change
		Regulation On Registration, Evaluation, Authorisation And Restriction Of Chemicals	
		Regulation On Health And Safety Measures At Work With Chemical Substances	
		Regulation On Registration, Evaluation, Authorization And Restriction Of Chemicals	

		Regulation On Prevention And Mitigation Of Major Industrial Accidents	The Ministry of Labor and Social Security
Ordinance on the inclusion of electricity-based fuels and co-processed biogenic oils in the greenhouse gas quota (37th BImSchV)	BMUV - Federal Ministry for Environment, Nature Conservation and Nuclear Safety	–	–
Ordinance laying down further provisions on the reduction of greenhouse gases from fuels	BMUV - Federal Ministry for Environment, Nature Conservation and Nuclear Safety	–	–
Allocation Ordinance 2007 (ZuV 2007)	BMUV - Federal Ministry for Environment, Nature Conservation and Nuclear Safety	–	–
Allocation Ordinance 2020 (ZuV 2020)	BMUV - Federal Ministry for Environment, Nature Conservation and Nuclear Safety	–	–
Energy Tax Implementation Ordinance (EnergieStV)	BMUV - Federal Ministry for Environment, Nature Conservation and Nuclear Safety	Special Consumption Tax Law (No. 4760)/ General Communiqué	Ministry of Treasury and Finance
Ordinance on Industrial Safety and Health (BetrSichV)	BFM - Federal Ministry of Finance	Occupational Health And Safety Law (No. 6331)	The Ministry of Labor and Social Security
		Regulation On Health And Safety Conditions In The Use Of Work Equipment	

Source: Developed by the Consultant

The above table provides a comprehensive overview of the German legal framework for hydrogen energy. It outlines relevant laws, responsible authorities, their areas of influence, and potential Turkish equivalents. Germany's hydrogen regulations are not consolidated in a single law. Instead, they are spread across various existing laws and ordinances adapted for hydrogen. The German government is actively revising and amending legislation to create a more streamlined and supportive environment for hydrogen development. Key areas addressed include hydrogen production, transportation, storage, and utilization by end-users.

Overall, the table highlights the need for Türkiye to develop a comprehensive hydrogen framework law similar to Germany's approach. Streamlining permitting processes and establishing clear regulations are crucial for attracting investment in Türkiye's hydrogen sector. Collaboration between relevant Turkish ministries and institutions is essential for effectively implementing hydrogen regulations.

RELEVANT INFORMATION ON THE LEGAL FRAMEWORK:

1. Production and Manufacturing Regulations - National and International Standards

EU:

On 10 February 2023 the Commission adopted two delegated acts related to the production and certification of renewable hydrogen. The Delegated Regulation on Additionality establishes the rules for the production of RFNBOs (Renewable Fuels of Non-Biological Origin). The Delegated Regulation on GHG (Green House Gas) Savings establishes rules for calculating life-cycle GHG emissions for RFNBOs. The rules apply to domestically produced and to imported hydrogen.

These Acts are part of a broad EU regulatory framework for hydrogen that includes energy infrastructure investments, state aid rules, and legislative targets for renewable hydrogen for the industry and transport sectors. They will ensure that all renewable fuels of non-biological origin (RFNBOs) are produced from renewable electricity. Foreseen under Articles 27(3) and 28(5) of the Renewable Energy Directive, the two Acts are interrelated, and both are necessary for the fuels to be counted towards EU countries' renewable energy targets.

Regarding the determination of standards, the first Delegated Act Defines when hydrogen, hydrogen-based fuels or other energy carriers can be considered as a renewable fuel of non-biological origin, or RFNBO. The rules are to ensure that these fuels can only be produced from “additional” renewable electricity generated at the same time and in the same area as their own production.

The European and international levels are the main sources of standardisation for hydrogen production. For the further development of European standards, it is important that the potential draft hydrogen standardisation request that has been prepared between CEN and DG Energy is updated and that additional requests be published as needed.

The Proposal For Regulation On The Internal Markets For Hydrogen ensures access to liquid markets for hydrogen producers and customers and the integrity of the internal gas market through upcoming regulatory reviews (e.g. review of gas legislation for competitive decarbonized gas markets).

Also, additional support measures for renewable hydrogen production have been identified in the provisions of the Renewable Energy Directive, including demand-side policies in end-use sectors.

For standards, a common threshold has been included in the proposed directive on the internal market for hydrogen to incentivize hydrogen production plants based on their whole life cycle GHG performance and to introduce a common low carbon threshold/standard for low carbon hydrogen.

The European Hydrogen Bank's aim is to support the scale-up of the hydrogen production market within the EU and connect EU renewable hydrogen supply with demand.

EU Emission Trading System; includes the production of hydrogen using electrolyzers.

The Commission published a communication on The European Hydrogen Bank on 16 March 2023 to accompany its legislative proposal for a Net-Zero Industry Act that seeks to boost EU manufacturing of clean technologies, including renewable hydrogen.

Germany:

The German National Hydrogen Strategy (Nationale Wasserstoffstrategie - NWS) aims to "establish hydrogen technologies as key elements of the energy transition to decarbonize production processes with the help of renewable energies" and "secure and shape the future national supply of CO2-free hydrogen and derivative products".

One of the options available to Member States under the Renewable Energy Directive (RED) is to increase the share of Renewable Energy Sources and waste heat/cooling by at least one percentage point/year, calculated on average for each of the periods 2021 - 2025 and 2026 - 2030, starting from the level reached in 2020 (Article 24 (4a)). According to the German National Energy and Climate Plan (NECP), the German legislator has opted for this option and has started to take appropriate measures to increase the share of renewable energy in district heating networks each year. According to the plan, these will mainly be financing measures. In this context, the production and manufacture of hydrogen also offered a large share of financing.

The Federal Chancellor, the Federal Minister for Economic Affairs and Climate Protection and the Federal Minister of Finance have agreed on a joint strategy for power plants. Accordingly, it was agreed that existing obstacles to the construction and operation of electrolyzers should be removed without restriction and that all opportunities should be used to accelerate the deployment of electrolyzers, especially those that must be operated system-supporting. In addition, there should be no double taxation and levies on electricity for storage and electrolysis so that there are market-based and system-beneficial incentives for hydrogen production. The use of surplus electricity will be made possible without restrictions; all existing regulatory barriers will be removed as far as possible. The agreement on the power plant strategy will be discussed with the EU Commission in Brussels this year.

The implementation of the federal government's energy and climate targets is expected to lead to a significant reduction in gas demand. This implies significant changes in the gas market and infrastructure challenges. Not all gas distribution networks will be economically viable. A long-distance pipeline network will be needed today as well as in the future. With the increasing integration of electricity-based methane production and the desired diversification of importing countries, changes are expected, especially in terms of capacity utilization and import routes. The "Gas Roadmap for the Energy Transition" study conducted within the Federal Environment Agency analyzes scenarios from the literature and based on this performs simplified model calculations for infrastructure requirements and associated costs.

The Renewable Energy Act (EEG-Erneuerbare Energien Gesetz) regulates tenders for plants to generate electricity from green hydrogen.

The Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz - BMUV) has prepared detailed specifications for hydrogen production in the German Zuteilungsverordnung (ZuV).

The Regulation on Proof of Origin and Regional Origin of Electricity from Renewable Energies includes regulations that require electricity consumption for green hydrogen production.

The Regulation on Facilities Requiring Authorization (4th BlmSchV) mentions that facilities for hydrogen production are among the facilities requiring authorization.

Türkiye:

Türkiye has a growing interest in hydrogen energy, but it currently lacks a specific legislative framework for its production and manufacturing. However, strategic roadmaps, like the "Türkiye Hydrogen Technologies Strategy and Roadmap," outline plans for its integration into the energy sector. Key goals include reducing production costs and increasing electrolyzer capacity. While no specific regulations exist yet, future strategies are expected to address this gap, potentially including legislation on hydrogen energy usage and production methods.

2. Storage and Transportation Regulations

EU:

Storage : The EU Council was held in 2021, with the Regulation of the European Parliament and of the Council on the Internal Markets for Renewable And Natural Gases And For Hydrogen And Regulation 2017/1938, to increase supply security and address possible crises. These regulations include special measures to increase cooperation and resilience, focusing especially on the effective and coordinated use of storage facilities and operational solidarity arrangements. The proposed measures aim to strengthen the EU energy system in a timely manner against future shocks. It was stated that Member States should explicitly include storage facilities in their regional security of supply risk assessments, taking into account the risks associated with the control of storage facilities by third-country entities.

Transportation : The Commission's upcoming Sustainable and Smart Mobility Strategy and related policy initiatives have proposed measures to facilitate the use of hydrogen and its derivatives in the transport sector. Also, the Renewable Energy Directive includes sub-targets for renewable hydrogen in industry and transport.

The Clean Hydrogen Partnership was established, focusing on key components for renewable hydrogen production, storage, transportation, distribution and priority end-uses of clean hydrogen at a competitive price.

The EU Green Deal's key actions include the European Climate Law to enshrine the climate neutrality objective by 2050 in EU law (the overarching goal of the EU Green Deal) and the introduction of the Fit for 55 and the Hydrogen and Decarbonised Gas Market packages.

The Trans-European Networks for Energy (TEN-E) is a policy focused on linking EU countries' energy infrastructure. Eleven priority corridors and three priority thematic areas have been identified as part of the policy. The EU helps countries in these priority corridors and thematic areas to work together to develop better-connected energy networks and provides funding for new energy infrastructure projects. Energy infrastructure is a key enabler for the energy transition, as reflected in the Commission's communication on the European Green Deal and a Clean Planet for all (COM(2018) 773 final), explicitly referring to the need for a review of the TEN-E Regulation to ensure consistency with climate neutrality objectives.

In EU, recent studies suggest that up to 20% volume of hydrogen can be blended into the existing natural gas grid without requiring major modifications to the infrastructure or causing significant technical issues. Individual EU member states have varying regulations and limitations on hydrogen blending within their own jurisdictions. Some countries haven't yet authorized any hydrogen blending in their natural gas networks. Countries like France, Spain, and Austria have limits ranging from 4% to 6%.

With RePowEU, the EU has set a target of importing half of the hydrogen it needs in 2030. However, since transporting hydrogen is costly, three main options are currently being discussed in the EU. These are as follows: pipelines, transportation of liquid hydrogen, and transportation of a hydrogen carrier substance such as ammonia. The EU Commission announced in

REPowerEU that it would develop a hydrogen infrastructure mapping by March 2023. The preliminary analyses in REPowerEU already contained “hydrogen import corridors”, which entail hydrogen imports from the EU’s neighbouring regions.

Germany:

Storage: With a gas storage volume of around 24 billion cubic meters (about 250 terawatt hours (TWh)), Germany has the largest gas storage volume in the EU. The German Bundestag decided in 2023 to take the first step towards building a pipeline network for hydrogen. Central connections between ports, power plants, storage facilities and industrial centres are planned to be prepared over the next ten years.

Pursuant to Article 24(8) of the RED, electricity grid operators are obliged to assess, at least once every four years in each of their regions, the potential of remote heating or cooling systems to store surplus electricity from renewable energy sources and to provide balancing and other system services, such as demand response, in cooperation with local user groups.

According to the German 2023 Market Reform Plan Monitoring Report, "The power plant list of the Federal Network Agency (Die Bundesnetzagentur - BNetzA) maps the electricity generation market in Germany. According to this list, a total of 243 GW of net nominal capacity generation plants are installed in Germany (as of July 19, 2023). Of this, 234.1 GW participate in the electricity market. Renewables account for around 150.5 GW of this (62.0%). A further 34 GW will exit the electricity market in the long term, to phase out coal-fired electricity generation. In response to the energy crisis, several fossil-fuel coal and oil power plants were temporarily allowed to continue operating on the market. In the medium term, Germany will replace these capacities primarily through the expansion of renewable energies, initially with gas and later with hydrogen-fired power plants (CHP)."

The Renewable Energy Act (EEG-Erneuerbare Energien Gesetz) paves the way for tenders for innovative concepts with hydrogen-based electricity storage.

Transportation: In July 2023, the planning status for a supra-regional hydrogen core network up to 2032 was presented with 309 hydrogen projects taken into account, a length of around 11,200 km, a hydrogen feed-in capacity of around 101 GW and a feed-out capacity for the hydrogen supply of 87 GW. of 87 GW for hydrogen supply. Comments from all stakeholders were recorded and consolidated in the draft application for the hydrogen core network and submitted to the Federal Network Agency and the BMWK on 15 November 2023. This optimised core network now has a length of 9,700 km, with a 60 per cent share of converted natural gas pipelines and investments totalling 19.8 billion euros. The feed-in and exit capacities amount to around 100 GW and 87 GW, respectively.

The amendment to the EEG defines the term "energy" in section 3 no. 14, where hydrogen is categorised as an independent energy carrier alongside gas. However, this only applies to pure hydrogen pipelines. The existing legal framework continues to apply for the blending of hydrogen into the natural gas network, based on the fact that hydrogen produced by electrolysis falls under the definition of gas.

Since individual EU member states have varying regulations and limitations on hydrogen blending within their own jurisdictions, and technically, it has been marked that 20% blending is possible, with the highest limit, Germany allows up to 10% blending (with exceptions for specific situations). The current regulations within the EEG establish various responsibilities at the point of blending or the use of a separate hydrogen pipeline, with optional rights given to hydrogen distributors. You may find relevant information in detail as follows:

In the current legislation, as mentioned above, Germany allows up to 10% volume of hydrogen to be blended into the natural gas grid as per the DVGW Technical Rules (Deutsche Vereinigung des Gas- und Wasserfachs - German Technical and Scientific Association for Gas and Water). Higher blending (up to 20%) is permitted for pilot projects with specific approval and under controlled conditions. These projects aim to test the feasibility and safety of higher blends. The German

government is currently working on revising the Gas Network Access Ordinance (Gasnetzzugangsverordnung - GasNZV), which regulates access to the natural gas grid. This revision might pave the way for increasing the legal limit beyond 10% in the future.

Several pilot projects in Germany are testing higher hydrogen blends (up to 20%) in real-world conditions. One notable example is the Westnetz GmbH project in Düren, which injected 20% hydrogen into the local gas network in October 2023. These projects are crucial for gathering data and informing future regulations.

In addition, German gas industry associations like DVGW and the Association of the Supra-regional Gas Transmission Grid Operators (Vereinigung der Fernleitungsnetzbetreiber im Gasbereich e.V. - FNB Gas) are actively involved in developing standards and guidelines for hydrogen blending, promoting its safe and efficient implementation.

Türkiye:

Türkiye is in the process of embracing hydrogen as a clean energy source, although specific legal frameworks for storage and transportation are still in development. International standards guide safety measures, while the Türkiye Hydrogen Technologies Strategy and Roadmap aims to establish infrastructure by 2053. The Ministry of Industry and Technology is expected to lead legislative efforts, focusing on technical standards and incentives. The General Directorate of Energy Affairs is also examining domestic storage incentives.

3. Hydrogen Quality Standards - National and International

EU:

The European Union is working on two separate proposal texts: the "Common Rules For The Internal Markets In Renewable And Natural Gases And In Hydrogen" Directive and the "Internal Markets For Renewable And Natural Gases And For Hydrogen" Regulation. Among these proposals, the definition of 'hydrogen quality' for the purpose of 'hydrogen systems' must now meet the applicable 'hydrogen quality standards' is included in the EU legislation as "means hydrogen purity and contaminants in line with It will be added as "applicable hydrogen quality standards for the hydrogen system", meaning it is still working on determining the quality standard in the EU.

The Renewable Energy Directive (RED II) indirectly sets sustainability criteria for renewable hydrogen, impacting its quality. The forthcoming Delegated Acts under RED II will further refine these requirements. Additionally, the European Committee for Standardization ("CEN") develops harmonized standards for hydrogen quality, which are crucial for market acceptance but not legally binding. In the "Hydrogen Standards Appendix-1: CEN CENELEC Technical Committees" and "Appendix-2: All European Hydrogen Standards based on CEN CENELEC, ISO and European Standards", you may find detailed and technical information on the standardisation of hydrogen energy.

Germany:

Germany can implement additional national regulations for hydrogen quality or adopt existing CEN standards as national ones. They often utilize technical guidelines and standards developed by national organizations like the German Institute for Standardization (Deutschen Instituts für Normung -DIN).

For instance, the BMWK-funded project called "Standardization Roadmap Hydrogen Technologies" has been actively supporting the rise of the hydrogen market and helping to create a high-quality infrastructure for hydrogen technologies. The DIN funds this project, the German Commission for Electrical, Electronic and Information Technology (Deutschen Kommission Elektrotechnik Elektronik Informationstechnik-DKE), the German Gas and Water Association (Deutschen Vereins des Gas- und Wasserfaches -DVGW), The Association For The Standardization and Further Development of the Railway Industry (Vereins für die Normung und Weiterentwicklung des Bahnwesens - NWB) and is a joint initiative of the

Association of the German Automotive Industry (Vereins Deutscher Ingenieure - VDA), the Federation of German Engineers (Verbands der Automobilindustrie - VDI) and the German Engineering Federation (Verbands Deutscher Maschinen- und Anlagenbau - VDMA).

Türkiye:

Although hydrogen energy lacks specific standards in Turkish legislation, efforts to establish a legal framework in collaboration with EMRA, TENMAK, and EIGM are underway. Türkiye currently relies on existing international standards for hydrogen quality, similar to those of the EU.

4. Security and Safety Standards and Regulations

EU:

The EU has several regulations directly impacting hydrogen safety and security. The Agreement concerning the International Carriage of Dangerous Goods by Road (“ADR”), which is crucial for ensuring the safe and secure transportation of hydrogen across borders within the EU and beyond, and Regulations concerning the International Carriage of Dangerous Goods by Rail (“RID”) regulates the transportation of dangerous goods, including hydrogen, by road and rail, respectively. It's important to note that while RID is not an EU-specific regulation, it plays a significant role within the EU framework for hydrogen safety and security, considering the extensive rail network within the region. The SEVESO Directive (Directive 2012/18/EU) controls major accident hazards involving dangerous substances, including hydrogen. SEVESO Directive protects public health and the environment from potential accidents involving hydrogen and other dangerous substances. Furthermore, the European Committee for Standardization (“CEN”) also develops harmonized standards for hydrogen infrastructure design, construction, operation, and maintenance, promoting safety and security. An additional consideration is that the International Organization for Standardization (“ISO”) and the International Electrotechnical Commission (“IEC”) have been playing crucial roles in developing international standards that can influence the European framework. In the “Hydrogen Standards Appendix-1: CEN CENELEC Technical Committees” and “Appendix-2: All European Hydrogen Standards based on CEN CENELEC, ISO and European Standards”, you may find detailed and technical information on the standardisation of hydrogen energy.

Germany:

Similar to quality standards, Germany can implement additional national regulations related to safety and security or adopt existing CEN standards. German regulations often follow international standards like ISO and IEC, but specific national requirements might exist. For instance, CEN standards might have outlined general training requirements, and Germany could have additional national regulations mandating specific training modules or certifications for personnel working with hydrogen infrastructure. Also while harmonized standards might exist for basic labeling, Germany could have additional national requirements specifying the format, language, or specific information displayed on hydrogen station labels. Additional regulations may have been needed at the national level not covered by EU or ISO standards, which could be a new technology or hydrogen application requiring additional national oversight.

Türkiye:

As Türkiye advances its hydrogen initiatives, there are no specific national safety standards in place yet. However, collaborations with stakeholders, including EMRA, are expected to lead to the development of tailored safety standards based on international best practices, such as ISO and IEC. While EMRA has some safety control authority, it's subject to regulations governing such controls.

5. Environmental Regulations

EU:

The EU Hydrogen Strategy addresses supporting the decarbonization of industry, transport, energy production and buildings across Europe through regulation, market creation, research and innovation in an integrated energy system.

To help implement a hydrogen strategy for a climate-neutral Europe, the Commission has launched the European Clean Hydrogen Alliance with industry leaders, civil society, national and regional ministers, and the European Investment Bank. The Alliance will create an investment pipeline for scaled-up production and support the demand for clean hydrogen in the EU.

The Hydrogen Bank will act as a significant financing program to accelerate the hydrogen value chain. This market-building tool that supports both the local production and consumption of renewable energy sources and the import of low-carbon hydrogen and hydrogen and its derivatives targets Europe's decarbonization.

The EU's Carbon Border Adjustment Mechanism (CBAM) is the EU's tool to put a fair price on the carbon emitted during the production of carbon-intensive goods entering the EU, and to encourage cleaner industrial production in non-EU countries. The gradual introduction of the CBAM is aligned with the phase-out of the allocation of free allowances under the EU Emissions Trading System (ETS) to support the decarbonisation of EU industry.

The review and revision of the Gas Directive 2009/73/EC and Gas Regulation (EC) No 715/2009 is referred to as the Hydrogen and Gas Markets Decarbonisation Package, published in December 2021. It enables the market to decarbonise gas consumption and puts forward policy measures required for supporting the creation of optimum and dedicated infrastructure and efficient markets.

Germany:

As part of the BImSchG procedure, during the authorization process for hydrogen production, the authorities also carry out a preliminary assessment to determine whether the planned plant will have a significant negative impact on the environment. If this is the case, a full environmental impact assessment (EIA) (Umweltverträglichkeitsprüfung (UVP)) is required in accordance with the procedure laid down in the Environmental Impact Assessment Act (Gesetz über die Umweltverträglichkeitsprüfung (UVPG)). In practice, however, preliminary assessments almost always conclude that there is no potential risk.

Under the German Emergency Climate Protection Program, investment incentive schemes are organized to promote green hydrogen conversion, particularly in other renewable energy sources, to reduce greenhouse gases.

Türkiye:

Türkiye's Environmental Impact Assessment (EIA) Regulation, established in December 2019, covers various projects, including renewables, but doesn't specifically address hydrogen energy due to its nascent stage. However, indirect factors like electrolysis and storage methods might prompt EIA considerations. For example, electrolysis projects would assess the environmental impact of electricity sources, while storage and transportation methods might require evaluation of potential environmental risks like leaks or accidents.

End-Use Sector Integration

EU:

The integration of the energy system of the different energy production and end-use sectors is at the heart of Europe's decarbonisation strategy. The decarbonisation of the EU energy market is divided into the following four steps: Decreasing energy demand, increasing the share of electricity, creating affordable renewable fuels, and last but not least, integrating the energy system.

Germany:

Renewable Energy Directive Article 24 also envisages strengthening consumer rights. In particular, end consumers need to be informed about energy efficiency and the share of renewable energy in district heating supply. It is not clear how this should be done in the case of district heating, as the operator of a district heating network in Germany usually does not have direct access to the end consumer. However, the European legislator has taken this into account in that information can also be provided on the provider's website or in the annual bill. The German legislator will therefore have to decide how information will be published by RES companies in practice when implementing the regulation.

In addition, customers of FW systems that are not efficient systems within the meaning of Article 2 No. 41 of the Energy Efficiency Directive (Energieeffizienzrichtlinie - EED) have the right to terminate or modify the contract to generate heat from renewable sources themselves. This provision partly corresponds to § 3 sentence 3 of the AVBFernwärmeV (contract modification), which is already in force. Amendments to national law are therefore only partially necessary. Suppose the cancellation is associated with the physical disconnection of the customer from the district heating network. In that case, RED II provides the district heating network operator with the possibility of compensation for the costs directly associated with the disconnection as well as for the non-amortizable costs associated with the heat supply to this customer. In the case of apartment buildings, the cancellation or modification of the contract can only be applied to the entire building.

Article 14 of the Directive contains an obligation for Member States to comprehensively assess the potential for the use of high-efficiency cogeneration and efficient district heating and cooling. Where the assessment shows that there is potential for the use of high-efficiency cogeneration or efficient district heating and cooling, Member States shall take appropriate measures to take into account these technologies and the use of heating and cooling from waste heat and renewable energy sources.

Member States shall ensure that any support available for cogeneration is conditional on the electricity generated being from highly efficient cogeneration. According to the requirements of the EED, high-efficiency cogeneration should achieve primary energy savings of at least 10% compared to reference values for separate electricity and heat generation. The efficient district heating and cooling definition in Article 2 No. 41 of the EED is also important in this context. Many legal regulations, including state aid regulations (GBER, UEBLL) and the Renewable Energy Directive (RED II) refer to this definition. An efficient district heating or cooling system is, therefore, one that uses at least 50% renewable energy, 50% waste heat, 75% CHP heat or a combination of these energies and 50% of this heat.

Türkiye:

In Türkiye, there are currently no specific regulations governing the integration of hydrogen energy into end-use sectors such as industry, transportation, and buildings. As the country explores hydrogen as a clean energy source, the focus is primarily on establishing foundational aspects like production and storage.

For instance, while the use of hydrogen in fuel cells for vehicles falls under the oversight of EMRA, the regulatory body for electric vehicle charging stations, specific regulations for hydrogen integration are still in development. Discussions are underway in the Turkish Grand National Assembly to enhance incentives and grants under existing energy efficiency laws, potentially expanding their scope to include hydrogen integration projects.

3.2.1.3 Permitting and Licensing

Regarding the regulation of the permission process in the EU, despite not being officially formalized, extensive negotiations between the European Parliament, the Council, and the Commission resulted in an interim political agreement on November 29, 2023. Documents from the tripartite meeting indicated a general consensus, particularly on a technical level, to exclude electrolyzers from the Industrial Emissions Directive (IED) coverage.

At the European level, the European Commission has already proposed a revision of the Industrial Emissions Directive for 2022. However, the initial proposal did not incorporate the exclusion of electrolyzers from the directive's scope. The report from the European Parliament suggested excluding electrolyzers only if their production capacity remained below 50MW electricity input (Annex I, point 4(2) lit. a). Conversely, the Council's general approach explicitly excluded electrolyzers without limitations. Yet, in a subsequent provision in Annex I, under point 6(6), the Council aimed to reintroduce electrolyzers with a production capacity exceeding 60 tonnes per day into the scope of the IED. The final decision on which option will be agreed upon remains uncertain.

As a consequence of European Union (EU) regulations, hydrogen production plans, regardless of the production methods, are subject to:

- Risk Assessments (as operationalized from the general obligations in the SEVESO Directive).
- Health and Safety requirements and conformity assessment procedures, as envisioned by the ATEX Directive.
- Integrated Environmental obligations, as the Industrial Emissions Directive (IED) requires.
- Environmental Impact Assessment procedures, as envisioned by the Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA) Directives.

While certain countries like Austria and the UK have centralized the authority to oversee the hydrogen production plant permitting process, in most others, such as Germany, various permits (construction, environmental, operating, etc.) must be obtained from different authorities, including local municipalities, regional, decentralized bodies, fire brigades, and working environment authorities. Due to the more stringent regulations in the EU compared to individual countries, below, you can observe a comparative analysis of the regulations between the EU and Türkiye to enable a more comprehensive comparison.

Table 14 Comparison of EU and Turkish Legislation

PRODUCTION OF HYDROGEN	
1. Safety and Health Protection:	
EU Legislation	TR legislation
Council Directive 98/24/EC of 7 April 1998 on the protection of the health and safety of workers from the risks related to chemical agents at work	Constitution of the Republic of Türkiye (T.C. Anayasası): Article 56 guarantees the right to a healthy and balanced environment and imposes a duty on the state to take necessary measures to prevent environmental pollution.
Directive 2009/104/EC of the European Parliament and of the Council of 16 September 2009 concerning the minimum safety and health requirements for the use of work equipment by workers at work	Law on Occupational Health and Safety (No. 6331): This law establishes the framework for ensuring workers' physical and mental well-being in workplaces. It outlines employer responsibilities regarding risk assessments, providing personal protective equipment, and establishing safe work practices.
Directive 1999/92/EC of the European Parliament and of the Council of 16 December 1999 on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres	Regulation on Occupational Health and Safety (RG-1 details the specific requirements for implementing the Law on Occupational Health and Safety. It covers areas like workplace inspections, employee training, and accident reporting.

Directive 2014/68/EU of the European Parliament and of the Council of 15 May 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment.

Regulation On Health And Safety Conditions In The Use Of Work Equipment: This regulation has been prepared within the framework of compliance with the European Union legislation, taking into account the European Parliament and Council Directive No. 2009/104/EC dated 16/9/2009 regarding the minimum safety and health conditions in the use of work equipment by employees in workplaces.

2. Environmental Protection:

EU Legislation	TR legislation
2023 Delegated Act on a methodology for renewable fuels on non-biological origin, defines under which conditions hydrogen, hydrogen-based fuels, or other energy carriers can be considered as renewable fuels of non-biological origin (RFNBO)The second act provides a methodology for calculating life-cycle greenhouse gas emissions for RFNBOs.	Environmental Law (No. 2863): This law sets the foundation for environmental protection in Türkiye. It defines environmental policies, establishes the Ministry of Environment, Urbanisation and Climate Change as the primary authority, and outlines regulations for various aspects like pollution control, waste management, and environmental impact assessments.
Directive 2012/18/EU of the European Parliament and of the Council of 4 July 2012 on the control of major-accident hazards involving dangerous substances (so-called SEVESO Directive)	Regulations such as Regulation on Environmental Impact Assessment, Regulation on Environmental Permit and Licence, Regulation on Combating Air Pollution, Regulation on Water Pollution Control, Regulation on Waste Management also support the law and provide detailed regulations.
Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control (IED)	Regulation on the Control of Air Pollution Caused by Stationary Sources (RG-21 establishes emission limits for air pollutants released from industrial facilities.
Directive 2014/52/EU of the European Parliament and of the Council of 16 April 2014 amending Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment).	Regulation on Environmental Impact Assessment: There is currently no specific EIA regulation regarding hydrogen energy in Türkiye. However, the general regulations regarding "Hydrogen and Hydrogen Production Facilities" in Annex I of the EIA Regulation must be complied with. There is generally no EIA requirement for facilities that produce hydrogen through electrolysis.
Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment (SEA Directive)	Regulation on the Control of Water Pollution (RG-12): This regulation sets standards for wastewater discharge and outlines measures to prevent water pollution.
Directive 2004/35/CE of the European Parliament and of the Council of 21 April 2004 on environmental liability with regard to the prevention and remedying of environmental damage	
3. Classification, Labelling, and Packaging:	
EU Legislation	TR legislation
European Regulation (EC) No 1272/2008 on classification, labelling and packaging of substances [CLP regulation]	Regulation on the Classification, Labeling and Packaging of Substances and Mixtures (KKDYB Kimyasalların Sınıflandırılması, Etiketlenmesi ve Ambalajlanması Hakkında Yönetmelik): This regulation aligns with the European Union's (EU) CLP Regulation (EC No 1272/2008) and ensures the classification, labeling, and packaging of substances and mixtures according to their hazardous properties.

4. Equipment and Systems in Explosive Atmospheres:	
EU Legislation	TR legislation
ATEX Directive 2014/34/EU - covering equipment and protective systems intended for use in potentially explosive atmospheres	Regulation on Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres (ATEX Directive Implementation) (RG-34): This regulation transposes the requirements of the ATEX Directive (2014/34/EU) into Turkish law. It ensures the safety of equipment and systems used in areas with a risk of explosion.
Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment (EIA Directive)	Regulation on Environmental Impact Assessment: This regulation requires the assessment of the environmental impacts of certain projects, similar to the EIA Directive (2011/92/EU) in Türkiye. EIA requirements are determined according to criteria such as scope, size, and location of plans and programs.
5. Market Availability and Harmonization:	
EU Legislation	TR legislation
Directive 2014/68/EU of the European Parliament and of the Council of 15 May 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment.	Law on Standardization (No. 5662) establishes the Turkish Standards Institution (TSE) as the national body for standardization and conformity assessment.
	Turkish Harmonization Process: Türkiye actively participates in the harmonization process with the European Union. This involves adopting EU directives and regulations into national law, ensuring product safety and facilitating market access for Turkish goods within the European market.

Source: Developed by the Consultant

In terms of Germany, The Federal Council of Germany urged the German government to facilitate permit requirements in the EU negotiations for revising the Industrial Emissions Directive at the national level. In many cases, hydrogen production plants are treated as traditional chemical facilities, disregarding the specific H₂ production method (PEM, alkaline, reforming...etc) or the presence of hazardous substances. This burdens environmentally friendly methods, subjecting them to the same requirements as industrial processes emitting emissions. The absence of streamlined processes for small-scale production further complicates environmental procedures.

In compliance with German law, the operation of electrolysis installations requires approval. To streamline the permitting process for electrolyzers, the Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz (Federal Ministry for the Environment, Nature Conservation, Nuclear Safety, and Consumer Protection, "BMUNV") is in the process of amending the 4. Verordnung über genehmigungspflichtige Anlagen (Ordinance on Installations Requiring a Permit, "4. BImSchV"), which complements the Bundes-Immissionsschutzgesetz (Federal Immission Control Law, "BImSchG"). The draft, published in German at the end of November, aims to anticipate amendments to the Industrial Emissions Directive (IED) and initiate the directive's transposition into German law before its formal adoption.

The German government aims to expedite the permitting process by eliminating unnecessary barriers while ensuring the safety of high-output installations. The draft proposal, presented by the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety, and Consumer Protection (BMUNV), suggests that electrolyzers with a capacity of up to 5 MW will be exempt from permitting requirements under the Federal Immission Control Act. However, installations with a rated electrical output of 68 MW or more, and a production capacity exceeding 50 tonnes of hydrogen per day, will require a permit under the same Act. Although the draft has not yet entered the formal parliamentary process, it outlines key changes to streamline the approval of electrolysis facilities.

As of today, the operation of electrolysis installations requires approval under the Federal Immission Control Act (BImSchG). To simplify the licensing process for electrolyzers, the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety, and Consumer Protection (BMUNV) is revising the Ordinance on Installations Requiring a Permit (4. BImSchV), which complements the Federal Immission Control Act (BImSchG). The draft, published in November 2023, aims to anticipate amendments to the Industrial Emissions Directive (IED) and proactively incorporate these changes into German law before their official adoption.

The legal framework lacks differentiation between industrial and non-industrial scale hydrogen production, necessitating a case-by-case assessment to determine the applicable permitting procedure. It is interpreted to include any installation used for commercial purposes, even if small-scale. As defined in the Federal Immission Control Ordinance, industrial-scale electrolyzers also fall into the scope of the Industrial Emissions Directive. Consequently, even electrolysis plants with relatively small capacities may undergo an extensive permitting process involving public participation under the Federal Immission Control Act and an environmental impact assessment as outlined in the Environmental Impact Assessment Act. This procedural complexity has the potential to impede investments and hinder economies of scale for smaller units. Currently, small-scale hydrogen production through electrolysis poses no significant environmental hazards, allowing for the exclusion of a general environmental pre-assessment up to a specific plant size.

In Germany, the permitting procedure for centralized hydrogen production facilities is governed by §10 of the Federal Immission Control Act, requiring a formal process with public participation (The permit procedure under BImSchG prescribes public participation. Therefore, the authority publishes the application documentation. The interested public is provided the opportunity to comment on the project.), including the building permit procedure and environmental impact assessment (Environmental Impact Assessment Act (Gesetz über die Umweltverträglichkeit, UVPG), Ordinance on Industrial Safety and Health (Betriebssicherheitsverordnung, BetrSichV), Hazardous Incident Ordinance (Störfallverordnung, 12. BImSchV), Ordinance for the protection of hazardous substances (Verordnung zum Schutz vor Gefahrstoffen) and Federal State Building Regulations (Landesbauordnung), Directive 2011/92.

To build a hydrogen production facility, considering permitting requirements and agreements apart from land use planning, the main requirements and applicable regulations include:

a - Environmental Assessment:

- Permit for construction and operation under the Federal Immission Control Act, which includes the building permit.
- Environmental impact assessment based on the following criteria:
 - For hydrogen storage on-site $\geq 200t$ – mandatory environmental impact assessment.
 - For hydrogen industrial production facility or hydrogen storage on-site $\geq 30t < 200t$ – an environmental impact assessment is required if the project could have a significant negative impact on the environment.
 - For hydrogen storage on-site $> 3t < 30t$ – an environmental impact assessment could be required based on specific local circumstances.

b - Risk Assessment:

- Risk assessment according to the Ordinance on Industrial Safety and Health, especially in workplaces with higher potential hazards.

c - Safety Requirements:

- Safety requirements are based on the Hazardous Accidents Ordinance, which includes written concepts for accident prevention, safety reports, alarm and emergency plans, and the appointment of an immission control officer.
- General safety requirements covering equipment and operational safety, emergency, danger, and defense plans, as well as safety distances determined through risk assessments.

d - Others:

- Occupational safety requirements under the Occupational Safety Act and the Ordinance on Workplaces.
- Compliance with requirements from Industrial professional associations, which have the authority to establish accident prevention regulations.

The key steps of permitting in the process include:

1. Defining the project scope.
2. Submitting an approval application with accompanying documents, including an expert opinion from an authorized inspection body (e.g., TÜV, DEKRA) in accordance with safety requirements, fire and explosion protection, and hazardous substances regulations.
3. Providing information to the public through project announcements, disclosure of approval applications, an opportunity for objections, and public display of plans.
4. Issuing construction and operation permits, including the building permit.
5. Commissioning.

In the case of green hydrogen production permits, there are gaps in Türkiye, as in most EU countries, and there is no general permit scheme. At this point, there are general permits required when commissioning a plant. When these permit procedures are examined, it is seen that they are based on 3 pillars: environmental impacts in the plant, fire and other risks, occupational health and safety issues.

While the current regulations are not specifically outlined for hydrogen, considering the permissions and licenses required to establish an industrial facility and commence production within the borders of Türkiye, additional permits may be necessary in accordance with existing laws for the project.

Several kW scale electrolyzer installation project were reviewed in Türkiye and found that the operator company didn't applied for any permission due to lack of procedure. As stipulated in the current laws, certain permits may require additional approvals in case the nature of the permit-subject situation changes. Areas that may require additional permits when evaluating hydrogen production within this scope are outlined below.

- ✓ CED (Environmental Impact Assessment): Permission specified in the Environmental Impact Assessment Regulation issued per the Environmental Law No. 2872, indicating whether an Environmental Impact Assessment is necessary.
- ✓ Emission Permit: Permit according to the Air Quality Protection Regulation issued in accordance with the Environmental Law No. 2872, specifying emission limits.
- ✓ Fire Competency Certificate: Fire competency certificate regarding the adequacy of measures taken against fires and explosions, as specified in Civil Defense Law No. 7126 and related regulations.
- ✓ Establishment Permit and Operation Certificate: Permit for establishment and operation, as required by the Occupational Health and Safety Regulation specified in the Labor Law No. 4857.
- ✓ Emergency Power Units (Generator) Facility Approval: As specified in the Electricity Market Law No. 4628 and related regulations, approval is required for emergency power units' facilities. The project is submitted for approval to the Ministry of Energy and Natural Resources.

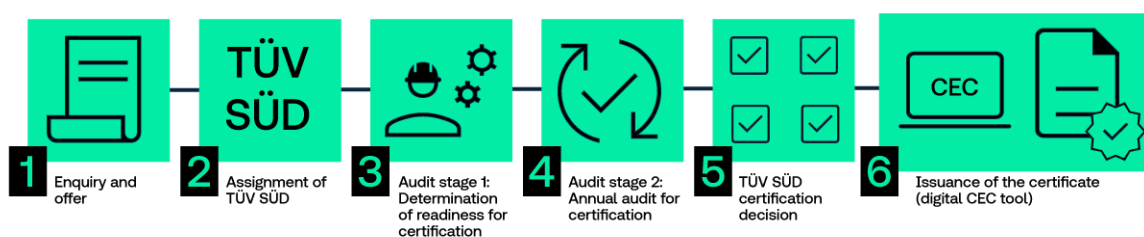
- ✓ **Energy Permit Certificate:** Certificate for energy consumption facilities as specified in the Electricity Market Law No. 4628 and related regulations, indicating energy permit for energy consumption facilities.

3.2.1.4 Certification

TÜV SÜD, a German company, has established a private standard and certification system for Green Hydrogen with a global application focus, particularly emphasizing Germany and Europe. The standard, CMS 70, introduced in 2011, aligns with RED II and the European Union's "fit for 55 strategy."

This certification standard specifically covers renewable hydrogen, excluding certification for low-carbon hydrogen from non-renewable sources. TÜV SÜD conducts the certification audits, but other accredited bodies can perform certifications if they comply with standards like DIN EN 45011:1998, ISO/IEC 17065:2012, or are accepted under the German Renewable Energy Act.

Figure 1 Certification Process



Source: TÜV-SÜD

The standard outlines requirements concerning feedstocks, input energies, and greenhouse gas intensity in production. It offers options such as book&claim or mass balancing for physically delivered green hydrogen. TÜV SÜD's Green Hydrogen provides three alternatives to meet additionality requirements related to renewable electricity used in hydrogen production:

- ✓ **New Installations:** 30% of electricity from renewable sources in facilities operational for the last 36 months.
- ✓ **Technology Mix:** Specific shares of hydropower, wind power, or other renewable sources from facilities in operation after 01/01/2020.
- ✓ **Funding:** A contribution of 0.2 ct/kWh of electricity used in green hydrogen production to a fund supporting renewable energy projects.

The standard is applicable to hydrogen consumption in various sectors, including its use as a chemical feedstock, in transportation, or for electricity storage, including hydrogen injection into the natural gas grid.

TÜV SÜD has contributed to the development of CertifHy and positions its standard as having more extensive requirements, such as mass balancing, compared to the CertifHy scheme. In this framework, the computation of the Carbon Footprint for a production batch must adhere to the methodology outlined in the International Organization for Standardisation (ISO) standards ISO 14044 and 14067. The system boundary encompasses all production stages required to achieve Hydrogen purity of at least 99.9%vol and a gauge pressure of no less than 3 MPa. Furthermore, the renewable source of energy utilized in the form of electricity, gas, or heat from the grid or a district heating network should be verified through the annulment of Guarantees of Origin.

The certified amounts of Green Hydrogen can be registered in the CertifHy guarantee-of-origin system for hydrogen produced from renewable sources, backed by the European Union. CertifHy is an initiative led by a consortium including HINICIO, the Association of Issuing Bodies (AIB), GREXEL, Ludwig Bölkow System Technik (LBST), CEA, and TÜV SÜD, financially supported by the Clean Hydrogen Partnership.

3.2.2 Green Hydrogen and Transition

Under the overarching theme of "Green Hydrogen and Transition," the selected 23 metrics comprehensively evaluate Germany and Türkiye's positions in the global shift towards sustainable and low-carbon energy solutions. The metrics are strategically grouped into three main categories: "CO2 and Industry Metrics," "Renewables, Energy Intensity, and Consumption Metrics," and "Transition and Innovation Index Metrics." This thematic arrangement establishes a clear link between the pursuit of green hydrogen, the broader energy transition, and the innovative strategies employed by each country. By examining aspects such as CO2 emissions, industry contributions, renewable energy adoption, and global rankings in energy transition and innovation indices, the report aims to uncover insights into the countries' commitments to green technologies and their preparedness for a sustainable future. The "Green Hydrogen and Transition" heading serves as a unifying framework, highlighting the interplay between these diverse metrics and their collective impact on fostering a more sustainable and resilient energy landscape.

The first heading delves into CO2 emissions, industry contributions, and energy consumption patterns. The second heading explores renewable energy adoption, energy intensity, and consumption trends. Lastly, the third heading assesses each country's positioning in global energy transition and innovation rankings. These three overarching themes provide a holistic understanding of each nation's environmental commitment, industrial practices, and innovation strategies, facilitating a nuanced comparison and identification of opportunities for improvement in the pursuit of a sustainable future.

The benchmarking study between Germany and Türkiye reveals distinctive environmental and industrial landscapes. Germany emerges as a leader in research and development for hydrogen and fuel cells, reflecting its advanced commitment to sustainable technologies. The nation maintains a strong foothold in renewables and exhibits lower industrial contributions to final energy consumption. On the other hand, Türkiye showcases robust industrial CO2 emission management, leading in the share of CO2 emissions by industry and demonstrating significant strides in the share of renewables. Both countries exhibit unique strengths and challenges, providing valuable insights for tailored policy measures. While Germany sets benchmarks in technological innovation, Türkiye excels in specific environmental and industrial dimensions.

Table 15 Industry and CO2 Metrix - Gernay vs Türkiye

CO2 and Industry - METRICS	GERMANY	TÜRKİYE	UNIT
CO2 Emission	624	401	Mt CO2
CO2 emissions by Industry	14,8%	20,3%	Share
Share of Renewables	38,6%	40,3%	Share
Share of Industry in Final Energy Consumption	25,00%	32,00%	Share
Industry Share of electricity in final consumption	44,00%	47,00%	Share
Natural Gas in Total Energy Supply	24,00%	27,00%	Share
Share of Gas Used by Industry	34,00%	37,00%	Share
Industrial energy use by source - Natural Gas	36,00%	30,00%	Share
Industrial energy use by source - Electricity	33,00%	31,00%	Share
Net Energy Imports	72,4%	73,6%	Share
Trends in Energy Import 2020-2022	1% Decrease	138% Increase	Share

Total RD&D in Million USD - Hydrogen and Fuel Cells	323,1	1,1	Million USD
Energy Consumption by Industry	25,00%	32,00%	Share
Renewables, Energy Intensity and Consumption – METRICS	GERMANY	TÜRKİYE	UNIT
Economy-wide Primary Energy Intensity – 2022	34.366	19.025	Megajoules per \$ GDP
Fossil Fuel Consumption - 2022	13.759	25.324	Exajoules
Carbon Intensity - 2022	53,04	64,64	tonne CO2-eq per Megajoule
Primary Energy Consumption per Capita - 2022	147,52	82,17	Gigajoules per capita
Energy Related Greenhouse Gas Emissions - 2022	652,35	453,25	Million tonnes of carbon dioxide equivalent
Natural Gas Consumption	77,3	51,2	Billion cubic metres
Renewable Power Generation	236,5	71,4	Terawatt-hours
Renewable Electricity generation (GWh)	230.800,2	118.555,36	GWh
RE share of electricity capacity (%)	58,63	53,88	%
Transition and Innovation Index - METRICS	GERMANY	TÜRKİYE	UNIT
WEF - Energy Transition Index 2023	11	65	Ranking
Global Energy Innovation Index 2022	9	51	Ranking
RECAI (EY) index, which ranks countries on the attractiveness of their renewable energy investment and deployment opportunities, 2022	7	25	Ranking

Source; IEA, IRENA, WEF, Energy Institute, WIPO

In this extensive benchmarking study comprising 23 key indicators, we comprehensively compare Germany and Türkiye, unravelling insights into their environmental and industrial performance. Germany exhibits higher CO₂ emissions at 624 Mt CO₂, surpassing Türkiye's 401 Mt CO₂, signalling notable differences in their carbon footprint. Türkiye leads in the share of CO₂ emissions by industry, standing at 20.3%, compared to Germany's 14.8%, highlighting distinct industrial emission patterns. Both countries show comparable commitments to sustainable energy sources, with Germany at 38.6% and Türkiye at 40.3% in the share of renewables. Germany maintains a lower industrial contribution to final energy consumption (25%) than Türkiye (32%). While Germany slightly trails Türkiye in the industrial share of electricity consumption (44% vs. 47%), both nations have comparable shares of natural gas in their total energy supply (24% and 27% for Germany and Türkiye, respectively). Türkiye leads in the share of gas used by the industry (37% vs. Germany's 34%), while Germany relies more on natural gas in industrial energy use (36% compared to Türkiye's 30%). Germany significantly outpaces Türkiye in research and development investment for hydrogen and fuel cells, with values of 323.1 million USD and 1.1 million USD, respectively. In energy consumption by industry, Türkiye surpasses Germany with a share of 32%, while Germany stands at 25%. These results underscore the nuanced energy landscapes and industrial dynamics of Germany and Türkiye, providing valuable insights for strategic and policy considerations.

3.2.3 Financing Green Hydrogen, Tax Regime and Incentives

3.2.3.1 Public Financing

The EU's hydrogen strategy and the REPowerEU plan present a holistic framework to facilitate the adoption of renewable and low-carbon hydrogen. This strategy aims to efficiently decarbonize the EU while diminishing reliance on imported fossil fuels cost-effectively while the REPowerEU Communication from the European Commission has set an ambitious target of producing 10 million tons of renewable hydrogen within the EU, along with an additional 10 million tons of annual hydrogen imports. This plan strengthens the execution of the EU hydrogen strategy, positioning renewable hydrogen as a key energy carrier in the shift away from fossil fuel imports from Russia. To achieve these objectives, a Joint Declaration was signed in May 2022 between EU electrolyser manufacturers and the European Commission, outlining expectations for regulatory advancements and establishing a manufacturing capacity target for 2025.

The evolving geopolitical landscape, especially due to Russia's invasion of Ukraine and global decarbonization efforts, has brought net-zero technologies, particularly electrolyzers, into focus. While the regulatory framework for hydrogen is defined in Europe, ongoing changes introduce uncertainties that impact investment decisions for hydrogen producers and off-takers. The involvement of public financing institutions like the European Investment Bank (EIB) becomes crucial to attracting private investment and addressing scaling risks. Although the EU Innovation Fund has allocated funds for clean tech manufacturing, including electrolyzers, additional measures at the national level are deemed imperative. The inaugural auction under the European Hydrogen Bank, supported by an EUR 800 million budget, aims to bridge the cost gap for renewable hydrogen producers, stimulating demand for electrolyzers. In February 2023, the EU introduced the Green Deal Industrial Plan, allocating 660 billion euros to bolster the competitiveness of the EU's green industry and expedite its shift towards climate neutrality. This initiative is geared towards facilitating manufacturing capacity expansion for net-zero technologies and products essential for achieving Europe's ambitious climate goals.

Germany strongly emphasizes green hydrogen as the primary sustainable pathway towards long-term net-zero goals, viewing blue hydrogen as a transitional measure. Türkiye, through its Medium-Term Program (MTP) for 2024-2026, collaboratively developed by the Ministry of Treasury and Finance and the Presidency of Strategy and Budget, emphasizes the "Green Transition" segment. This underscores the implementation of objectives and actions outlined in the Green Deal Action Plan, specifically focusing on integrating relevant technologies.

On the Turkish side, the economy requires a significant makeover, which aligns well with the principles of the Green New Deal. Despite facing challenges, especially limited financial resources, opportunities presented by the global Green New Deal paradigm, such as the European Green Deal, create a foundation for Türkiye to make rapid and substantial progress.

Table Comparing Financing for Green Hydrogen - Germany vs Türkiye

FINANCING HYDROGEN TECHNOLOGY	
GERMANY	TÜRKİYE

To strengthen its ability to meet climate protection targets and expedite the transition to climate neutrality, the German government has expanded the Energy and Climate Fund (EKF) to establish the Climate and Transformation Fund (KTF). This newly formed fund, operating as a special fund of the Federal Government, has emerged as a crucial financial tool to drive the energy transition and climate protection initiatives. The German government recently approved the budget for its flagship Climate and Transformation Fund (KTF) on August 9, 2023, allocating a substantial 212 billion euros to finance various projects spanning building renovation, industrial decarbonization, and green transition efforts in the industry sector between 2024 -2027. The KTF, being excluded from the typically stringent German spending rules, has become a primary instrument for financing major government projects. For 2024 alone, the government has earmarked 57.6 billion euros for a diverse range of projects to advance the green transition. The Investment Plan to Tackle Climate Change outlines the Fund's economic plan for 2024, with a total allocation of 57.6 billion euros, representing a significant increase of 21.6 billion euros compared to the 2023 target. The German Ministry for the Economy and Climate Protection is set to receive the lion's share, with 47.4 billion euros dedicated to its projects. The priority funding areas encompass a broad spectrum, including energy-efficient enhancements to building infrastructure, reducing industrial carbon emissions, expanding renewable energy sources, promoting electromobility, and establishing a global hydrogen economy. Additionally, the KTF will play a crucial role in supporting the international dimension of hydrogen development. In a notable move, Germany has committed to spending 18.6 billion euros from the Climate and Transformation Fund on the development of the hydrogen industry between 2024 and 2027, with 3.8 billion euros allocated for 2024. This allocation reinforces Germany's dedication to advancing the international dimension of hydrogen initiatives, emphasizing its pivotal role in the global green transition.	As of 2021, Türkiye is actively engaged in initiatives to enhance the National Energy Efficiency Financing Mechanism, as specified in the Green Deal Action Plan. The Republic of Türkiye aims to establish a Sustainable Finance Framework to uphold its sustainability commitments and outline strategies for securing Green, Social, and Sustainable Financing Instruments. Additionally, within the context of energy efficiency support, industrial enterprises with an annual total energy consumption of 500 TEP (ton equivalent of oil) and above have been supported for energy efficiency investments since 2009 under the Energy Efficiency Law No. 5627. These investments, focusing on enhancing efficiency through projects and voluntary agreements, are part of the National Energy Efficiency Action Plan, which aims to make support models for energy efficiency more effective and develop sustainable financing mechanisms. To provide additional financial support for the implementation of energy efficiency investments, the "National Energy Efficiency Financing Mechanism" has been defined. In the National Energy Efficiency Action Plan, a specific Action Code for Hydrogen has been identified, outlining measures under the title "E9 - Taking Measures for the Development of Hydrogen Technology in Harmony with National Energy Targets." During a visit by project experts to the Ministry, it was conveyed that the scope of Energy Efficiency Financing support could be expanded to include hydrogen applications in the industry. Taxonomy has been identified as a crucial factor in the effectiveness of financing mechanisms. Despite the ongoing development of investment incentive mechanisms, there is currently no dedicated budget allocated specifically for hydrogen within this process.
Germany has advanced its commitment to achieving clean energy objectives by unveiling financial support for gas power plants capable of transitioning to hydrogen. In a noteworthy move, the government is set to invest a substantial 16 billion euros to expedite the uptake of low-carbon energy sources. This initiative represents a pivotal milestone in Germany's ambitious transition plan, signalling a dedicated effort to foster the integration of hydrogen technology within its energy landscape.	As per PwC, Türkiye would require a \$9.1 billion investment for the necessary 12.1 GW electrolyzer capacity for green hydrogen production. Shura FRPORT, in analyzing Türkiye's National Hydrogen Strategy, stated that a \$45.4 billion investment would be needed if 5% of the country's total final energy consumption were to be covered by green hydrogen.
In alignment with this commitment, substantial investments totalling 12.36 billion euros) are anticipated between 2023 and 2040 for the Hydrogen Industry, as outlined by Frost & Sullivan. Key allocations include 3.6 billion euros for the conversion to fuel cells (FCs) in automobiles, trains, and small inland transportation vessels, 3.4 billion euros for developing hydrogen refuelling station (HRS) infrastructure, 1.1 billion euros for research and development (R&D) on hydrogen to synthetic fuels, 1 billion euros for new hydrogen technologies and large-scale facilities, 600 million euros for hydrogen research and industrialization through the Real-World Laboratories program, 50 million euros for R&D on the application of hydrogen in aviation and marine, 700 million euros for FC heaters, and 1.91 billion euros for hydrogen and FCs R&D. Additionally, 9 billion euros is dedicated to supporting the launch of the hydrogen market (7 billion euros), with an additional 2 billion euros earmarked for international collaboration and cooperation.	Even though there is no dedicated financial programme for Hydrogen Production, The announcement dated December 2023 from the Ministry of Industry and Technology of the Republic of Türkiye regarding the "Strategic Prioritization And Technical Evaluation Of Investment Projects" Specifies the following areas as priorities concerning hydrogen: • Low Carbon Emission or Carbon-Free Hydrogen Energy System Technologies (Green, Pink, Blue, Turquoise Hydrogen Production, Transportation, Storage, and Usage, etc.) • Hydrogen Technologies (Development of chemical hydrogen storage systems, Green steel production using hydrogen, etc.)
In the realm of taxonomy, Germany has introduced its green taxonomy specifically for export credits. This classification system bears some similarities to the EU's sustainable finance taxonomy, which categorizes economic activities across the EU based on their impact on six climate and environmental objectives. Within the energy sector, the "green" classification	In line with this, legislation is being prepared in Türkiye to determine the sustainability of investments, considering the taxonomy regulations of the EU and international organizations. The "Guidelines For Reporting And Identification Of Users And Beneficiaries Of Green Taxonomy In Türkiye" report and Taxonomy Framework Document have been prepared by the Ministry of Environment, Urbanization, and Climate Change Balance, and ongoing efforts continue.

encompasses renewable energy, power storage, electricity and heating grids, along with hydrogen production.

3.2.3.2 Tax Structure

The tax structure in Germany is intricately crafted to serve as a supportive financial mechanism for hydrogen production, encouraging a transition towards a carbon-free direction.

In adherence to the Renewable Energies Act (EEG), energy consumers typically bear an EEG levy as part of their electricity expenses in Germany. To mitigate the production expenses associated with hydrogen, the National Hydrogen Strategy has initiated a reassessment to determine if the electricity utilized for green hydrogen production can be exempted from various taxes, levies, and charges, including the EEG levy. Consequently, under the provisions of the updated Renewable Energies Act (EEG 2021), effective from January 1, 2021, companies engaged in green hydrogen production may be entirely relieved from the obligation to pay the EEG levy for the electricity they use. This exemption is anticipated to significantly reduce costs associated with hydrogen production. Additionally, electricity-intensive companies involved in grey hydrogen production may also experience a reduction in the EEG levy.

As of February 27, 2024, electricity used for producing green hydrogen is partially exempt from taxes, levies, and surcharges in Germany. The current levies are the KWKG levy, the offshore grid levy and the Section 19 StromNEV levy, as well as the concession levy, the electricity tax and the grid fees.

- ✓ EEG surcharge (EEG-Umlage): This surcharge has been completely abolished as of January 1, 2023. This means there is no charge on electricity used for green hydrogen production regarding the EEG surcharge.
- ✓ According to Section 25 of the Energy Financing Act (EnFG), the KWKG and offshore grid levy are reduced to zero for electricity used to produce green hydrogen. The facility must be commissioned before January 1, 2030 and the facility is connected to the grid via its own metering point. The requirements for "green hydrogen" are expected to be regulated in an ordinance based on Section 93 of the German Renewable Energy Sources Act (EEG).
- ✓ Combined heat and power levy (KWKG-Umlage): This levy is reduced to zero if the electricity used meets certain criteria, including used to produce green hydrogen. Offshore grid levy is also reduced to zero under the same conditions as the KWKG-Umlage.
- ✓ Electricity Tax Exception: Electricity Tax Act allows waiving, reimbursing, or refunding electricity tax for manufacturing companies using electricity for electrolysis, upon application.
- ✓ Grid Fees Exemption: 118 (6) of the Energy Industry Act allows a 20-year exemption from grid fees for electricity purchased for plants producing hydrogen through water electrolysis. Electrolyser must be newly constructed after December 31, 2008. Commissioned within 18 years from October 4, 2011.

3.2.3.3 Incentives and Support Schemes

In terms of designed incentives schemes, given its ambitious energy and climate objectives outlined in the "European Green Deal," aiming to reduce the EU's greenhouse gas emissions by 55% by 2030 compared to 1990, the European Commission places significant importance on hydrogen in the European energy transition. The primary emphasis is creating a European hydrogen market and developing cross-border hydrogen infrastructures.

The European Union (EU) supports hydrogen production and low-carbon hydrogen initiatives through various programs and funding mechanisms. These include the Connecting Europe Facility – Energy and Connecting Europe Facility – Transport, which focus on enhancing energy and transport infrastructure. The designation of Important Projects of Common European Interest underscores the EU's commitment to strategic initiatives. Horizon Europe, the Clean Energy Transition Partnership, and the European Clean Hydrogen Alliance contribute to research, innovation, and collaborative efforts in the field. Financial support is also provided through programs such as the European Investment Bank (EIB), InvestEU, the Just Transition Fund, the LIFE programme, the Modernisation Fund, and the Recovery and Resilience Facility. Additionally, the Hydrogen Bank

plays a crucial role in supporting hydrogen-related projects and initiatives, reflecting the EU's comprehensive approach to fostering sustainable and low-carbon hydrogen solutions.

Figure 2 European Programmes



Please find the Horizon 2020 Project list of Germany and Türkiye in Annexes.

In June 2020, Germany introduced its National Hydrogen Strategy as a crucial step toward renewable energy adoption and carbon emission reduction. The German government allocated 9 billion euros for hydrogen initiatives to support the strategy. While a comprehensive national hydrogen infrastructure is still in development, Germany's robust gas infrastructure is considered suitable for hydrogen transport. Additionally, localized hydrogen infrastructure clusters in commercial areas, integrating production and consumption, already exist.

Certain aspects of Germany's regulatory framework pose challenges for hydrogen deployment, including relatively high energy costs, partially attributed to the EEG levy. The government has initiated measures to address this issue, with ongoing reforms expected. The Renewable Energies Act (EEG 2021), enacted in January 2021, allows partial EEG levy exemption for electricity used in hydrogen production. Full exemption for green hydrogen generation is possible if specific criteria are met.

Financial support from the Federal Ministry for Economic Affairs and Energy for fuel cell and hydrogen technologies is closely tied to the "National Hydrogen and Fuel Cell Technology Innovation Programme" ("NIP"), initiated in 2006. This program seamlessly transitions into NIP2, covering the period from 2016 to 2025. Until 2016, the Federal Government provided a cumulative total of 700 million euros. From 2016 to 2026, public funding is set to reach 1.4 billion euros. In a forward-looking move in June 2020, the government introduced a "package for the future," allocating an additional 7 billion euros to expedite the market adoption of hydrogen technology within Germany and 2 billion euros to foster international collaborations.

The NIP2 program strategically builds upon technological and market advancements achieved in the initial generation. Aiming for the imminent market launch phase, the objective is to ensure continued collaboration among the scientific community, industry stakeholders, and government entities under a unified framework. The focus remains on advancing innovations in hydrogen and fuel cell technologies not yet market-ready, establishing necessary infrastructure, and employing suitable instruments and measures to support the market introduction of technologies on the verge of widespread adoption.³³

³³ Federal Ministry for Economic Affairs and Energy

The extensive German energy reform legislation, commonly known as the "Easter Package," was officially enacted in 2023. This legislative framework is set to reshape German energy law, introducing significant changes to key regulations like the German Energy Industry Act (Energiewirtschaftsgesetz, EnWG), the German Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG), and the German Offshore Wind Energy Act (Windenergie-auf-See-Gesetz, WindSeeG). With the ambitious goal of conducting two tenders totaling over 8,000 MW, an amendment to the Renewable Energy Sources Act (EEG) specifically targets the market expansion of hydrogen technology.

One tender focuses on innovative hydrogen storage concepts, with the Federal Network Agency commencing the process from 2023, starting at 400 MW. The annual volume is projected to reach 1,000 MW by 2028, resulting in a total tender volume of 4,400 MW. Further criteria for these tenders will be clarified in subsequent legal ordinances. The legislation emphasizes that plant combinations must include onshore wind turbines or solar plants along with a chemical electricity storage system using hydrogen.³⁴

The second tender pertains to electricity generation from green hydrogen plants, aiming for a volume of 4,400 MW by 2026, starting at 800 MW in 2023. The law stipulates that the choice of location should contribute to a secure, cost-effective, consumer-friendly, efficient, and environmentally compatible grid-based supply of electricity, gas, and hydrogen to the general public.

As a subsidy, Germany is gearing up to conduct auctions to promote the construction of new gas-fired power plants, with subsequent conversion to hydrogen-based operation expected in the mid-to-late 2030s. The government's power plant strategy involves tendering new capacities for hydrogen-ready gas-fired power plants, potentially reaching up to 4 x 2.5 GW. These facilities are expected to transition to hydrogen-based operation between 2035 and 2040. Recognizing the importance of "hydrogen-ready" gas plants as a complementary solution to intermittent renewables, the initiative aims to ensure a reliable electricity supply during the country's transition away from coal-fired power generation.

The comprehensive plan includes:

1. Tenders for 15 gigawatts (GW) of both new and existing gas units, requiring conversion to hydrogen by 2035. The initial phase involves auctioning 10 GW, starting from 2024-2026, including up to 6 GW of new projects.
2. Tenders supporting power production from renewables-based hydrogen in 4.4 GW "hydrogen sprinter power plants" located in regions with early access to the fuel. Auctions for new projects or converted gas power plants are scheduled for 2024-2028.
3. Tenders for 4.4 GW of projects integrating renewable electricity with electrolyzers for green hydrogen production, hydrogen storage, and hydrogen power plants.

The CfD Funding Program, initiated by the German Federal Department of Economic Affairs and Climate Protection (BMWK), aims to support the decarbonization of highly emission-intensive industrial enterprises. This program encourages the adoption of climate-friendly technologies, including green hydrogen, by providing government support to mitigate initial financial risks. Contracts for Difference (CfDs) under this program act as hedging instruments, compensating for financial disparities and promoting the development of green technologies. Recipient selection for CfDs occurs through a competitive bidding process based on the lowest costs per tonne of CO₂ avoided, with eligibility criteria focused on operating within Emission Trading System sectors, project size, and climate efficiency. The contractual arrangement includes returning allowances to the government promoting cost reduction, particularly in anticipation of rising CO₂ prices within the Emission Trading System during the 15-year contract period.

³⁴ Federal Network Agency

List of Incentives for Germany - Hydrogen Market and Supply Chain Development

Germany has a novel subsidy programme worth billions of euros in a bid to make its prized heavy industry climate neutral. . Climate protection contracts funding program (Carbon Contracts for Difference, CCfD);To encourage industrial adoption of green hydrogen technologies, like building new electrolyzers, the German government is launching a pilot program for Carbon Contracts for Difference (CfDs).

Through CfDs, the government guarantees to cover the difference between the actual cost of reducing emissions (or a pre-defined project-specific price per ton of avoided emissions) and the current price in the EU Emissions Trading System (ETS). This significantly reduces the risk of fluctuating carbon prices for investors. According to IEA, according to the Carbon Contract for Difference concept, energy-intensive industries will be compensated by climate protection agreements for a period of 15 years to cover their additional costs (OPEX and CAPEX) to convert their production. These climate protection agreements thus make green technologies more attractive for energy-intensive industries.

A double-digit billion budget is expected to be allocated by the federal government for this scheme. In June 2024 European Commission signed off on a EUR 4bn programme for two-way contracts for difference.To be eligible, projects will need to reduce emissions by 60% within three years and by 90% within 15 years. The instruments allow industries and the government to agree on a carbon strike price for a project.

If costs to replace fossil fuels run lower than that, the firm pays the government the difference. Higher replacement costs mean the government owes money. <https://www.bmwk.de/Redaktion/DE/Wasserstoff/Foerderung-National/018-pilotprogramm.html>

Germany has achieved the milestone of being the initial member state to participate in an EU initiative promoting domestic renewable hydrogen production via the European Hydrogen Bank. Through the "Auctions-as-a-Service" program, Germany gains the ability to offer financial assistance to projects within the country that may not have secured EU funding in broader auctions. This allows the government to choose the most competitive projects without the necessity of conducting a separate national auction. The Ministry of Economic Affairs has declared its commitment to allocate 350 million euros for electrolyser projects in Germany and has already earmarked 800 million euros for European projects.

Section 28d of the German Renewable Energy Sources Act (EEG2023) introduces a fresh set of regulations regarding the tender volume and bidding dates specifically tailored for innovative hydrogen-based electricity storage concepts. The inaugural call for proposals under these provisions is scheduled to occur in 2024. The recently established Section 39o of the EEG serves as the legal foundation for these tenders, outlining the prerequisites that system combinations participating in the process must satisfy. Administered by the Federal Network Agency (BNetzA), these tenders are inclusive of facilities that integrate onshore wind turbines or solar power plants with chemical electricity storage utilizing hydrogen as the storage gas.wo tenders with a volume of more than 8,000 MW in total are planned with the EEG amendment in 2023 as part of the so-called Easter Package of the German government. For innovative concepts with hydrogen-based electricity storage (§ 39o EEG 2023), the total tender volume is 4,400 MW (§ 28 f EEG 2023). From December 2023, the first tender will be issued by the Federal Network Agency (BNetzA) with a volume of 400 MW; by 2028, the annual volume will be increased to 1,000 MW.

Funds for launching a hydrogen network with more than Within the EU, invest-ments have been channelled through the IPCEI initiative. The federal government supports participation in projects in the context of EU initiatives. It has also worked to advance the process towards the Important Project of Common European Interest (IPCEI) on hydrogen. This is a central funding instrument for the ramp-up of hydrogen at EU level.1,800 km of pipelines in Germany are expected to flow by 2027/2028 through the bloc's Important Projects of Common European Interest (IPCEI) financing scheme, with the goal of connecting all major generation, import and storage centres to customers by 2030

The German government and KfW Group have consolidated promotional and financing tools within the PtX Platform. (As an institution under public law, KfW Bank 80% of which is owned by the German Federal Government, with the remaining 20% owned by the German federal states). Funding is allocated to projects across the entire PtX value chain, spanning from the generation of green electricity through renewable sources to the production and transportation of green hydrogen and its derivatives. These derivatives, such as methane, methanol, or ammonia, find applications in heavy industry, aviation, shipping, and basic chemicals. The PtX Platform addresses the challenges of bankability, particularly in developing countries and emerging economies across the global South. The primary goal is to support capital-intensive PtX projects that may not currently be considered "bankable" by simplifying the financing process and bridging existing financial gaps. KfW takes on a central role, offering guidance, assembling financing packages, and overseeing project implementation.
In February 2024, The German government announced the transfer more than 3.5bn euros (\$3.8bn) to the country's pioneering green hydrogen purchasing programme, H2Global, in order to fund further subsidy auctions for renewable H2 and its derivatives between 2027 to 2036. H2 Global was born from a public-private dialogue under the umbrella of the Business Alliance Energy (Unternehmensallianz En-ergie). To accelerate the global adoption of green hydrogen and stimulate investments, the government initiated the H2Global project in 2021 through a "double auction" approach. This entails acquiring hydrogen or its derivatives at competitive prices from the international market and subsequently selling them to the highest bidder. The fund is open to Large-scale Companies and SMEs. The H2Global initiative, the first international trading platform for green hydrogen and its derivatives, launched at the beginning of the legislature, is to promote non-European imports of green hydrogen and support the global market ramp-up. In H2Global, prices and quantities for trading in green hydrogen derivatives are to be determined transparently for the first time. The mechanism of H2Global consists of two separate auctions. The first step determines which exporter is offering the lowest price for deliveries of green hydrogen. In a second step, the purchased quantity is auctioned among the interested buyers. The companies with the highest bid are awarded the deliveries. A payment to HINT compensates for the difference between the higher purchase price and the lower sales price.CO GmbH. The cost difference will decrease in the medium term. The required compensation for the cost difference is thus reduced and becomes obsolete in the long term.
Funding within the framework of the IPCEI Hydrogen; IPCEI Hydrogen is designed to foster innovation, demonstration, and deployment of hydrogen technology, comprising four integrated project clusters involving more than half of the European Union member states and Norway. These projects span the entire hydrogen value chain, covering production, import, transportation, and end-use applications. As of now, the European Commission has notified two clusters of projects, referred to as "waves," under State Aid rules. The first wave, named "Hy2Tech," and the second wave, named "Hy2Use," encompass nearly 80 projects, each characterized by substantial individual budgets ranging from several million to several hundreds of millions of euros per project.
H2 Roadmap / H2 Compass Introduction by Federal Ministry of Education and Research (BMBF); The H2 Compass project draws up and evaluates options and application scenarios for hydrogen. The Compass is to serve as the basis for a Hydrogen Roadmap. The BMWK and the BMBF are jointly funding the H2 Compass project in the 7th Energy Research Programme; ACATECHh and DECHEMA are running it. The National Hydrogen Council and the H2 research network are closely involved.
Funding of measures to develop regenerative fuels Technology-neutral and intermodal funding to (further) develop renewable fuel options. The funding particularly goes towards development and demonstration projects and innovation clusters for advanced biofuels, hydrogen, power-to-gas and power-to-liquid. VDI/VDE Innovation + Technik GmbH and Fachagentur Nachwachsende Rohstoffe e. V. (FNR) are the project managers responsible for the funding
The funding program for climate protection contracts aims to assist industrial enterprises in investing in environmentally friendly production facilities that might otherwise lack economic viability, particularly in sectors such as steel, cement, paper, or glass. This immediate investment results in substantial reductions in greenhouse gas emissions. Crucially, this initiative sparks the much-needed transformation of the market, incentivizing developing and constructing essential technologies and infrastructure within Germany. This includes the establishment of production facilities and pipelines for hydrogen, expertise in financing, constructing, and operating eco-friendly plants, and the creation of markets for

environmentally friendly end products (green lead markets). Thus, climate protection contracts serve as a pivotal tool for climate protection and contribute significantly to positioning Germany as a hub for industry and innovation.

Through the 'Decarbonisation of Industry' funding program, the German Federal Ministry for Economic Affairs and Climate Action (BMWK) provided support for projects in energy-intensive industries until the conclusion of 30 June 2024. The program aimed to achieve a substantial and lasting reduction in process-related greenhouse gas emissions. Funding goes towards – in each case in the field of energy-intensive industry with process-related emissions – research and development from TRL 4, trialling in test/pilot facilities and investment in facilities to use and implement measures on an industrial scale which are suited, given the current status of the underlying technologies, to reducing GHG emissions as far and as permanently as possible.

The Federal Ministry for Economic Affairs and Climate Action (Bundesministerium für Wirtschaft und Klimaschutz - BMWK), within the scope of the German export credit guarantees program (Exportkreditgarantien), the federal government has supported projects in the fields of wind and solar energy, green hydrogen and electric railway infrastructure with export credit guarantees in 2023. In export credit guarantees, Türkiye is among the target countries with the highest export transaction volume in 2023, amounting to 2.79 billion euros.

List of Incentives for Germany – Hydrogen R&D – Innovation

The National Organization for Hydrogen and Fuel Cell Technology (NOW GmbH) is a program company for research funding that provides funding programs; <https://www.now-gmbh.de/en/funding/fundingfinder/>

The German Federal Ministry for Economic Cooperation and Development (BMZ) has entrusted KfW with 270 million euros of funds to support Power-to-X markets in developing and emerging countries. KfW has set up Power-to-X D&G GmbH (hereinafter the “PtX Development Fund”) for these purposes. The goal of PtX Development Fund is to provide non-reimbursable grants to industrial-scale projects at various stages along the green hydrogen value chain including production, processing, storage, transportation, distribution and application of Power-to-X technologies as well as additional associated measures for the generation of renewable energy.

National Innovation Programme on Hydrogen and Fuel Cell Technology (NIP) Phase II 2016 – 2026 (research, development and innovation). The aim of the NIP is to establish competitive hydrogen and fuel cell technologies in the transport sector. Support is granted to projects in the field of hydrogen and fuel cell technology, particularly for road, railway, water and air transport, and special applications. The R&D funding is focused on demonstration, innovation and market preparation measures. Funding under the R&D funding guideline, in particular, goes to projects that aim to achieve TRL 5-8.

‘Regulatory Sandboxes for the Energy Transition’ is a pillar in the context of the 7th Energy Research Programme; supplementing basic and applied research, it particularly aims to trial and further develop innovative technologies in a real-life environment and on an industrial scale. In the regulatory sandboxes, project partners take a holistic approach to testing new technologies and business models in real life. Regulatory Sandboxes for the Energy Transition generally start at TRL 6-7 and range up to TRL 8-9. They are thus close to the market and highly mature.

“Hydrogen Republic Germany” competition for ideas | Basic research into hydrogen
Introduction by Federal Ministry of Education and Research (BMBF); The funding goes towards research and development projects for highly innovative solutions for core issues relating to green hydrogen along the entire value chain, materials research and key enabling technologies of the next generation and the generation after that, also system studies to integrate green hydrogen into the energy system, basic research.

Energy Research Programme; This programme provides funding for research and development as a basis for future applications in the fields of transport, hydrogen production, residential energy supply, sector coupling, industrial applications, special markets for fuel cells and horizontal issues. 8th Programme is about to take off.

Germany is the first EU country to make use of the “Auctions-as-a-service” feature, putting up 350 million euros from its national budget for renewable hydrogen production projects located in Germany in case eligible bids for German projects cannot receive Innovation Fund support due to budget limitations.

List of Incentives for Türkiye - Hydrogen Market and Supply Chain Development

Renewable Energy Resource Areas (YEKA) and Support Mechanism for Electricity Generation from Renewable Energy Sources (YEKDEM) Mechanisms offer long-term purchase and price guarantees for the investors in Türkiye and facilitate long-term financing. The General Directorate of Renewable Energy conducts tenders in Renewable Energy Zones, so-called YEKA-zones, for a fixed power capacity. All types of renewable energy sources are eligible. Although there isn't a specific program for hydrogen, YEKDEM stands out as a crucial incentive model that has significantly influenced Türkiye's past decade. It has played a vital role in supporting localization policies. Under the Support Mechanism for Electricity Generation from Clean Energy Sources (YEKDEM), power plants certified for renewable energy sources activated between July 1, 2021, and December 31, 2025, enjoy a guaranteed purchase price for their electricity production for ten years. Additional domestic contribution support is provided for five years if these plants use domestic equipment. However it is crucial to mention that current feed-in tariff scheme that apply to clean energy power plants do not cover Hydrogen production yet. Investments in industrial facilities, including producing electric or hydrogen-powered transportation vehicles, must be a minimum of TRY 50 million within the priority investment areas.
The Ministry of Energy and Natural Resources of the Republic of Türkiye has the Domestic Components Regulation dated May 2021 within the scope of Domestic Component Support. This regulation covers the procedures and principles related to the domestic contribution prices applied to components used in power generation facilities based on renewable energy sources to support the use of domestic components.
The Ministry of Trade emphasized that trade rules with the European Union, Türkiye's key partner, will soon be influenced by sustainability and green transformation. As part of this, the Decision on the Amendment of Export Incentives (No. 8191) was published in the Official Gazette (No. 32469, dated 23.02.2024). This decision introduces support for projects aligned with the Green Deal. In support of Green Deal Compliance Projects, the Ministry will cover 50% of consultancy service expenses for companies, up to a total of 10 million liras, over a 5-year period.
Turseff or EBRD provide grants/supports to the sector. There is a need to develop new and innovative models of financing energy efficiency that should be developed by accounting for Türkiye's national circumstances. These models can take the form of revolving funds, property assessed clean energy (PACE), ESCOs, energy efficiency obligations, or on-bill financing. The models should address specific requirements applicable to various building types, consumers and regions and aim for the deployment of both existing and new energy efficiency and renewable energy technologies.
❖ European Bank for Reconstruction and Development (EBRD) provides support via different instruments to all segments of the hydrogen value chain: - Senior, subordinated, mezzanine or convertible debt. - Equity investment. - Blended finance using concessional financing (debt or grant) from our donors. - First-loss guarantees. ❖ EBRD has been running a hydrogen acceleration program covering the Southern and Eastern Mediterranean region (SEMED), Türkiye, Caucasus, Moldova, Western Balkans, Uzbekistan, Kazakhstan, Ukraine, and Moldova. ❖ The program is divided into three main work streams: - Country market assessment and diagnostics: production and demand forecast, hydrogen production, regulatory and policy review and recommendations. - Investment case studies: working with EBRD clients to conduct a technical and financial feasibility assessment of potential projects related to low-carbon hydrogen. - National Hydrogen Strategy: development of full national strategies for selected countries.

Türkiye has Project Incentives for Hydrogen Investments from the Ministry of Technology and Innovation. Hydrogen investments are among the potential investment areas, and they include tax, land, and financial incentives. The comprehensive support package for energy-related initiatives consists of a 50% subsidy on energy consumption for a maximum of 10 years. In addition, interest support is provided for investment loans, extending up to 10 years. Moreover, the government offers capital contribution support by entering into a partnership with investors, holding a 49% stake for a specified period. The government commits to exiting this partnership by selling its shares within a maximum timeframe of 10 years. These measures aim to foster and incentivize sustainable and energy-efficient investments in various sectors.

List of Incentives for Türkiye – Green Hydrogen R&D – Innovation

The Scientific and Technological Research Council of Türkiye (TÜBİTAK) is a national agency of Türkiye whose stated goal is to develop "science, technology and innovation" policies, support and conduct research and development with annual budget of 3,197 million TL. In the Türkiye Green Industry Project, under the headings of Research and Development (R&D) and Innovation, there are support titles related to hydrogen production and storage under the sub-headings of Clean and Circular Economy and Clean, Accessible, and Secure Energy Supply. Moreover, the Green Transformation in Industry Call of 1832 is a program allocated with financing of 450 million dollars under the coordination of the Ministry of Industry and Technology with the support of the World Bank, implemented by TÜBİTAK and KOSGEB within the scope of the Türkiye Green Industry Project. Within the program, the support duration is a maximum of 24 months, with a project budget ceiling of 7,500,000 TL for micro/small-scale firms, 12,000,000 TL for medium-scale firms, and 22,500,000 TL for large-scale firms. Within the call, interest-free repayable support will be provided to capital companies, with a maximum of 50% to be repaid.

The Ministry of Science, Industry and Innovation has outlined innovation in cleantech as one of the focus points of the industrial strategy, and TÜBİTAK, the Scientific and Technical Research Council, also treats it as a core innovation track. The amount of early-stage finance is relatively low, despite the presence of several venture capital funds and corporate venture capital investors.

Under the TENMAK TUGEP Support Program, it aims to support product/technology development projects including all kinds of research, development, innovation, design, technology acquisition, testing, and localization activities aimed at transforming tools, equipment, materials, services, products, methods, processes, systems, and production techniques related to hydrogen. Currently, there is a Research and Development Incentive for Hydrogen Technologies and Fuel Cell Call.

3.2.4 Production, Utilization and Hydrogen Cost

3.2.4.1 Production and Utilization

By the conclusion of 2022, Europe boasted 476 operational hydrogen production facilities, collectively capable of generating 11.33 million tons of hydrogen annually. Among these facilities were 97 water electrolysis projects, with 67 featuring a minimum capacity of 0.5 MW, resulting in a cumulative production capacity of 174.28 MW. Throughout the same year, the total hydrogen production reached 8.23 million tons. Considering the estimated hydrogen consumption, these production facilities operated at an average utilization capacity of 73%, while Germany demonstrated a notably higher utilization rate of 81%.³⁵

The leading eight countries in production capacity—specifically, Germany, Netherlands, Poland, Italy, France, Spain, the UK, and Belgium—collectively contribute to 74% of Europe's total hydrogen production capacity.

Germany's hydrogen production capacity is categorized by the production process, with 1.85 million tons stemming from reforming, 0.29 million tons from by-products, and 0.01 million tons from water electrolysis annually. The primary method

³⁵ Clean Hydrogen Partnership

for hydrogen production remains steam reforming of natural gas (SMR), although less prevalent techniques such as partial oxidation (POX), gasification, and autothermal reforming (ATR) also find applications across various industries, encompassing refining, ammonia production, methanol production, and other large-scale hydrogen production processes. In 2022, hydrogen production capacity in Germany with the production process type(s) selected was 2148.95 kt, with an average utilization factor of 0.74. There are 109 hydrogen production plants (excluding water electrolysis plants with a production capacity of less than 0.5 MW) for the production process type(s) selected in Germany. ³⁶ Please find the List of Hydrogen Production and Consumption Projects in Germany and Germany Hydrogen Production in 2022 by process type in Annexes.

Germany is a key player in the European Union's hydrogen scene, leading in production capacity and output. With an annual production capacity of 2.15 million tons and an output of 1.74 million tons, Germany takes a significant role. However, when we look at utilization rates, Germany ranks fifth among European countries, boasting an impressive 81%.

Despite this ranking, Germany showcases a strong performance, particularly in its utilization percentage, positioning itself favourably in the hydrogen market compared to other countries. In terms of existing plant capacity, Germany emerges as a dominant force, contributing 38% to the total installed water electrolysis capacity in Europe. This is equivalent to a substantial 64.12 MW or 10,597.95 tons per year.

Türkiye has set ambitious targets for its hydrogen sector, aiming to reduce the cost of hydrogen production to \$2.4 per kilogram by 2035, with a further goal to halve this figure by the 2050s. The National Hydrogen Plan outlines a target share of 3.5% for hydrogen in the gas mixture by 2035. To support these goals, the plan includes plans to achieve 2 GW of installed electrolyzer capacity by 2030 and 5 GW by 2035. Türkiye leverages its renewable energy potential, existing port infrastructure, and proximity to the EU and MENA regions for efficient hydrogen production and export. The project is further supported by project-based incentives and tailor-made incentives to promote sustainable growth in the hydrogen sector.

3.2.4.2 Levelised Cost of Energy

The costs associated with hydrogen production through electrolysis, directly linked to European renewable energy sources, range from 4.18 to 9.60 €/kg H₂, with an average across all countries at 6.86 €/kg H₂. These costs comprise various components, including grid fees and taxes, CAPEX (Capital Expenditure), renewable electricity costs, and other operating expenses. Notably, electricity costs constitute the largest share, making up approximately 90% of the total, while CAPEX represents the second most significant portion, contributing 33% to the overall cost in average. Notably, Germany exceeds the average.³⁷

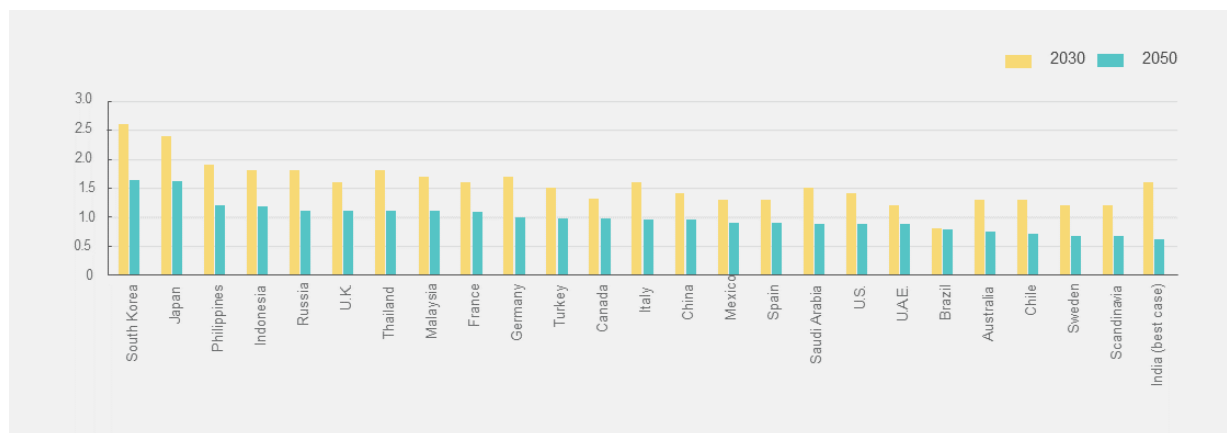
Despite the advantage of avoiding network costs and taxes associated with using a renewable energy source for electrolysis, the capacity factor of the electrolyser is constrained by the capacity factor of the linked renewable source.

It is crucial to consider a notable point when assessing the levelized production costs in 2022—they have experienced a substantial increase compared to 2021. This escalation is attributed to the abrupt surge in energy prices following heightened demand post-COVID-19 pandemic and the Ukraine conflict. Further details on the progression of prices for different technologies are expounded upon in subsequent sections.

³⁶ European Hydrogen Observatory

³⁷ Clean Hydrogen Partnership

Figure 3 Comparison of levelized cost of green hydrogen in selected countries



Source; BloombergNef and RMI

This heading is based on the Levelised Cost of Energy (LCOE) calculation is based on European Hydrogen Observatory tool/calculator.

The table below represents the Levelized Cost of Hydrogen (LCOH) comparison between Germany and Türkiye. Türkiye has an advantage in cost over Germany, which it can utilize over the long term. Specifically, Türkiye's overall LCOH is generally lower, making hydrogen production more economical in the country.

However, as seen in the table, Türkiye's CAPEX (capital expenditure) ratio is relatively higher. Nevertheless, other costs such as electricity, other operating expenses, and (if applicable) grid fees are lower. This positions Türkiye more competitively in the long run.

Table 16 Levelized Cost of Hydrogen (LCOH) Comparison Between Germany & Türkiye

Parameters	Units	Germany			Türkiye		
Electrolyser Unit							
Installed Power	kW	10,000	10,000	10,000	10,000	10,000	10,000
CAPEX	EUR/kW	1,250	1,250	1,250	1,350	1,350	1,350
Energy Consumption	kWh/kg	52.40	52.40	52.40	52.40	52.40	52.40
Stack Durability	h	80,000	80,000	80,000	80,000	80,000	80,000
Stack Degredation	% per 1000h	0.12%	0.12%	0.12%	0.12%	0.12%	0.12%
Stack Replacement Costs	% CAPEX	35%	35%	35%	35%	35%	35%
Other OPEX	% CAPEX	2 %	2 %	2 %	2%	2%	2%
Electricity Source		Wholesale	PV	On-shore wind	Wholesale	PV	On-shore wind
Operating hours	h/year	4.000	1.180	2.190	4,000	2,213	1,752
Average electricity costs	EUR/MWh	120	73.36	69.14	84.82	45.4	45.4
Grid fees	EUR/MWh	28.80	0	0	17.99	0.00	0.00
Electricity taxes	EUR/MWh	42	0	0	18.51	0.00	0.00
LCOH							
Total	EUR/kg	11.83	9.07	6.54	8.46	5.44	6.2
CAPEX	EUR/kg	1.19	4.03	2.17	1.29	2.32	2.93
Electricity	EUR/kg	6.54	3.93	3.77	4.62	2.47	2.45
Other OPEX	EUR/kg	0.52	1.11	0.60	0.56	0.64	0.81
Grid Fees	EUR/kg	1.30	0	0	0.98	0	0
Taxes	EUR/kg	2.29	0	0	1.01	0	0

Source: Consultant Calculation

General Assumptions of LOCH Calculator:

- It is assumed that a direct connection to the electrolysis unit is used for PV and onshore wind, excluding grid fees and electricity taxes. For wholesale electricity and offshore wind, it is assumed that grid connection is used, including grid fees and electricity taxes.
- The subsidies and additional revenues are always '0' under the default values. Any subsidies or additional revenues you might receive for a project can be captured in the user-specified values.
- The LCOH calculator assumes the cost of capital as 6% and the number of operating hours as 4,000 per year when using wholesale electricity (by taking the average of the 4000 cheapest hours). Other OPEX reflected in the LCOH cost include both the stack replacement costs and other OPEX as expressed in the table as a function of CAPEX.
- Please note that the default data does not show actual hydrogen production costs from operational water electrolysis plants in Europe but is the best estimate of what production costs could be expected to be achieved given the current costs of multi-MW state-of-the-art electrolysis systems and the latest available annual electricity costs.³⁸

Assumptions for Türkiye:

- Installed electrolyzer power, the energy consumption of the electrolyzer, stack durability and stack degradation kept the same for Germany and Türkiye.
- Stack replacement costs and other OPEX costs remained the same for Germany and Türkiye.
- Operating hours for Türkiye based on capacity factor for average PV and onshore wind in Türkiye.
- CAPEX prices assumed %8 higher for Türkiye. (electrolyzer equipment import costs added)
- The wholesale electricity prices for Türkiye based on March 2024 prices.³⁹
- The PV and on-shore electricity prices are based on March 2024 YEKDEM prices.⁴⁰

3.2.5 Technology and Innovation

3.2.5.1 Hydrogen Production: Electrolyzer Technology

Globally, there are currently 4 main electrolyzer technologies: Alkaline, PEM, AEM and Solid oxide. Solid oxide electrolysis technology has not yet been commercialized among these technologies, and AEM technology needs scale-up studies. However, it has big advantages for kW scale applications with high output pressure and low CAPEX. Alkaline and PEM electrolyzers are the technologies used in the planning of GW-scale projects that are currently being established in the world. When we consider the advantages of these two technologies over each other:

- ✓ In high-capacity projects (100MW), the CAPEX cost of alkaline electrolyzers is at least 30% lower compared to PEM technology.
- ✓ In the case of high capacities, the operation of the electrolyzers is considered as industrial-scale power plants, which reduces the concerns of high concentrations of caustic electrolytes during the operation of alkaline electrolyzers.

³⁸ <https://observatory.clean-hydrogen.europa.eu/tools-reports/levelised-cost-hydrogen-calculator>

³⁹ <https://enerjiajansi.com.tr/elektrik-birim-fiyatlari/>

⁴⁰ <https://enerjiajansi.com.tr/yekdem-fiyatlari/>

- ✓ The start-up time is one of the most important differences between these two technologies. PEM Electrolyzers have a faster startup response time can range from a few seconds to a few minutes. So, PEM electrolyzers can quickly ramp up to full production capacity when power is supplied, making them suitable for applications requiring rapid response to fluctuations in renewable energy sources like solar and wind. On the other hand; Alkaline Electrolyzers typically have a slower startup response time can range from several minutes to over an hour. Alkaline electrolyzers require more time to reach their optimal operating conditions due to the need for electrolyte conditioning and temperature stabilization.

PEM electrolyzers generally have a quicker startup response time than alkaline electrolyzers, making them more suitable for applications requiring rapid response and flexibility, such as grid balancing and hydrogen refueling stations. However, both types of electrolyzers play important roles in hydrogen production, with alkaline electrolyzers often favoured for large-scale, continuous hydrogen production due to their lower cost and efficiency at scale.

Mainly 3, electrolyzer types stand out for the ceramic industry: AEM electrolyzers with their ease of use and modular structure for initial demonstration activities in kW scale, Alkaline electrolyzers with their low CAPEX cost in large MW-scale projects to meet the hydrogen needs of production lines, and finally PEM electrolyzers, which stand out with their fast response time when directly connected to intermittent renewable energy sources and operated off-grid only with these sources.

Table 17 Manufacturers of Electrolyzers - Germany vs Türkiye

Germany	Türkiye
Germany has a foundation in the manufacturing of electrolyzers. Europe and Germany prioritize PEM technology and funding are eligible for PEM technology. However, when renewable sources do not directly feed the electrolyzers, PEM technology is not critically necessary (quick response is not needed). But because of the high promotion of PEM technology, end users often choose PEM for a new project. That results in non-feasible projects due to high CAPEX of PEM electrolyzers..	While there is small scale productions or pilot implementations, There is no mass production electrolyzer manufacturer in Türkiye for either technology. This means Türkiye need to import electrolyzer and other hydrogen equipment (compressor, storage, valves... etc.) and this means higher CAPEX for each project

Source: Developed by the Consultant

3.2.5.2 Hydrogen Storage

In every green hydrogen project, storage solutions are indispensable, whether transporting hydrogen between locations, storing produced hydrogen for future use, or buffering before integration into processes. Hydrogen can be physically stored in various forms: as a liquid, compressed gas, or chemically in solid form, depending on the intended application.

While liquid hydrogen storage is impractical for distances under 1000km and large tonnage transportation, compressed hydrogen storage in gas form emerges as the optimal solution for applications in the ceramic industry.

Type-I stainless steel tanks, capable of storing hydrogen at pressures of around 200bar, are prevalent across Europe and Türkiye for high-pressure hydrogen storage. Conversely, all-composite type-IV tanks, operating at pressures of 450-700bar and offering greater hydrogen storage capacity per volume compared to type-I tanks, are commonly utilized in Europe, including Germany, but have yet to see implementation in Türkiye.

Several challenges exist regarding hydrogen storage solutions in Türkiye. Firstly, the high capital expenditure (CAPEX) associated with type-IV tanks poses a significant hurdle. Characterized by their all-composite design, these tanks are the costliest option for high-pressure hydrogen storage. Compounding this issue is the limited availability of certified type-IV tank manufacturers globally, it is also very limited to Start-Up companies in Türkiye. Furthermore, while Türkiye has manufacturers of G-size industrial gas cylinders, suitable for smaller capacities, there is a notable absence of higher-capacity steel type-I tanks suitable for stationary applications. Additionally, the certification of hydrogen storage solutions remains an ongoing concern.

Addressing these challenges will be pivotal for advancing hydrogen storage infrastructure and facilitating the widespread adoption of hydrogen technologies in Türkiye.

3.2.5.3 Hydrogen Pipelines

Hydrogen transition in the ceramic industry is based on using hydrogen as a kiln fuel, which is strongly related to hydrogen-blended natural gas and pure hydrogen pipelines. Basically, hydrogen transmitting pipelines are classified as dedicated and rededicated pipelines. Specially designed new pipelines for hydrogen usage, called dedicated and retrofitting of existing pipelines for hydrogen usage called re-dedicated pipelines. Both dedicated and re-dedicated pipeline projects are started globally. In Europe, pipeline projects have been established to create hydrogen corridors throughout Europe. The idea is to transfer hydrogen by injection to existing natural gas pipelines, build new pipelines to deliver pure hydrogen or build new dedicated pipelines for hydrogen-blended natural gas.

Barriers to the widespread adoption of hydrogen technology in Türkiye include the absence of announced projects for hydrogen pipeline infrastructure and the lack of signals for the transfer of hydrogen-blended natural gas via existing pipelines. Additionally, the uncertainty surrounding the centralized production of green hydrogen poses a significant challenge. It remains unclear whether green hydrogen production will be centralized and offered as a service to various sectors or if individual sectors and companies will establish their own production facilities. This uncertainty affects investment decisions, with some companies eager to invest in green hydrogen while others, particularly those in carbon-intensive industries like ceramics and steel, are evaluating the feasibility of establishing their own production facilities. Furthermore, despite Germany's interest in importing green hydrogen from Türkiye, the absence of plans for a dedicated pipeline presents a logistical hurdle to cross-border hydrogen trade.

3.2.5.4 Intellectual Property

Intellectual property (IP) numbers by country can serve as valuable innovation indicators. Concerning intellectual property, the Y02 classification, which pertains to technologies or applications for mitigating or adapting to climate change, is employed. The rising number of patent applications signifies increased research and development efforts in Hydrogen technology. This table provides a comparative overview of patent classifications associated with hydrogen technology and fuel cells, contrasting Türkiye (TR) and Germany (GE) within the Y02 series. In Hydrogen Technology (Y02E60/30), Germany takes the lead with a significant number of patents, applicants, and inventors, outpacing Türkiye notably. This trend persists in Hydrogen Storage (Y02E60/32) and Fuel Cells (Y02E60/50), where Germany excels over Türkiye in patent publications, applicants, and inventors. Although Türkiye has a presence in these categories, the quantitative disparity is evident. Unfortunately, specific data on Hydrogen Distribution (Y02E60/34) from Türkiye is unavailable, while Germany displays a noteworthy presence in this domain. Regarding Hydrogen Production from Non-carbon Containing Sources (Y02E60/36), Türkiye holds a more modest position compared to Germany, with fewer patents, applicants, and inventors. This analysis underscores Germany's prominent role in patent activities related to hydrogen technology and fuel cells within the specified classifications, emphasizing its advanced position in these technological domains.

Table 18 Comparing IP Applications – Germany vs Türkiye

Classification	Name	Türkiye (TR)			Germany (GE)		
		Publication Country	Applicant Country	Inventors Country	Publication Country	Applicant Country	Inventors Country
Y02E60/30	Hydrogen technology	29	4	21	23.412	26.378	25 451
Y02E60/32	Hydrogen storage	6	-	-	2.260	3.697	3.605
Y02E60/34	Hydrogen distribution	-	-	-	44	107	92

Y02E60/36	Hydrogen production from non-carbon containing sources, e.g. by water electrolysis	3	1	2	1.623	2.504	2.182
Y02E60/50	Fuel cells	20	3	19	15.288	21.082	20.535

Source; Espacenet

3.2.6 Market Regulations, Trade, Agreements and Collaborations

3.2.6.1 Market Regulations;

EU:

The Fit for 55 is a EU gas market design package, and it aims to progressively replace fossil gas in the EU with renewable and low-carbon gases, including hydrogen.

The EU's Carbon Border Adjustment Mechanism (CBAM) is the EU's tool to put a fair price on the carbon emitted during the production of carbon-intensive goods entering the EU, and to encourage cleaner industrial production in non-EU countries.

On 15 December 2021, the European Commission adopted a hydrogen and decarbonised gas markets package consisting of three major legislative proposals: a recast regulation on EU gas and hydrogen markets (subject of this briefing); a recast directive on EU gas and hydrogen markets; and an entirely new regulation to reduce methane emissions in the EU energy sector. These proposals aim to transform the legislative framework for EU gas markets, which has changed little since the third energy package was adopted in 2009. The review and revision of the Gas Directive 2009/73/EC and Gas Regulation (EC) No 715/2009 is referred to as the Hydrogen and Gas Markets Decarbonisation Package, published in December 2021. It enables the market to decarbonise gas consumption and puts forward policy measures required for supporting the creation of optimum and dedicated infrastructure and efficient markets. The proposed revision creates a level playing field based on EU-wide rules for the hydrogen market and infrastructure and removes barriers that hamper their development.

Germany:

The NWS aims to "establish regulatory requirements for the market deployment of hydrogen technologies". Regarding the acceptance of renewable hydrogen on the market, Germany imposes requirements according to EU regulations. Accordingly, hydrogen produced is also considered renewable if the following three conditions are met;

- i) From January 1, 2028, additional wind and solar systems for hydrogen production must be built or be no more than 36 months old before they can be used under a power purchase agreement (PPA) or through a direct line.
- ii) From 2030 onwards, hydrogen can only be produced during the hour in which the relevant PPA system produces electricity. Until then, hydrogen can also be produced when no electricity from the renewable energy system is available. The condition for this is that the electricity deficit is balanced during the month.
- iii) The hydrogen production facility must be located in the same auction zone as the electricity production facility. This excludes connected bidding zones where the electricity price is the same or higher than in the bidding zone where hydrogen production takes place. There are exceptions for offshore systems.

The hydrogen trade market in Germany operates through a collaborative and multi-stakeholder approach. While the government sets the overall direction, the actual functioning of the market is influenced by various players working together within the established regulatory framework.

In addition, Germany, under the EU Carbon Border Adjustment Mechanism (CBAM) regulations, initially registers in the tax phase a) direct emissions of certain imported goods from the electricity sector and the iron and steel, aluminium, cement, fertilizer and hydrogen industrial sectors and b) indirect emissions of industrial sectors that do not receive electricity price compensation (cement, fertilizer). This mainly concerns basic materials, intermediate products and a small number of processed products. Complex products such as automobiles will initially be excluded from CBAM due to the administrative burden involved. However, CBAM will gradually be extended to other products. Since October 2023, importers have to report to the European Commission on the direct and indirect (i.e. electricity-related) emissions of their products affected by the CBAM. The tax phase will start in 2026, during which time the purchase and delivery of CBAM allowances will become mandatory for CBAM obligors.

Türkiye:

To establish hydrogen as a tradable commodity, it must be governed within a market framework and connected to a regulatory body, market stabilization service provider, or exchange. Türkiye's legal framework for hydrogen production and utilization is expected to address this aspect, likely falling under the purview of policy-making ministries. Discussions with government agencies and independent administrative authorities suggest that once this framework is in place, various authorizations concerning the hydrogen market will likely be under the jurisdiction of either the stock exchange or EMRA, the market regulatory authority.

3.2.6.2 Trade, Agreements and Collaborations

A European Strategy for Hydrogen ; Stresses that the EU should promote its hydrogen standards and sustainability criteria internationally; calls in this regard for the development of international standards and the setting up of common definitions and methodologies for defining overall emissions from each unit of hydrogen produced, as well as international sustainability criteria as a prerequisite for any hydrogen import and imports of pre-hydrogen products; emphasises that, in order to avoid any carbon leakage, all hydrogen imports should be certified in the same way as EU-produced hydrogen, including production and transportation, and should be consistent with the future carbon border adjustment mechanism of the European Union; also calls on the Commission and the Member States to invest in the necessary infrastructure and the transformation of existing infrastructure at ports and in cross-border connections for the import of renewable hydrogen; encourages the Commission to promote the role of the euro as the reference currency in the international trade of hydrogen.

Expanding on the political efforts outlined above, Germany is actively involved in bolstering the development of European and global hydrogen supply chains. In Europe, there is anticipated to be a significant surge in demand for hydrogen, particularly in sectors such as refining, industry, transport, and power generation. Projections underscore a substantial increase in low-emission hydrogen production, utilizing both renewable electricity and fossil fuels with Carbon Capture, Utilization, and Storage (CCUS). A noteworthy rise in cumulative installed electrolysis capacity supports this growth.

Germany's National Hydrogen Strategy aims to advance PtX technologies, including Power-to-Gas (PtG) and Power-to-Liquid (PtL), for extensive adoption across industries and mobility. The primary objective is for Germany to become a prominent exporter of green hydrogen. Acknowledging the challenges in fulfilling long-term domestic demand, Germany is actively pursuing partnerships with other countries to produce green hydrogen and import green hydrogen utilizing existing natural gas pipelines.

In 2022, Germany played a significant role in the European hydrogen landscape by exporting 1,177 tons of hydrogen, making up 3.45% of Europe's total exports, with Belgium leading the way. Simultaneously, Germany imported 1,122 tons of hydrogen, accounting for 3.28% of Europe's total imports.

The hydrogen sector in Europe is expected to witness consistent growth in demand, with projections indicating a significant increase from 9.86 million tons in 2030 to 14.62 million tons in 2040 and further expansion to 16.88 million tons in 2050.

Germany emerges as a major consumer, holding the highest conventional hydrogen consumption among European countries, contributing to 21% of the total European demand.

Various sectors influence the demand for clean hydrogen across different countries. In Germany, emerging hydrogen applications take precedence over traditional sectors such as refining, ammonia production, other chemicals, and methanol production. Strategic investments and policy adjustments in Türkiye could propel its green hydrogen production to 3.4 million tons yearly by 2050, potentially exporting between 1.5 and 1.9 million tons yearly by the same year.⁴¹ Germany's partnerships in Hydrogen span the globe, involving countries close to Germany as well as those farther away, each characterized by varying levels of pre-existing capacity for renewable energy development.⁴²

Germany's strategy for hydrogen imports reflects a comprehensive exploration of various trade routes and transport infrastructures, demonstrating a deliberate effort to establish a diversified hydrogen supply. This approach aims to position Germany at the forefront of the emerging global innovation system, fostering numerous research and development partnerships. Notably, Australia has emerged as a crucial collaborator in this endeavor.

Germany strongly advocates for green hydrogen production and its application in challenging-to-decarbonize industrial and transport sectors. Sustainability considerations are integrated into subsidy schemes and capacity-building initiatives. However, questions regarding the production and use of fossil-based hydrogen remain unaddressed. Germany has adopted a global approach, engaging with countries worldwide. Despite significant initiatives at the EU level, the import strategy places greater emphasis on non-EU countries. Remarkably, H2 Global, Germany's flagship instrument for stimulating hydrogen supply chains, initially did not target EU member states. In total, there are 43 non-European countries with hydrogen activities driven by German ministries, either individually or jointly.

On November 10, 2023, Germany introduced amendments to the Energy Industry Act, focusing on regulations for planning and approving the national core hydrogen network, utilizing the existing gas infrastructure. This ambitious initiative aims to promote hydrogen as a clean energy source, addressing emissions in industries like steel and chemicals. Furthermore, Germany signed agreements with the UK, the Netherlands, Austria, and Denmark to collaborate on developing an international hydrogen industry and cross-border hydrogen infrastructure, emphasizing the growing importance of hydrogen in the global energy landscape.

Germany actively participates in research and innovation by supporting international collaborations in technology development and conducting comprehensive analyses of the sector. Research partnerships with other leading European technology entities and Australia are a major focal point. Domestically, Germany supports international scholars through initiatives like the International Future Labs and facilitates the presence of international researchers through projects like the Redefine H2 Economy project. Significant research and development projects, such as ThyssenKrupp's "Element One" project in Saudi Arabia and the project involving Uniper, the Abu Dhabi National Oil Company, and Jera in Japan, receive financing from the BMWK.

Expanding on the political endeavours mentioned earlier, Germany is actively engaged in bolstering the development of European and global hydrogen supply chains. Within the EU, investments have been funneled through the IPCEI initiative, with Germany supporting 62 IPCEIs in collaboration with other member states. Beyond the EU, the BMWK advocates for production capacities in potential export nations through its H2 Global initiative. Administered by the H2 Global Foundation, this initiative utilizes an auction mechanism to offer subsidies for both hydrogen supply and usage. Through a competitive bidding process, the Hydrogen Intermediary Network Company (HINT.CO) awards long-term (10-year) contracts for hydrogen purchase and short-term (2-year) contracts for its sale to users. These contracts operate under the Contracts for Difference (CfD's) scheme, where HINT.CO covers the price difference using funds provided by the BMWK. Supply contracts under this scheme are granted for hydrogen delivery to ports in the Netherlands, Belgium, or Germany, aiming to

⁴¹ Shura

⁴² HYTAP Working Paper

stimulate the development of necessary supply chains. Initially targeting hydrogen supply outside the EU, H2 Global is anticipated to expand its scope to include EU countries as well. Born from a public-private dialogue facilitated by the Business Alliance Energy, H2 Global is just one among several significant initiatives. Others include funding programs like "Internationale Wasserstoffprojekte" (International Hydrogen Projects), offering grants of up to 15 million euros for research and innovation, and the International Hydrogen Ramp Up program (H2Uppp), which aids SMEs in developing and emerging countries with project preparation for hydrogen initiatives through technical guidance.⁴³

In terms of Türkiye, both the Hydrogen Energy Technologies Strategy and Roadmap and the Green Deal Action Plan published by the Ministry of Trade in 2021 emphasize the importance of international commercial collaboration and cooperation. Within this framework, the Ministry of Trade has been assigned the responsibility of maintaining certain international collaborations and access to financing as outlined in the Green Deal Action Plan.

Table 19 Comparison of Market Regulations - Eu, Germany vs Türkiye

	EU	Germany	Türkiye
Market Regulations	The Fit for 55 is a EU gas market design package and it aims to progressively replace fossil gas in the EU with renewable and low-carbon gases, including hydrogen. The EU's Carbon Border Adjustment Mechanism (CBAM) is the EU's tool to put a fair price on the carbon emitted during the production of carbon intensive goods that are entering the EU, and to encourage cleaner industrial production in non-EU countries. On 15 December 2021, the European Commission adopted a hydrogen and decarbonised gas markets package consisting of three major legislative proposals: a recast regulation on EU gas and hydrogen markets (subject of this briefing); a recast directive on EU gas and hydrogen markets; and an entirely new regulation to reduce methane emissions in the EU energy sector. These proposals aim to transform the legislative framework for EU gas markets, which has changed little since the third energy package was adopted in 2009. The review and revision of the Gas Directive 2009/73/EC and Gas Regulation (EC) No 715/2009 is referred to as the Hydrogen and gas markets decarbonisation package, published in December 2021. It enables the market to decarbonise gas consumption and puts forward policy measures required for supporting the creation of optimum and dedicated infrastructure, as well as efficient	The NWS aims to "establish regulatory requirements for the market deployment of hydrogen technologies". Regarding the acceptance of renewable hydrogen on the market, Germany imposes requirements according to EU regulations. Accordingly, hydrogen produced is also considered renewable if the following three conditions are met; i) From January 1, 2028, additional wind and solar systems for hydrogen production must be built or be no more than 36 months old before they can be used under a power purchase agreement (PPA) or through a direct line. ii) From 2030 onwards, hydrogen can only be produced during the hour in which the relevant PPA system produces electricity. Until then, hydrogen can also be produced when there is no electricity available from the renewable energy system. The condition for this is that the electricity deficit is balanced during the month. iii) The hydrogen production facility must be located in the same auction zone as the electricity production facility. This excludes connected bidding zones where the electricity price is the same or higher than in the	To establish hydrogen as a tradable commodity, it must be governed within a market framework and connected to a regulatory body, market stabilization service provider, or exchange. Türkiye's legal framework for hydrogen production and utilization is expected to address this aspect, likely falling under the purview of policy-making ministries. Discussions with government agencies and independent administrative authorities suggest that once this framework is in place, various authorizations concerning the hydrogen market will likely be under the jurisdiction of either the stock exchange or EMRA, the market regulatory authority.

⁴³ Hytap

	markets. The proposed revision creates a level playing field based on EU-wide rules for the hydrogen market and infrastructure and removes barriers that hamper their development	bidding zone where the hydrogen production takes place. There are exceptions for offshore systems. The hydrogen trade market in Germany operates through a collaborative and multi-stakeholder approach. While the government sets the overall direction, the actual functioning of the market is influenced by various players working together within the established regulatory framework.	
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3.2.7 Special Economic Zones / Hydrogen Valleys

Hydrogen Valleys play a pivotal role in stimulating investment and nurturing the growth of the green hydrogen industry through a multifaceted approach. Acting as hubs for large-scale demonstration projects, these Valleys offer tangible proof of the feasibility and scalability of green hydrogen technologies, alleviating uncertainties for potential investors. By concentrating hydrogen-related activities in specific regions, they effectively manage risks associated with technology deployment, market acceptance, and regulatory concerns. Additionally, governments often provide economic incentives within Hydrogen Valleys, such as grants, subsidies, and tax incentives, enhancing the financial attractiveness of green hydrogen projects and encouraging long-term commitments.

Infrastructure development is another critical aspect, with Hydrogen Valleys driving the establishment of production facilities, pipelines, and storage systems, lowering initial costs and risks associated with new infrastructure. By stimulating demand for green hydrogen in targeted sectors, these Valleys ensure that investments translate into practical applications, bolstering confidence in the market's viability. Collaboration opportunities within Hydrogen Valleys foster partnerships among private companies, research institutions, and public entities, facilitating knowledge exchange and reducing research and development expenses. Moreover, the concentration of hydrogen activities enables the scaling up of technologies, attracting investments as technologies mature and achieve economies of scale.

Figure 4 Aspects of Hydrogen Valleys



International collaboration often characterizes Hydrogen Valleys, attracting foreign investments and fostering global partnerships in the rapidly expanding green hydrogen market. Furthermore, the alignment of Hydrogen Valleys with national

and regional energy policies establishes a conducive regulatory environment, minimizing uncertainties and providing a stable framework for investments. In summary, Hydrogen Valleys create an environment that addresses technological, financial, and market-related challenges, making them indispensable in incentivizing the development of a sustainable and flourishing green hydrogen sector.

The concept of specific Special Economic Zones (SEZs) exclusively dedicated to green hydrogen production might not be as prevalent as in some other countries. However, Germany has implemented various policies and initiatives to support and boost the hydrogen industry, including green hydrogen. While Germany might not have traditional SEZs explicitly dedicated to green hydrogen, the aforementioned initiatives reflect the country's commitment to advancing hydrogen technologies. In this sense Hydrogen Valleys offer an integrated approach to hydrogen production, utilization, and infrastructure development. Germany can efficiently deploy and scale up various hydrogen technologies and applications by concentrating efforts in specific regions.

Based on the data on The Hydrogen Valley platform, Germany has larger-scale projects (16 in total) with significant investments, Türkiye's projects, such as the South Marmara Hydrogen Shore, emphasize regional development and targeted end-use sectors, including energy and industrial applications. Germany's multitude of Hydrogen Valley projects, their diverse nature, and substantial investments demonstrate a more advanced and mature approach to green hydrogen development compared to Türkiye. Türkiye, with its single major project, is making strides in aligning with its national strategy and creating a foundation for future growth in the green hydrogen sector. Both countries contribute uniquely to the broader European landscape in the transition to a hydrogen-based economy. Please find the detailed list of the Hydrogen Valley Project in the Annexes.

Table 20 Comparison of Hydrogen Valleys

Key Points for Germany	Key Points for Türkiye
Diversity: Germany's Hydrogen Valley projects cover a wide range of activities, including H2 production, storage, transport, and distribution. Projects like Clean Hydrogen Coastline, eFarm, and H2Rivers demonstrate a comprehensive hydrogen ecosystem-building approach.	Limited Number: Türkiye currently has one major Hydrogen Valley project, the South Marmara Hydrogen Shore. While this project has a lower production capacity compared to some German counterparts, it is a significant step towards establishing a presence in the green hydrogen sector.
Scale and Investment: Several German projects involve significant investments, reflecting a commitment to large-scale hydrogen production. For example, the Grande Region Hydrogen EEIG aims to produce 65,000 T/year, emphasizing the country's ambition for substantial hydrogen output.	Strategic Focus: The South Marmara Hydrogen Shore project in Türkiye emphasizes specific sectors, such as energy and industrial use. Despite the lower number of projects, there seems to be a strategic focus on regional development and targeted applications.
End-Use Sectors: The German projects target diverse end-use sectors, including mobility, energy, and industrial applications. This highlights a holistic approach to integrating hydrogen into various facets of the economy.	Investment Commitment: Türkiye's investment of 36.81 million euros in the South Marmara Hydrogen Shore underscores a commitment to kickstarting the hydrogen industry and aligning with the country's energy transition goals.

Source: Developed by the consultant

The regulatory landscape for Hydrogen Valleys encompasses a wide range of provisions, reflecting the diverse strategies and priorities of each region. Key regulatory considerations include land allocation facilitated by ministries and government agencies, pre-investment studies covering various aspects of feasibility, and strategic evaluations of land and mining rights.

The significance of CO₂ reductions, project costs, and state aid is evident, along with the necessity for permits, including construction, environmental, and civil work permits, all regulated by state authorities. Additionally, the importance of a regulatory framework to incentivize industrial players, as exemplified by RED II, and adherence to European, national, and local funding programs underscore the need for a comprehensive approach. Differentiation between grey, blue, and green hydrogen, exemption from taxes, public awareness, and sensitivity to environmental concerns also play crucial roles. The pursuit of collaborations, such as the IPCEI program, further emphasizes the interconnectedness of regulatory challenges and financial support mechanisms. It is evident that the success of Hydrogen Valleys relies not only on technological advancements but also on navigating a complex regulatory landscape and securing financial incentives at various levels of governance.

3.3 Preparation of the Regulatory Path

3.3.1 Scope of regulatory environment in Türkiye

Under the heading "Scope of regulatory environment in Türkiye," the report examines the current regulatory landscape across various dimensions in Türkiye. Overall, the report provides a nuanced understanding of Türkiye's regulatory environment, highlighting areas of progress and areas for further development regarding hydrogen.

This section is meticulously crafted through a combination of extensive desk research and in-depth face-to-face meetings conducted by the project team with pertinent authorities. A detailed list of these interactions is provided in the Annexes, offering a comprehensive foundation for the insights presented in the report.

3.3.1.1 Legislation and Regulatory Framework

3.3.1.1.1 Production and Manufacturing Regulations - National and International Standards

In Türkiye, a well-established legislative framework is currently lacking in addressing the production and manufacturing of hydrogen energy. However, there is a growing interest in hydrogen as a clean energy source, prompting the Turkish government to recognize its potential and release strategic roadmaps outlining plans for its development and integration into the energy sector.

One such roadmap, the "Türkiye Hydrogen Technologies Strategy and Roadmap," prepared by the Turkish Energy, Nuclear, and Mining Research Organization (TENMAK) and published by the Ministry of Energy and Natural Resources, evaluates Türkiye's current situation and provides vision and policy recommendations. Key vision recommendations include reducing the cost of green hydrogen production and increasing the installed power capacity of electrolyzers over the coming decades. While there is currently no prohibition on hydrogen energy production and manufacturing in Türkiye, there is also no specific legislation regulating these activities. These issues are anticipated to be addressed in the 2024-2028 Strategy Document and subsequent action plans issued by the Ministry of Energy and Natural Resources.

Additionally, feedback from relevant units of the Ministry of Industry and Technology and the Ministry of Trade suggests that separate legislation on hydrogen energy will be developed. This legislation is expected to address key aspects such as the purpose of hydrogen energy usage in production and manufacturing and the distinction between green and blue hydrogen production methods.

3.3.1.1.2 Hydrogen Blending into Natural Gas Pipeline

No regulations exist for blending hydrogen into natural gas pipelines in Türkiye. This lack stems from two main issues: the absence of a designated ministry to create such regulations and the absence of defined technical standards to serve as a baseline. Even if legislation is drafted, implementation requires readily available technical standards and trained personnel to enforce

them. These standards would encompass the entire hydrogen lifecycle, including production, infrastructure, storage, transportation, distribution, utilization, safety protocols, quality control, and environmental impact assessments.

Therefore, simultaneously developing technical standards and legislation is crucial for enabling hydrogen blending in natural gas infrastructure and utilizing it in furnaces. Additionally, capacity building within relevant ministries is essential to train personnel who can inspect projects against these standards and ensure compliance with the regulations. Furthermore, collaboration with the Turkish Standards Institution (TSE) is necessary to establish standards for components like pipes, valves, and seals that will come into contact with the blended gas. Aligning these standards with the European Committee for Standardization (CEN/CENELEC) will ensure compatibility with European practices.

Another major obstacle lies in the full responsibility of natural gas distribution companies for the entire gas installation, including the final point of consumption (the chimney). Under current regulations, these companies are hesitant to approve hydrogen-blended gas installations due to the lack of defined technical standards. To address this, clear and relevant technical standards along with trained personnel are crucial to ensure safe and responsible use of the blended gas within existing infrastructure.

Interviews with stakeholders, including ministries and regulatory bodies (with the Ministry of Energy, the Ministry of Trade, the Ministry of Industry and Technology, the Energy Markets Regulatory Authority and TENMAK), revealed that while each is working on increasing their hydrogen expertise, they are awaiting a clear mandate to initiate legislation. This demand for clear regulations stems from industry players and investors, and the pressure is further amplified by the upcoming Carbon Border Adjustment Mechanism (CBAM) that will impact carbon-intensive sectors. Increased pressure from these sectors could accelerate the development of the necessary regulations.

Even though blending natural gas with biomethane (constituting approximately 90% of natural gas) is not possible/legal within the current regulatory framework, the current situation and the anticipated timeframe for regulatory changes suggest focusing on short-term investments utilizing 100% hydrogen gas infrastructure until hydrogen blending becomes a viable option.

3.3.1.1.3 Storage and Transportation Regulations

While Türkiye currently lacks specific legal frameworks for hydrogen storage and transportation, recent developments signal a growing acceptance of hydrogen as a clean energy solution. Existing legislation supporting renewable energy sources indirectly benefits hydrogen production from renewables, such as electrolysis using renewable electricity, which can then be stored and utilized in various applications.

Like the EU, Türkiye refers to international standards set by ISO and IEC for ensuring hydrogen storage and transportation safety. The Türkiye Hydrogen Technologies Strategy and Roadmap highlights the need to develop distribution and transmission pipelines by 2053 to expand hydrogen usage in energy-intensive sectors and facilitate the adoption of advanced storage technologies.

Even though not specifically designated for hydrogen, the transportation of dangerous goods in Türkiye is regulated by the "Regulation on the Transport of Dangerous Goods by Road". This Regulation has been prepared based on the Agreement on the International Transport of Dangerous Goods by Road (ADR), to which our country is a party and to which the United Nations sets standards. Additionally, the Turkish Ministry of Transport and Infrastructure oversees the implementation and enforcement of these regulations. According to this Regulation and ADR, filling, packing, loading, sending, receiving, discharging and tank-container/portable tank operators operating in the field of road transport of dangerous goods are obliged to apply to the Ministry for one or more of these fields of activity and obtain a Dangerous Goods Activity Certificate.

For dangerous goods transportation, the Essentials are:

Classification: Dangerous goods are classified by properties (flammability, toxicity, explosiveness) for proper handling, packaging, and transport requirements.

Licensing and Training: Mandatory specialized training and licenses for all involved personnel, including drivers and handlers.

Packaging and Labeling: Proper packaging meets safety standards and clearly indicates contents and associated risks.

Transportation Vehicles: Vehicles must meet safety standards and carry appropriate safety equipment like fire extinguishers and spill containment kits.

Documentation: Essential shipping manifest and emergency response information must accompany shipments, complying with regulations.

Emergency Response: Adequate plans and personnel training for handling incidents during transportation coordinating with local authorities.

Risk Assessment and Management: Companies must conduct risk assessments and implement measures to mitigate hazards during transportation.

Transportation of compressed hydrogen in Türkiye, like transportation of other dangerous goods, is subject to regulations and safety standards to ensure the safe handling and transport of this highly flammable and potentially hazardous substance. The transportation of compressed hydrogen falls within the scope of ADR, which has the force of law in accordance with Article 90 of the Constitution of the Republic of Türkiye, the "Regulation on the Transport of Hazardous Substances by Road" and other relevant national legislation implemented by the Ministry of Transport and Infrastructure. Compressed hydrogen is classified as a dangerous good due to its flammable nature. Transportation information is given on Section 14 of the Material Safety Data Sheets. UN number and UN proper shipping name is UN 1049-Hydrogen, Compresses, and it is categorized under Class 2.1 (Flammable gases) according to the ADR classification system.^{44 45}

Overall, for the hydrogen dedicated law and regulations in terms of transportation and storage, discussions with government agency representatives suggest that the Ministry of Industry and Technology will be pivotal in shaping forthcoming legislation, particularly regarding technical standards for storage fuels, pipeline connections, and new hydrogen infrastructure. Moreover, considerations regarding incentives for domestic hydrogen storage tanks are under scrutiny by the General Directorate of Energy Affairs, indicating ongoing efforts to align regulations with emerging hydrogen technologies and infrastructure needs.

3.3.1.1.4 Hydrogen Quality Standards - National and International

Although there are currently no national standards for hydrogen energy in the Turkish legislation, it has been learned in the interviews with government agencies that active efforts to standardise hydrogen energy and establish a legal framework in cooperation with the Energy Market Supervisory Authority ("EMRA"), TENMAK and the General Directorate of Energy Affairs ("EİGM") are accelerating in the coming period. Until then, similar to the EU, Türkiye has been utilising existing international standards developed by ISO and IEC as a reference point for hydrogen quality. Detail information about the international hydrogen standards can be found in the following headings.

3.3.1.1.5 Security and Safety Standards and Regulations

Due to the current state of hydrogen development in Türkiye, no dedicated national security and safety standards have been specifically established for hydrogen. As Türkiye progresses in its hydrogen development plans, the government will likely collaborate with relevant stakeholders to develop dedicated national safety and security standards specifically for hydrogen. These standards will likely be based on international best practices (such as ISO and IEC) and tailored to the specific context of Türkiye. For example, while EMRA is authorised to carry out specific safety controls in the energy sector, this authority is granted to EMRA by the law regulating such controls.

⁴⁴ Material Safety Data Sheet – Hydrogen, Compressed, Version1.1, Linde

⁴⁵ Güvenlik Bilgi Formu, Hidrojen (Basıncılı Gaz Halinde), Rev.3, Habaş

3.3.1.1.6 Environmental Regulations

Türkiye has a well-established Environmental Impact Assessment (EIA) Regulation (published in December 2019) that applies to various projects, including renewable energy projects. There is no specific mention of hydrogen energy within the EIA regulation. This is likely because the technology is still in its early stages of development in Türkiye.

However, indirect considerations might be relevant. For instance, electrolysis: If a hydrogen project utilizes electrolysis for hydrogen production, the EIA would likely assess the environmental impact of the electricity generation source (e.g., potential air emissions from a power plant). On the subject of hydrogen storage and transportation, Depending on the chosen storage and transportation methods (e.g., compressed gas pipelines, salt caverns), the EIA might need to address potential environmental risks associated with leaks, spills, or accidents.

3.3.1.1.7 Foreign Trade Regulations

Both in the Hydrogen Energy Technologies Strategy and Roadmap and in the Green Deal Action Plan published by the Ministry of Trade in 2021, attention has been drawn to the issue of international commercial cooperation and cooperation. In this context, the Ministry of Trade was given the task of maintaining international cooperation and access to financing up to date in the Green Deal Action Plan.

3.3.1.1.8 End-Use Sector Integration

Currently, there are no specific regulations in Türkiye focused on the End-Use Sector Integration of hydrogen energy. This means no dedicated legal framework outlines how hydrogen can be utilized in different sectors (e.g., industry, transportation, buildings) and how its integration will be managed. Türkiye is still in the early stages of exploring hydrogen as a clean energy source. As such, the focus is currently on establishing the foundational aspects like production and storage before delving into specific regulations for end-use integration.

For example, the use of hydrogen energy in fuel cells in the automotive sector is under the close scrutiny of EMRA, which regulates electric vehicle charging stations. In this context, when the framework law on hydrogen is established, it is obvious that the state structure that brought this formation into being will follow the developments towards end-use sector integration.

Since hydrogen can be transported to hydrogen filling stations within the scope of the standards for the transport of hazardous substances, it is obvious that it will be an important player in the fuel sector in the near future. At this point, it would be convenient to prioritise the special legal regulation on hydrogen filling stations among the regulations to be made on a sectoral basis following the framework law on hydrogen.

However, in the sectoral assessment made with the Department of Renewable Energy and New Technologies of the Ministry of Energy and Natural Resources, in the scenario where the projects related to the integration of hydrogen energy into the end use sector will be evaluated within the scope of efficiency-enhancing projects, it is envisaged to provide grant support within the scope of the existing Energy Efficiency Law. It should also be noted that negotiations are ongoing in the Turkish Grand National Assembly to increase the incentives and grants included in this law and expand its scope.

3.3.1.1.9 Market Regulation

For hydrogen to be traded as a tradable good, it must be regulated in a market and linked to a regulator, a market stabilisation service provider or an exchange. As mentioned above, Türkiye's legal framework for producing and utilising hydrogen energy will likely shed light on this issue after policy-making ministries have established it. During the discussions with government agencies and independent administrative authorities, it is foreseen that after establishing this framework, a number of authorisations related to the hydrogen market will be included in the jurisdiction of the stock exchange or EMRA, the market regulatory authority.

3.3.1.1.10 Economic and Financial Regulations

As of today, Türkiye doesn't have a well-established set of economic and financial regulations dedicated explicitly to hydrogen energy. The legal framework surrounding hydrogen in Türkiye is still in its early stages of development.

However, it seems likely that grants, subsidies, tax reductions or loan guarantees will be available in the near future to encourage investments in hydrogen production, storage and infrastructure development. Türkiye currently obtains such grants and loans mainly from EU-funded projects and tenders (e.g. Hydrogen Valley Project).

Discussions with government agencies are currently evaluating the financial opportunities to be provided in pilot projects involving the use of hydrogen energy. It was also noted in conversations that the Ministry of Trade is working on establishing carbon pricing schemes or emissions trading systems to incentivise the production of low-carbon hydrogen.

3.3.1.2 Permitting and Licencing for Green Hydrogen Production

There are primary obstacles to permitting hydrogen projects. At this point, providing recommendations to policymakers and relevant authorities at both the European Union and national level is critical. This analysis's identified barriers and recommendations encompass the entire hydrogen value chain and are categorized into three main areas: regulatory, administrative, and capacity building.

Regulatory Framework:

A specific and tailored regulatory framework for clean hydrogen production, transportation, storage, and utilisation is largely lacking across most EU countries and Türkiye. Consequently, there is ambiguity surrounding the authorization process, including relevant authorities, timelines, and applicable procedures. It is recommended to prioritize the transposition of such frameworks into national law and expedite the establishment of necessary elements to facilitate efficient permitting.

The current regulatory framework for hydrogen lacks specificity and tailoring, primarily due to its historical association with fossil-based production methods. This absence of clear legislation hampers the development of clean hydrogen production, transportation, storage, and usage. The legislative framework fails to adequately address hydrogen's significance in the energy transition and decarbonization, particularly in challenging-to-decarbonize sectors. Additionally, there's ambiguity in national legislation regarding the classification of hydrogen in various applications, impacting permitting procedures.

Permitting processes involve multiple government levels, from central to regional and local authorities, exacerbating challenges due to outdated regulations and inadequate consideration of hydrogen in urban planning. Consequently, the authorization framework for hydrogen projects is non-existent in most Member States, lacking designated authorities, clear definitions, and relevant permitting bodies. Urgent action is required to address these regulatory gaps and streamline the permitting process for hydrogen projects.

Regulatory Barriers:

- Lack of appropriate legislative framework
- Lack of prioritization of hydrogen legislation
- Requirement for development of hydrogen standards

Consequences of Regulatory Barriers:

- Lack of consistency in permit granting processes leads to subjective judgments from permitting officers and inconsistent outcomes for similar projects.

- Technically incorrect permitting processes that fail to reflect project characteristics, often applying rules designed for other sectors like natural gas to hydrogen.
- Long and expensive approval procedures, particularly for electrolyzers classified under the Industrial Emissions Directive (IED), result in delays and increased operator costs.
- Lengthy approval timelines, exceeding two years in some cases, due to unclear frameworks and additional local assembly approvals, further delaying project commencement.
- Additional costs for companies to demonstrate compliance with unsuitable legislation or norms add complexity to the permitting process.

Administrative Streamlining:

The clarity in the permitting process can be enhanced by adopting national Hydrogen permitting manuals, which provide comprehensive guidance for project developers. Measures such as clear timelines, digitalisation of processes, and establishing one-stop shops can further streamline permitting procedures and improve efficiency.

The permit process for hydrogen projects across EU countries is complex and lacks harmonisation. Varying national and regional legislation and processes create a fragmented landscape, leading to inconsistencies and delays. Decision-making involves multiple levels of authority, resulting in differing experiences and efficiency levels between regions. In Italy, regional bodies oversee hydrogen plant permits, each focusing on environmental protection and fire prevention, often requiring project modifications.

Uncertainty persists regarding coordinating bodies within countries, leading to delays and confusion, particularly due to a lack of expertise and clear regulations among national authorities. Local town halls, sometimes having the final say, often lack updated urban plans that account for hydrogen activities despite EU priorities for decarbonisation.

Administrative Barriers:

- Complexity and inconsistency in permitting procedures
- Lack of harmonisation
- Fragmented authority over permitting
- Absence of clear requirements
- Implementation of one-stop-shop systems
- Streamlining of processes
- Introduction of time limits and digitalisation
- Implementation of fast-track procedures
- Utilization of hydrogen permitting guides

Capacity Building:

Public servants may lack technical expertise in hydrogen, hindering both authorization and final certification processes. Member States should invest in providing relevant training and support schemes to ensure that authorities possess adequate skills. Regular assessments of resources should be conducted to address staffing and financial needs.

Lack of Knowledge and Expertise: Public servants overseeing hydrogen projects may lack technical expertise, leading to cautious decision-making and unnecessary requests for additional data or studies. Local authorities, in particular, struggle with authorizations for end-user hydrogen projects due to the sector's novelty. This results in a reluctance to take responsibility and make decisions within unclear normative frameworks, causing delays in the permitting process. Companies face extra costs and delays in providing technical details to non-technical permitting officers.

Understaffing of Permitting Authorities: Understaffing in permit-granting authorities poses a significant barrier to project deployment, similar to challenges in renewable energy projects. Scaling up hydrogen projects to meet ambitious 2030 targets requires sufficient skilled staff. This issue is even more critical in Hydrogen Valleys, geographical areas integrating various hydrogen applications, as substantial project pipelines require efficient processing to avoid delays. Insufficient resources are a risk hindering the rollout of hydrogen projects, and this needs to be addressed to ensure the development of the European Hydrogen Economy proceeds smoothly.

Lack of correct authorization for permit processes: In line with the lack of a legal framework, the lack of delegation of authority as to which department of the ministry will handle hydrogen projects is seen as the most crucial obstacle to the permitting process in Türkiye.

Capacity Building Barriers:

- Inadequate expertise among national authorities
- Understaffing of regulatory bodies
- Enhancement of authority knowledge
- Regular assessments of resource availability (staffing, financial, etc.)

Recommendations for Permitting:

- **Prioritizing Hydrogen Regulatory Framework:** There's a critical need to streamline and clarify regulatory frameworks across Member State administrations to facilitate future green hydrogen deployment. Accelerating the implementation of hydrogen-related legislation is essential for clarifying permitting processes and promoting awareness and knowledge transfer. The complexity of projects and technologies associated with hydrogen, combining new renewable technologies, underscores the necessity of appropriate regulations within existing frameworks. The European Commission's ongoing legislative proposals require prompt transposition into national law to establish a clear and stable regulatory environment. This includes directives like the Renewable Energy Directive and the Hydrogen and Decarbonized Gas Package legislation.
- **Development of EU Hydrogen Standards:** Clear and common technical standards at the European level are vital to support local permitting processes and address the lack of knowledge and expertise. Standardization is crucial for preventing misclassifications of hydrogen projects and ensuring safe and efficient implementation of solutions. Standards should cover all stages of the hydrogen value chain, from production to end-use, and account for different technologies and regulatory aspects. Standardization processes should begin promptly to facilitate large-scale hydrogen deployment. The Working Group on Standards within the European Clean Hydrogen Alliance is developing a roadmap for this purpose, building on existing standards for hydrogen refuelling stations set by organizations like CEN.
- **One-stop shop:** The Renewable Energy Directive and the Hydrogen and Decarbonized Gas Package propose a national contact point for Member States, facilitating communication with relevant authorities. Implementing "one-stop shop" for hydrogen project permitting, managed by a designated lead authority, would streamline processes and reduce administrative burdens. Regional authorities could assist in coordination, improving efficiency and reducing time and costs.
- **Streamline of permit processes:** Clear and coordinated procedures are essential for authorities inexperienced in hydrogen projects to respond effectively. Permitting procedures should be standardized across regions, considering project size, location, environmental risks, and integrated system aspects. Flexibility should be offered for small-scale projects and those co-located with renewables. Environmental impact analysis for co-located projects should be integrated for efficiency.
- **Fast-track procedures:** Certain projects, such as R&D, small-scale, pilot, or strategic initiatives, could benefit from fast-track procedures, prioritizing their approval without compromising requirements. Projects of common interest (PCIs) could receive accelerated planning and permitting processes at the national level.

- **Digital procedures:** Digitalization of e-government processes can enhance speed, coordination, and efficiency, supporting one-stop-shop permitting and centralization efforts. National Recovery Funds could support digitalization initiatives, leveraging digital solutions and GIS data to streamline permitting processes and prevent redundant studies.
- **Time limits:** The length of permitting processes impacts investment interest in new technologies, with costs increasing as time extends. Mandatory maximum time limits for permitting renewable hydrogen projects are proposed to ensure predictability and efficiency, such as two to three years for large-scale projects. Addressing legal limits and appeal processes is crucial for streamlining permitting timelines.
- **Hydrogen permitting guide:** A publicly accessible guide explaining licensing processes for hydrogen projects would benefit both permitting authorities and companies. Such guides, already available in some regions like Portugal and Aragon in Spain, provide clarity and standardization, facilitating the scaling up of hydrogen technology. They should differentiate between various hydrogen applications, focus on practical experience, and cover all project stages from development to commissioning. EU guidelines on hydrogen permitting should incorporate these recommendations for swift project implementation.
- **Enhancing Knowledge of National Authorities:** It is necessary to ensure that permit-granting bodies and environmental assessment authorities are well-equipped with skilled personnel. Continuous education programs at the national level are crucial to enhancing technical and legal knowledge for smoother authorization processes. Specific initiatives like developing hydrogen-related expertise, establishing communication forums, implementing skilling programs, and leveraging funding opportunities can facilitate efficient permitting. Regular assessments are necessary to address challenges like understaffing and provide financial assistance where needed.

By addressing these barriers and implementing the recommended measures, policymakers can facilitate the transition towards a hydrogen-based economy and promote the widespread adoption of clean hydrogen technologies.

The absence of or outdated legislation poses significant challenges to developing and deploying hydrogen projects across Europe. Currently, there is a lack of a specific regulatory framework tailored to clean hydrogen production, transportation, storage, and usage. This deficiency fails to recognize hydrogen's pivotal role in the energy transition and decarbonization efforts, particularly in hard-to-abate sectors. The regulatory ambiguity extends to the classification of hydrogen in various applications, complicating permitting procedures for non-conventional off-takers.

Permitting processes involve multiple layers of government administration, from central to regional and local authorities. Outdated regulations and insufficient consideration of hydrogen in urban planning further impede permitting efficiency. The limited availability of suitable industrial land exacerbates the challenge, hindering project development.

In summary, the lack of a coherent regulatory framework, unclear definitions, and inadequate permitting bodies hinder the authorization of hydrogen projects across the Member States and Türkiye, necessitating urgent action to streamline regulations and enhance administrative clarity.

3.3.1.3 European Standards

3.3.1.3.1 General Info / General Structure of Standardization (European Standardization)

Most global standardisation activities are performed by ISO (the International Standardisation Organisation) and by IEC (the International Electrotechnical Commission). Both organisations work according to the same principles and procedures as CEN and CENELEC. CEN and CENELEC have dedicated agreements with the International Organisation for Standardisation (ISO) and the International Electrotechnical Commission (IEC), promoting the benefits of European Standards to international trade and market harmonisation. The high level of convergence between European and international

standards is facilitated by the ongoing technical cooperation between CEN and ISO (Vienna Agreement) and between CENELEC and IEC (Frankfurt Agreement).⁴⁶

The European Committee for Standardization (CEN) and the European Committee for Electrotechnical Standardization (CENELEC) are the umbrella organizations responsible for establishing hydrogen-related standards in Europe. Under various technical committees, they engage in collaborative efforts to meet the needs of stakeholders such as business, industry, commerce, service providers, public authorities, regulators, academia, research centres, European trade associations, environmentalists, consumers, trade unions, small and medium enterprises, and other public and private institutions regarding hydrogen standards.

The European Committee for Standardization is one of three European Standardization Organizations (together with CENELEC and ETSI) officially recognized by the European Union and by the European Free Trade Association (EFTA) as responsible for developing and defining voluntary standards at the European level.⁴⁷

The Sector Forum Energy Management Working Group (SFEM/WG) Hydrogen was established to analyse technology and standardization status, identify barriers and needs, engage key stakeholders, and develop a collaborative framework with regulatory bodies and RDI programs. Additionally, the update extends to cross-cutting areas such as safety and training to enhance societal acceptance of hydrogen, which is crucial for its successful market adoption. The working group's scope encompasses hydrogen production through electrolysis, transportation, distribution, and usage, including mixtures with natural gas (H2NG), focusing on promoting broader societal acceptance and market uptake.⁴⁸

SFEM/WG Hydrogen has refined its scope around the three interfaces of electrolyser systems: with the electricity grid, natural gas system, and hydrogen system, aiming at integrating power-to-gas into the energy system. Task Forces were established focusing on grid interaction (Task Force 1/2), natural gas system (Task Force 3), hydrogen system (Task Force 4), and cross-cutting items (Task Force 5), addressing safety, technical topics, regulation, and societal aspects. The scope of work of the CEN-CENELEC SFEM WG Hydrogen is given below. The scope excludes hydrogen production by means other than electrolysis but provides an outlook on green hydrogen production and methanation.⁴⁹

Figure 5 Scope of work of the CEN-CENELEC SFEM WG Hydrogen



Source: CEN/CENELEC Standards

⁴⁶ Roadmap on Hydrogen Standardization, European Clean Hydrogen Alliance, March 2023

⁴⁷ CEN-CENELEC/TC 6 Hydrogen Energy Systems Business Plan-Executive Summary, CEN-CENELEC, 2017

⁴⁸ Hydrogen Quality for Blending with Natural Gas, Technical Recommendations, Marcogaz, June 2022

⁴⁹ Sector Forum Energy Management/Working Group Hydrogen 2018 Update, CEN-CENELEC, 2019

Several technical committees under CEN are dedicated to addressing the standards required for hydrogen's use across various sectors and the intersecting areas of these sectors. The main hydrogen standardization committee is **CEN-CENELEC/TC 6: Hydrogen in energy systems**. The benefits expected from the work of the CEN-CENELEC/TC 6 include:

- Harmonization of standardization processes related to hydrogen in energy systems, covering systems, devices, connections, terminology, safety issues, and more.
- Provision of coherent functional and technical requirements to support stakeholders in their operational practices regarding hydrogen in the energy system.
- Contribution to Europe's energy objectives by promoting standards on hydrogen for sustainability, security, and competitiveness.
- Removal of technical barriers to trade and open hydrogen markets through alignment of requirements.
- Support of EC requirements for non-discrimination and objectivity through technical harmonization.
- Cost savings and removal of technical barriers through common technical requirements.
- Acceleration and support of hydrogen development, implementation, operation, management, safety, and public acceptance.
- Technically safeguarding and strengthening European-wide safety, reliability, and interoperability of hydrogen in the energy system.
- Strengthening self-responsibility in standardization and avoiding duplication of work across sectors.
- Operating as a mirror committee to relevant ISO and IEC committees to ensure alignment and optimization of resources.
- Facilitating cooperation between CEN, ISO, IEC, and CENELEC for worldwide information exchange on hydrogen, contributing to the elimination of trade barriers.
- Overall, the work of TC 6 aims to advance standardization efforts in hydrogen technologies to support Europe's energy objectives and facilitate international cooperation and trade. [2]

Mainly there are four Technical Committees are working on standardization of hydrogen technologies under CEN-CENELEC. These are: CEN/CLC/JTC 6- Hydrogen in energy systems, CEN/TC 234- Gas infrastructure, CEN/TC 268- Cryogenic vessels and specific hydrogen technologies applications, CEN/TC 23- Transportable gas cylinders. The scope, structure, work program, and published standards of CEN-CENELEC Hydrogen and Ceramic Sector related technical committees are summarized in Appendix-1.

3.3.1.3.2 Hydrogen Standards for Production, Storage & Distribution, Utilization and Cross Cutting Issues

Hydrogen standards are essential for ensuring the seamless operation and safety across various facets of hydrogen technology, propelling the development of technology amidst the ongoing energy revolution and the urgent need to address climate change. Hydrogen, derived from diverse sources including coals, natural gas, industry by-products, and water, undergoes production processes often situated far from the points of end-use. This necessitates efficient storage and transportation mechanisms, forming an essential intermediate link in the hydrogen value chain. Hydrogen storage and transportation infrastructure, encompassing tube trailers, pipelines, and storage facilities, plays a crucial role in delivering hydrogen to its intended destinations. Hydrogen can be transported in various states, including gaseous and liquid forms, and hydrogen carriers that store hydrogen in chemical compounds can be utilized.

Gas quality standards for hydrogen blending into natural gas for the ceramic industry are crucial to ensure safe and efficient operations. These standards encompass parameters such as hydrogen concentration limits, impurity levels, calorific value, and combustion characteristics. They aim to guarantee the quality and stability of the blended gas, minimizing potential risks to equipment, processes, and human health while maximizing the benefits of hydrogen utilization. These standards are not only for hydrogen quality but also encompass natural gas and infrastructure requirements, ensuring compatibility and integrity throughout the blending and distribution process. Compliance with these standards ensures that the blended gas meets the

specific requirements of ceramic manufacturing processes, facilitating the transition towards cleaner energy sources and reducing carbon emissions in the industry.

It is of high priority to update existing standards for the design and test of the application for the use of H2 blends⁵⁰ (e.g. materials, safety, performance, emissions, leakages, product testing, ...) and 100% H2 in the long run. Therefore, it is important to define gas qualities in advance to adopt specific burner designs. The hydrogen gas quality/impurities have a huge impact on e.g. the Wobbe Index and, therefore, the combustion process, efficiency, and emissions. These potential influences need to be evaluated and tested in pre-normative studies/lab tests.⁵⁰

Note: A joint Task Force of the CEN-CENELEC Sector Fora for Gas infrastructure, Gas utilization and Energy management WG Hydrogen is investigating the hydrogen quality needs of industrial end-users, also looking into the impact of trace components and impurities and also into possible technical mitigation solutions.

Additional technical adaptations like specific sensors or material aspects have also to be considered. Specific field tests with various applications are also needed for the adopted burners.

At the same time, it is important to update the existing European standards for the use of 100% H2 and H2 blends to prepare the basis for certified burners. Therefore, harmonised test conditions need to be defined and validated under lab conditions. For the feedstock subsector, it was only possible to identify a few topics in the timeframe for preparing this roadmap. In order to develop a detailed work programme, further work will be needed.⁵¹

Standards for all hydrogen value chains, including production, storage and transportation, and utilization, are globally prepared and published by renowned organizations such as ISO, ANSI, CGA, NFPA, ASME, CEN, SAC, and JISC, provide comprehensive guidelines for ensuring safety, efficiency, and interoperability in hydrogen handling processes. [12]. This study focuses on the ceramic sector Public-Private Partnership (PPP) involving Germany and Türkiye so, European standards are listed and classified in the Table below for further reference and analysis. All hydrogen-related standards listed by CEN CENELEC, ISO and European Standards are given in Annex-2. In **Fehler! Verweisquelle konnte nicht gefunden werden.**, only ceramic sector-related standards are listed.

Table 21 Hydrogen Standards Applicable in Europe

No	Standard Name	Status	Publication Date	Related H2 Value Chain
1	ISO 16110-1:2007 Hydrogen generators using fuel processing technologies	Status: Published	Publication date: 2007-03	Production - Cross Cutting; Safety
2	ISO 16110-2:2010 Hydrogen generators using fuel processing technologies - Part 2: Test methods for performance	Status: Published	Publication date: 2010-02	Production
3	ISO 22734:2019 Hydrogen generators using water electrolysis - Industrial, commercial, and residential applications	Status: Published	Publication date: 2019-09	Production

⁵⁰ Common Business Practice – Hydrogen Quality Specifications, European Association for the Streamlining of Energy Exchange (EASEE)- gas, 14 September 2021

⁵¹ Sector Forum Energy Management/Working Group Hydrogen 2018 Update, CEN-CENELEC, 2019

4	EN 17533:2020 Gaseous hydrogen Cylinders and tubes for stationary storage	Status: Corrigendum	Publication date: 2020-11-17	Storage & Distribution
5	EN 17339:2020 Transportable gas cylinders. Fully wrapped carbon composite cylinders and tubes for hydrogen	Status: Standard	Publication date: 2020-07-09	Storage & Distribution
6	ISO 11114-4:2017 Transportable gas cylinders. Compatibility of cylinder and valve materials with gas contents. Part 4: Test methods for selecting steels resistant to hydrogen embrittlement	Status: Published	Publication date: 2017-04	Storage & Distribution Cross Cutting; Materials
7	CEN/TR 17797:2022 Gas infrastructure - Consequences of hydrogen in the gas infrastructure and identification of related standardisation need in the scope of CEN/TC 234	Status: Published	Publication Date: 23-Mar-2022	Storage & Distribution
8	CEN/TS 17977:2023 Gas infrastructure. Quality of gas. Hydrogen used in rededicated gas systems	Status: Published	Publication Date: 15-Nov-2023	Storage & Distribution
9	EN 17649:2022 Gas infrastructure - Safety Management System (SMS) and Pipeline Integrity Management System (PIMS) - Functional requirements	Status: Published	Publication Date: 03-Aug-2022	Storage & Distribution Cross Cutting; Safety
10	CEN/TR 16395:2023 Gas Infrastructure - CEN/TC 234 Pressure Definitions - Guideline Document	Status: Published	Publication Date: 15-Nov-2023	Storage & Distribution
11	SIST EN 12732:2022 Gas infrastructure - Welding steel pipework - Functional requirements	Status: Published	Publication Date: 10-Jan-2022	Storage & Distribution
12	PREN 17928-1 Gas infrastructure. Injection stations . Part 1: General requirements	Status: Not Published	Publication Date: 30-Nov-2023	Storage & Distribution
13	PREN 17928-3 Gas infrastructure Injection stations. Part 3: Specific requirements regarding the injection of hydrogen fuel gas	Status: Not Published	Publication Date: 30-Nov-2023	Storage & Distribution

14	PREN 12007-5 Gas infrastructure - Pipelines for maximum operating pressure up to and including 16 bar - Part 5: Service lines - Specific functional requirements	Status: Not Published	Expected Publication Date: 12-Nov-2024	Storage & Distribution
15	SIST EN 12583:2022 Gas Infrastructure - Compressor stations - Functional requirements	Status: Published	Publication Date: 17-Aug-2022	Storage & Distribution
16	ISO 14687:2019 Hydrogen fuel quality. Product specification - This standard will be replaced by ISO/DIS 14687	Status: Published	Publication date: 2019-11	Cross Cutting; Quality
17	EASEE-gas CBP 2005-001/02, Harmonisation of Natural Gas Quality - EASEE-gas Reference CBP Hydrogen Quality Specification	Status: Published	Publication date: 2021-09	Cross Cutting; Quality
18	EASEE-gas CBP 2022-001/01, Hydrogen quality specification	Status: Approved	Publication date: 2021-09-14	Cross Cutting; Quality
19	BS EN 16726:2015+A1:2018 Gas infrastructure. Quality of gas. Group H	Status: Active	Publication date: 2018-09-25	Cross Cutting; Quality
20	BSI PAS4444:2020, Hydrogen-fired gas appliances. Guide	Published: 30 Apr 2020	Withdrawn: 14 Dec 2021	Cross Cutting; Quality
21	ISO 6145-1:2019 Gas analysis . Preparation of calibration gas mixtures using dynamic methods. Part 1: General aspects	Status: Published	Publication date: 2019-09	Cross Cutting; Quality
22	TS EN ISO 6145-1 Gas analysis Preparation of calibration gas mixtures using dynamic methods Part 1: General aspects - Turkish version of the standard ISO 6145-1:2019 Gas analysis. Preparation of calibration gas mixtures using dynamic methods. Part 1: General aspects	Status: Active	Publication date: 2019-12-16	Cross Cutting; Quality
23	ISO/TR 15916:2015 Basic considerations for the safety of hydrogen systems	Status: Published	Publication date: 2015-12	Cross Cutting; Safety
24	ISO/TS 19883:2017 Safety of pressure swing adsorption systems for	Status: Published	Publication date: 2017-03	Cross Cutting; Safety

	hydrogen separation and purification			
25	ISO 26142:2010 Hydrogen detection apparatus. Stationary applications	Status: Published	Publication date: 2010-06	Cross Cutting; Safety
26	ASME B 31.12 Hydrogen Piping and Pipelines	Status: Published	Publication date: 2024	Cross Cutting; Instrumentation
27	ISO/TR 20491:2019 Fasteners. Fundamentals of hydrogen embrittlement in steel fasteners	Status: Published	Publication date: 2019-02	Cross Cutting; Materials
28	ISO 15330:1999 Fasteners. Preloading test for the detection of hydrogen embrittlement. . Parallel bearing surface method	Status: Published	Publication date: 1999-09	Cross Cutting; Materials
29	ISO 16573-1:2020 Steel. Measurement method for the evaluation of hydrogen embrittlement resistance of high strength steels. Part 1: Constant load test	Status: Published	Publication date: 2020-08	Cross Cutting; Materials
30	ISO 9587:2007 Metallic and other inorganic coatings. Pretreatment of iron or steel to reduce the risk of hydrogen embrittlement - This standard will be replaced by ISO/CD 24251-1	Status: Published	Publication date: 2007-11	Cross Cutting; Materials
31	ISO 9588:2007 Metallic and other inorganic coatings. Post-coating treatments of iron or steel to reduce the risk of hydrogen embrittlement - This standard will be replaced by ISO/CD 24251-1	Status: Published	Publication date: 2007-12	Cross Cutting; Materials
32	ISO 10587:2000 Metallic and other inorganic coatings. Test for residual embrittlement in both metallic-coated and uncoated externally-threaded articles and rods	Status: Published	Publication date: 2000-02	Cross Cutting; Materials
33	ISO 2626:1973 Copper. Hydrogen embrittlement test	Status: Published	Publication date: 1973-11	Cross Cutting; Materials
34	BS EN 2831:1993 Hydrogen embrittlement	Status: Published	Publication date: 1993-05-15	Cross Cutting; Materials

	of steels. Test by slow bending			
35	BS EN 2832:1993 Hydrogen embrittlement of steels. Notched specimen test	Status: Published	Publication date: 1993-05-15	Cross Cutting;Materials
36	ISO 7539-11:2013 Corrosion of metals and alloys. Stress corrosion testing . Part 11: Guidelines for testing the resistance of metals and alloys to hydrogen embrittlement and hydrogen-assisted cracking,	Status: Published	Publication date: 2013-04	Cross Cutting;Materials
37	BS EN 10229:1998 Evaluation of resistance of steel products to hydrogen induced cracking (HIC)	Status: Published	Publication date: 1998-07-15	Cross Cutting;Materials
38	ISO 17081:2014 Method of measurement of hydrogen permeation and determination of hydrogen uptake and transport in metals by an electrochemical technique	Status: Published	Publication date: 2014-06	Cross Cutting;Materials
39	ISO/DIS 24078 Hydrogen in energy systems Vocabulary	Status: Under development	N/A	Cross Cutting
40	ISO/TS 19870:2023 Hydrogen technologies Methodology for determining the greenhouse gas emissions associated with the production, conditioning and transport of hydrogen to consumption gate	Status: Published	Publication date: 2023-11	Cross Cutting

Please find the file in the Annexes for Comprehensive European Hydrogen Standards based on CEN CENELEC, ISO, and European Standards, which includes all related standards.

3.3.2 Stakeholder Analysis

The stakeholder analysis reveals the key players and their potential influence and interest in hydrogen-related initiatives. Please note that the Analysis for stakeholders has been developed, focusing on PPP Project and its potential stakeholders along the way.

Public Institutions such as the Ministry of Energy and Natural Resources and the Ministry of Industry and Technology have a significant influence due to their pivotal roles in energy policy and regulation. They are crucial stakeholders to manage closely, given their very high impact and interest.

Other public institutions like the Ministry of Trade and the Ministry of Transportation and Infrastructure also wield considerable influence and exhibit a high level of interest. Keeping them informed is essential to ensure their support and cooperation.

Regulatory bodies such as the Energy Market Regulatory Authority (EPDK) are key stakeholders that need to be managed closely due to their significant influence and interest in hydrogen initiatives.

NGOs like the Green Hydrogen Producers Association and the Hydrogen Technologies Association play vital roles in advocating for green energy solutions. They possess moderate to high influence and interest, necessitating their involvement and keeping them informed.

Equipment suppliers and hydrogen suppliers, such as TEKSİS İleri Teknolojiler Kimya İmalat ve Dış Ticaret Ltd. Şti. and Linde Gaz A.Ş., have a high level of influence and interest. Managing them closely is essential to ensure their support and collaboration in hydrogen projects.

Financial institutions also play a crucial role in providing funding for hydrogen initiatives. While they exhibit a high level of influence, their interest may vary. Keeping them informed about project developments is necessary to secure their financial backing.

Table 22 Stakeholder Analysis

STAKEHOLDER ANALYSIS													
Identification		Working Field	Analysis										
Stakeholder	Role and Possible Cooperation Field	INFLUENCE ; The level of influence this stakeholder may have	INTEREST ; The level of interest this stakeholder may have	Stakeholder Matrix					Score	Score	Total Score	Analysis Result	
The Ministry of Energy and Natural Resources	Public Institutions, Regulatory Bodies And Others	Very High	Very High	Influence	V				X	4	4	16	Key Stakeholder: Manage Closely
					H					0	0		
					M					0	0		
					L					0	0		
						L	M	H	V				
					Interest								
The Ministry of Industry and Technology	Public Institutions, Regulatory Bodies And Others	Very High	Very High	Influence	V				X	4	4	16	Key Stakeholder: Manage Closely
					H					0	0		
					M					0	0		
					L					0	0		
					Interest								

Ministry of Trade	Public Institutions, Regulatory Bodies And Others	Very High	Moderate	Influence	V H		X			4	0	8	Keep Informed
					H					0	0		
					M					0	2		
					L					0	0		
						L	M	H	V H				
					Interest								
Ministry of Transportation and Infrastructure	Public Institutions, Regulatory Bodies And Others	Very High	Moderate	Influence	V H		X			4	0	8	Keep Informed
					H					0	0		
					M					0	2		
					L					0	0		
						L	M	H	V H				
					Interest								
EPDK: Energy Market Regulatory Authority	Public Institutions, Regulatory Bodies And Others	Very High	High	Influence	V H			X		4	0	12	Key Stakeholder: Manage Closely
					H					0	3		
					M					0	0		
					L					0	0		
						L	M	H	V H				
					Interest								
Tedaş: Turkish Electricity Distribution Company	Public Institutions, Regulatory Bodies And Others	Moderate	Moderate	Influence	V H					0	0	4	Keep Informed
					H					0	0		
					M		X			2	2		
					L					0	0		
						L	M	H	V H				
					Interest								
Teiaş: Turkish Electricity Transmission Corporation	Public Institutions, Regulatory Bodies And Others	Moderate	Moderate	Influence	V H					0	0	4	Keep Informed
					H					0	0		
					M		X			2	2		
					L					0	0		
						L	M	H	V H				
					Interest								
Tetaş: Türkiye Elektrik	Public Institutions, Regulatory	Moderate	Moderate	Influence	V H					0	0	4	Keep Informed
					H					0	0		

Ticaret Ve Taahhüt A.Ş.	Bodies And Others				M		X			2	2		
					L					0	0		
						L	M	H	V H				
					Interest								
Turkish Standarts Institution And Other Accreditation Agencies	Public Institutions, Regulatory Bodies And Others	High	High	Influence	V H					0	0	9	Keep Satisfied
					H			X		3	3		
					M					0	0		
					L					0	0		
						L	M	H	V H				
					Interest								
Development Agencies and Business Support Organizations	Public Institutions, Regulatory Bodies And Other	Moderate	Moderate	Influence	V H					0	0	4	Keep Informe d
					H					0	0		
					M		X			2	2		
					L					0	0		
						L	M	H	V H				
					Interest								
Municipalities	Public Institutions, Regulatory Bodies And Other	Moderate	Moderate	Influence	V H					0	0	4	Keep Informe d
					H					0	0		
					M		X			2	2		
					L					0	0		
						L	M	H	V H				
					Interest								
Universities	Research and Development	Low	Moderate	Influence	V H					0	0	2	Monitor (Minimum Effort)
					H					0	0		
					M					0	2		
					L		X			1	0		
						L	M	H	V H				
					Interest								
Türkiye Enerji Nükleer ve Maden Araştırma Kurumu (TENMAK)	Research and Development	High	High	Influence	V H					0	0	9	Keep Satisfied
					H			X		3	3		
					M					0	0		
					L					0	0		
						L	M	H	V H				
					Interest								

Tübitak Marmara Research Center (MAM)	Research and Development	Moderate	High	Influence	V H					0	0	6	Keep Informe d
					H					0	3		
					M			X		2	0		
					L					0	0		
						L	M	H	V H				
					Interest								
Boğaziçi University Climate Change and Policies Application and Research Center (İklimBU)	Research and Development	Moderate	High	Influence	V H					0	0	6	Keep Informe d
					H					0	3		
					M			X		2	0		
					L					0	0		
						L	M	H	V H				
					Interest								
ICEC - Sabancı University Istanbul International Center For Energy and Climate	Research and Development	High	High	Influence	V H					0	0	9	Keep Satisfied
					H			X		3	3		
					M					0	0		
					L					0	0		
						L	M	H	V H				
					Interest								
GAZBİR - Turkish Natural Gas Distributors Association	NGOs	Moderate	Moderate	Influence	V H					0	0	4	Keep Informe d
					H					0	0		
					M		X			2	2		
					L					0	0		
						L	M	H	V H				
					Interest								
H2DER - Green Hydrogen Producers Association	NGOs	Moderate	High	Influence	V H					0	0	6	Keep Informe d
					H					0	3		
					M			X		2	0		
					L					0	0		
						L	M	H	V H				
					Interest								
Hydrogen Technologies Association	NGOs	Moderate	High	Influence	V H					0	0	6	Keep Informe d
					H					0	3		
					M			X		2	0		

					L					0	0		
						L	M	H	V H				
					Interest								
ENSİA - Association of Energy Industrialists and Businessmen	NGOs	Moderate	High	Influence	V H					0	0	6	Keep Informed
					H					0	3		
					M			X		2	0		
					L					0	0		
						L	M	H	V H				
					Interest								
BOTAŞ	Pipeline Infrastructure Developer	Very High	Very High	Influence	V H				X	4	4	16	Key Stakeholder: Manage Closely
					H					0	0		
					M					0	0		
					L					0	0		
						L	M	H	V H				
					Interest								
AKSA Doğalgaz	Natural Gas Distrubitor	Very High	Very High	Influence	V H				X	4	4	16	Key Stakeholder: Manage Closely
					H					0	0		
					M					0	0		
					L					0	0		
						L	M	H	V H				
					Interest								
TEKSİS İleri Teknolojiler Kimya İmalat ve Dış Ticaret Ltd. Sti.	Equipment Suppliers - H2 equipment developer	High	High	Influence	V H					0	0	9	Keep Satisfied
					H			X		3	3		
					M					0	0		
					L					0	0		
						L	M	H	V H				
					Interest								
ASPİLSAN Enerji Sanayi ve Ticaret A.Ş.	Equipment Suppliers - H2 equipment developer/manufacturer	Moderate	High	Influence	V H					0	0	6	Keep Informed
					H					0	3		
					M			X		2	0		
					L					0	0		
						L	M	H	V H				
					Interest								

2A Mühendislik Sanayi ve Ticaret A.Ş.	Equipment Suppliers - Turn-key plant projects	Moderate	High	Influence	V H					0	0	6	Keep Informe d
					H					0	3		
					M			X		2	0		
					L					0	0		
						L	M	H	V H				
					Interest								
Abdioğulları Plastik ve Ambalaj Sanayi A.Ş.	Equipment Suppliers - Membrane Manufacturer	Moderate	High	Influence	V H					0	0	6	Keep Informe d
					H					0	3		
					M			X		2	0		
					L					0	0		
						L	M	H	V H				
					Interest								
BCS Enerji Mühendislik ve Endüstriyel Ürünler San. Tic. Ltd. Şti	Equipment Suppliers - H2 Burner Manufacturer	Moderate	High	Influence	V H					0	0	6	Keep Informe d
					H					0	3		
					M			X		2	0		
					L					0	0		
						L	M	H	V H				
					Interest								
Lentatek Uzak Havacılık ve Teknoloji A.Ş.	Equipment Suppliers - H2 equipment developer/manu facturer	Moderate	High	Influence	V H					0	0	6	Keep Informe d
					H					0	3		
					M			X		2	0		
					L					0	0		
						L	M	H	V H				
					Interest								
Linde Gaz A.Ş.	Hydrogen Suppliers	Very High	Very High	Influence	V H				X	4	4	16	Key Stakeho lder: Manage Closely
					H					0	0		
					M					0	0		
					L					0	0		
						L	M	H	V H				
					Interest								
HABAŞ Sınai ve Tıbbi Gazlar İstihsal Endüstri A.Ş.	Hydrogen Suppliers	Very High	Very High	Influence	V H				X	4	4	16	Key Stakeho lder: Manage Closely
					H					0	0		
					M					0	0		
					L					0	0		

						L	M	H	V H				
						Interest							
Financial Institutions	Financing	High	Moderate	Influence	V H					0	0	6	Keep Informed
					H		X			3	0		
					M					0	2		
					L					0	0		
						L	M	H	L				
					Interest								

3.3.3 Legislative and Regulatory Risk Assessment and Road Map Table

The Risk Assessment and Roadmap Table serves as a structured framework for evaluating and addressing potential risks associated with regulatory processes related to PPP initiative. This table provides a systematic approach to identifying, analyzing, and mitigating risks and outlining a strategic roadmap for navigating through these challenges.

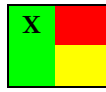
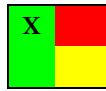
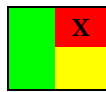
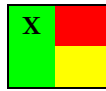
Each risk is clearly defined under the Risk Identification column, ranging from the absence of a well-established legislative framework for hydrogen energy to uncertainties surrounding hydrogen transportation and storage. The Qualitative Analysis section assesses the probability and impact of each risk on project objectives, using a risk matrix to categorize them as low or high. Risks with a high likelihood of occurrence and a substantial impact are marked for priority attention.

The "Actions To Be Taken" column outlines specific mitigation strategies for each risk, including advocacy efforts for comprehensive legal frameworks, collaboration with stakeholders to develop regulations, and engagement with policymakers to explore incentives and support mechanisms.

Table 23 Risk Assessment and Road Map Table

RISK ASSESSMENT AND ROAD MAP TABLE						
Risk Identification			Qualitative Analysis			
Status	Name of the Risk	Risk Description	Probability	Impact	Risk Matrix	ACTIONS TO BE TAKEN
Active; Actively monitored & controlled.	Name of the Risk	Detailed description of the risk.	Assessment of the likelihood of occurrence. Valid entries are Low or High.	The severity of the risk's effect on the project objectives. Valid entries are Low or High.	High: Substantial impact. Low: Minimal impact on cost, schedule, or technical..	Mitigation Strategy
Active	Lack of Well-Established Legislative Framework	* Absence of comprehensive legal framework for hydrogen energy in Türkiye. * Creates uncertainty for investors regarding permits, safety standards, and overall project feasibility.	High	High	Probability H  L  L H Impact	* Advocate for a comprehensive legal framework for hydrogen energy, collaborating with relevant ministries. * Support the development of technical standards for hydrogen blending in partnership with experienced hydrogen companies. * Engage with regulatory bodies to build their technical expertise on hydrogen projects.
Active	Absence of Clear Legal Framework for Hydrogen Production	* Lack of legal clarity and responsible authority for permitting, safety standards, and environmental considerations for hydrogen production facilities.	High	High	Probability H  L  L H Impact	* Engage with policymakers and relevant authorities to participate in the development of a clear legal framework for hydrogen production. * Partner with established players in the hydrogen sector to navigate the current regulatory environment.
Active		* Uncertainty around safety protocols, infrastructure	High	High	Probab ity H  X	* Collaborate with stakeholders to develop regulations for safe and efficient hydrogen

	No Legal Regulations on Hydrogen Transportation	development, and liability for transporting hydrogen.			L L H Impact	transportation. * Explore participation in pilot projects to test and demonstrate hydrogen transportation technologies.
Active	No Legal Framework for Hydrogen Storage	* Lack of regulations for hydrogen storage, including technical specifications, safety protocols, and site selection criteria.	High	High	Probability H L X L H Impact	* Advocate for the development of a legal framework for hydrogen storage that ensures safety and environmental protection. * Partner with research institutions to develop innovative and cost-effective hydrogen storage solutions.
Active	No Specific Regulations for Hydrogen End-User Sector	* Uncertainty for companies and individuals who want to utilize hydrogen, hindering market development.	High	High	Probability H L X L H Impact	* Collaborate with industry associations and clusters to develop guidelines for hydrogen end-user applications. * Engage with policymakers to explore potential incentives and support mechanisms for hydrogen end-users.
Active	Lack of Regulation and Technical Standards for Hydrogen blending	* No specific regulations exist for blending hydrogen into natural gas pipelines. * The responsible ministry and technical standards for production, infrastructure, safety, and environmental impact are undefined.	High	High	Probability H L X L H Impact	* Advocate for clear regulations on hydrogen blending within the legal framework. * Support the development of technical standards for various aspects of hydrogen utilization (production, infrastructure, safety, environmental impact).
Active	Fragmented Regulatory Landscape	* The absence of dedicated legislation and clear definitions for hydrogen activities leads to a complex process. * Inconsistent decision-making across different authorities.	High	High	Probability H L X L H Impact	* Advocate for a comprehensive legal framework that streamlines the permitting process. * Engage with relevant ministries to harmonize regulations and ensure consistent decision-making.

Active	Limited Technical Expertise of Public	* Public servants overseeing hydrogen projects may lack the necessary expertise, resulting in cautious decision-making and delays in authorization processes.	High	Low	Probability	H L	 L H Impact	* Engage with regulatory bodies to build their technical expertise on hydrogen projects through training programs. * Partner with experienced hydrogen companies/clusters/projects to provide technical support during project development and approval processes.
Active	Pipeline Infrastructure Development Requirement	* Building new infrastructure for transporting and storing hydrogen requires significant investment. * Potential delays due to technical challenges (e.g., material compatibility) or permitting issues.	High	Low	Probability	H L	 L H Impact	* Implement a phased approach with pilot projects to test the technology and identify technical challenges. * Conduct feasibility studies to assess technical feasibility and potential challenges. * Adopt international standards for hydrogen infrastructure and equipment to ensure compatibility and safety.
Active	Lack of Regulations for Safety Requirements	* Ensuring existing natural gas infrastructure can safely handle blended hydrogen might require modifications, potentially increasing project costs. * Compatibility challenges between existing infrastructure and blended gas.	High	High	Probability	H L	 L H Impact	* Conduct feasibility studies to determine compatibility of existing infrastructure with blended gas and identify necessary modifications. * Adopt international standards for hydrogen infrastructure and equipment to ensure compatibility and safety.
Active	Cost of Hydrogen Production - Support and Incentives...etc	* Green hydrogen production, the most environmentally friendly option, might be initially expensive compared to traditional energy sources without financial incentives.	High	Low	Probability	H L	 L H Impact	* Lobby for government subsidies or tax breaks to make green hydrogen production more cost-competitive. * Explore alternative production methods with lower costs (e.g., blue hydrogen with carbon capture).
Active			High	High	Pro	ts		

		* Lack of specific regulations for hydrogen production facilities in Türkiye. * Case-by-case assessment to determine the applicable permitting procedure creates uncertainty for project developers.			H L	X	* Advocate for the development of a comprehensive legal framework for hydrogen production in Türkiye. * Partner with experienced hydrogen companies familiar with the Turkish permitting process.
	Uncertain Permitting Process				L H	Impact	
Active	Responsibility of Natural Gas Distribution Companies	* Current regulations require natural gas distribution companies to approve and take responsibility for hydrogen-blended natural gas installations for the entire process, including the point of combustion. * These companies might not have the expertise or resources to ensure the safety of blended gas throughout the entire system.	High	High	Probability	H L X L H Impact	* Clearly define technical standards for blended gas safety through the legal framework. * Collaborate with natural gas distribution companies to ensure their proficiency in managing and maintaining blended gas infrastructure. * Encourage the development of training programs and capacity building initiatives for relevant stakeholders.
Active	Uncertain Regulatory Environment for Tax and Incentives	* Evolving tax and incentive frameworks create an uncertain investment climate for hydrogen producers.	High	High	Probability	H L X L H Impact	* Closely monitor regulatory developments and proactively engage with relevant authorities to influence policy decisions. * Partner with established players in the green hydrogen sector to navigate the regulatory landscape
Active	Limited Public Funding	* Scarce financial resources pose a challenge when considering dedicated funds. * Absence of a specific budget allocation for hydrogen production.	Low	High	Probability	H L X L H Impact	* Advocate for the development of dedicated funding programs for hydrogen initiatives in Türkiye. * Partner with international funding institutions to leverage their expertise and financial resources

Active	Unclear Regulatory Framework for Hydrogen Trading	* Lack of established regulations for hydrogen trading in Türkiye. * Uncertainty about which regulatory body will oversee the hydrogen market (e.g., stock exchange, EMRA).	Low	High	Probability	H L X L H Impact			* Advocate for the development of a clear and comprehensive regulatory framework for hydrogen trading in Türkiye. * Engage with policymakers and relevant authorities to influence the regulatory framework and secure a favorable environment for hydrogen producers.
Active	Incompatibility with EU Regulations - Carbon Border Adjustment Mechanism (CBAM)	* Divergence between Turkish regulations and evolving EU hydrogen market rules could hinder cross-border trade opportunities, particularly considering the CBAM.	High	High	Probability	H L X L H Impact			* Closely monitor EU regulatory developments, particularly regarding the CBAM, and advocate for harmonization of Turkish regulations with EU standards. * Partner with European companies to gain insights into EU market regulations and best practices to ensure CBAM compliance.

3.3.4 Check List Table

The "Check List" has been developed to serve as a tool for systematically managing legal considerations and actions within hydrogen projects or operational contexts.

Each action or consideration is clearly outlined, covering various aspects such as developing a legal framework, advocating for legislative priorities, collaborating with stakeholders, and investing in training programs.

The involved actors or parties potentially responsible for executing each action are identified, ranging from ministries and regulatory authorities to public agencies, industry experts, and research institutions.

Impact areas are categorized to assess the significance of each action, with a focus on legal and regulatory environments, standardization, capacity building, finance, technology development, and public awareness.

Priority levels are assigned to prioritize actions based on their potential impact and urgency, ensuring that critical tasks receive appropriate attention.

Indicators for monitoring progress are defined for each action, allowing for measuring outcomes and tracking performance over time. These indicators include the enactment of legislation, the number of training programs conducted, the level of industry adoption of standards, and the implementation of government subsidies or tax breaks. Data sources to be collected are specified for monitoring purposes, ranging from legal records and government announcements to project reports, industry surveys, and media coverage.

The "Check List" table provides a structured framework for ensuring legal compliance and effective project management, enabling stakeholders to identify, classify, prioritize, and monitor actions related to PPP hydrogen initiative.

Table 24 Check List Table

CHECKLIST					
List of Actions				Monitoring and Evaluation	
Considerations / Actions	Actors	Impact Area	Priority Level	Indicator for Monitoring	Data Sources to be Collected
A detailed list of legal aspects or requirements	Identification of the parties of the action	Classification of the Actions based on their impact	The level of Priority	Definition of Indicator	How will it be measured?
Develop and implement a comprehensive legal framework for hydrogen energy	Ministries, legal experts	Legal & regulatory environment	High	Enactment of a hydrogen law; comprehensiveness of the legal framework	Legal records, government announcements
Advocate for prioritization of hydrogen legislation & development of clear regulatory frameworks	Ministries, regulatory authorities	Legal & regulatory environment	High	Number of legislative proposals submitted and passed; Time taken for approval	Legal records, government announcements
Collaborate with stakeholders to develop common technical standards and guidelines	Public agencies, industry experts, TSE	Standardization & technical expertise	High	Number of standards developed; Level of industry adoption of standards	TSE records, industry surveys
Establish a structure for hydrogen project permitting such as one-stop shop g	Public agencies	Legal & regulatory environment	High	Time required for permit issuance; Number of applications rejected	Legal records, government announcements
Invest in training programs for public servants overseeing hydrogen projects	Public agencies, national and international universities	Capacity building	Medium	Number of training programs conducted; Number of public servants trained	Public agency reports, training program records

Standardize permitting procedures	Public agencies including municipalities	Legal & regulatory environment	High	Time required for permit issuance; Online accessibility of permitting process	Permitting agency records, government websites
Initiate discussions with TSE on hydrogen-blended natural gas standards	Public agencies, TSE	Legal & regulatory environment	Medium	Number of technical discussions held; Progress on developing new standards	Progress reports
Advocate for aligning Turkish standards with European standards	Ministries, TSE	Legal & regulatory environment	Medium	Level of alignment achieved between Turkish and European standards	Legal records, government announcements
Collaborate with stakeholders to enhance technical proficiency in natural gas distribution companies	Public agencies, industry associations, clusters, natural gas distribution companies	Capacity building	High	Number of training programs conducted; Improvement in technical expertise	Training program records, industry surveys
Encourage carbon-intensive sectors to advocate for relevant legislation	Industry associations, clusters, companies in carbon-intensive sectors	Legal & regulatory environment	High	Number of advocacy campaigns launched; Level of industry participation	Industry association reports, media coverage
Phased implementation with pilot projects to test technology & build public confidence	Public agencies, research institutions, private companies	Technology development & competitiveness	Medium	Number of pilot projects launched; Public response to pilot projects	Project reports, media coverage
Advocate for government subsidies or tax breaks for hydrogen production and use	Industry associations, clusters, private companies	Finance	Medium	Level of government subsidies or tax breaks implemented	Public announcements
Adopt international standards for hydrogen infrastructure and equipment	Public agencies, clusters, private companies	Legal & regulatory environment	High	Level of adoption of international standards	Legal records, government announcements

Collaborate with experienced national and international hydrogen companies/clusters/projects	Public agencies, private companies	Public awareness & technology development	Medium	Number of collaboration agreements signed; Number of projects participated in; Progress on joint projects	Project reports, grant agreements, industry publications
Invest in internal R&D for hydrogen technologies	Companies	Technology development & competitiveness	Medium	Number of R&D projects undertaken; Patent applications filed	Internal R&D reports, patent office records
Conduct feasibility studies for hydrogen projects in Türkiye	Companies, clusters and universities and research institutions	Technology development & competitiveness	High	Number of feasibility studies completed; Investment decisions based on studies	Feasibility reports
Promote hydrogen solutions through targeted marketing & communication	Companies, industry organizations, clusters	Public awareness & technology development	Medium	Level of media coverage; Public inquiries received	Marketing monitoring data
Engage with universities and research institutions for knowledge transfer	Companies	Technology development & competitiveness	Medium	Number of collaboration agreements signed; Joint research projects undertaken	Collaboration agreements, research project reports

3.4 Findings and Recommendations

In the European Union and Germany, hydrogen energy production, storage, distribution and delivery to the end user occupies an important place in the legal framework. Considering the analyses and comparisons made within this project's scope, it is clear that the place of hydrogen energy in the EU energy sector is becoming increasingly important day by day. This increase pushes EU countries to make serious changes in their domestic laws. As can be seen in Germany, which was selected as a benchmarking country in this report, a detailed legislative framework is in progress, and pilot projects and initiatives are being carried out in this context. In Turkish legislation, the position of hydrogen energy in production, storage, distribution, and end-user is not yet fully determined. Especially considering the Legislative Table prepared within the scope of the report, it is seen that Germany is working on enacting legislation on almost every stage of hydrogen energy from production to the end user, but the legislation that can be equivalent to these legal texts in Türkiye is more in the form of general regulations. Likewise, in Türkiye, neither distinct legislation on the regulation of hydrogen energy nor a regulation within the general legislation has yet been introduced to the literature.

Within the framework of the energy law in Türkiye, however, renewable energy sources and energy efficiency are given great importance. Therefore, studies on hydrogen's role in the energy transition are ongoing. The priority in this transformation is to determine the hydrogen energy policy. Currently, with the Türkiye Hydrogen Technologies Strategy and Roadmap published a while ago by the Ministry of Energy and Natural Resources, the issue of increasing the use of green hydrogen energy in carbon-intensive sectors and blending it into natural gas has been presented as a target, but no steps have been taken to establish its legal framework. In particular, the General Directorate of Energy Affairs of the Ministry of Energy and Natural Resources, which published the strategy, is expected to assume the policy-making role at this point. In this way, it will be possible to coordinate the establishment of the legal framework and distribute and control the authority to the relevant ministries and state institutions. Each ministry and state institution is expected to undertake specific tasks in this framework. For example, it is indicated in the sectoral formation of hydrogen technologies and energy of the Ministry of Energy and Natural Resources that TENMAK (Turkish Energy, Nuclear and Mining Research Institution) will be responsible for cooperating with public and private legal entities in this field, conducting and commissioning scientific researches, coordinating, encouraging and supporting these researches. Likewise, EMRA (Energy Market Regulatory Authority) will regulate the hydrogen market after it is established and authorised, and it will manage the relations with the market actors. Nevertheless, at this point, it can be observed that Turkish legislators are closely following the practices in the EU, Germany, the UK and the Netherlands, which have been considerably developing in terms of hydrogen energy legislative studies and concrete practices.

Gaps in Turkish Legislation:

As mentioned above, Turkish law does not have a binding regulation on hydrogen energy. Considering the scenario planned within the scope of this project, in order for this initiative to be successful, at least a framework of legislation on hydrogen energy should be available. Thus, the path will be drawn from standards to responsibility. When we look at the hydrogen production, storage, distribution and end-user columns in the Legislative Table, it will be observed that no single column is ticked. Although hydrogen energy is not available in the legislation that we think may be the equivalent of the German legislation placed in the table, after the “*framework law*” is established, it is expected to be added to the Turkish legislation in the table in this respect.

For example, in Germany, the Energy Financing Act has been designed to provide financial support and incentives to projects related to energy generation, efficiency and renewable energy sources, aiming to facilitate the implementation of sustainable energy projects and contribute to the country's energy transition goals, and full exemption from taxes for electricity required to produce green hydrogen. The current binding law in Turkish legislation that can cover such regulations are the Energy Efficiency Law and the Electricity Market Law. The Energy Efficiency Law regulates the procedures and principles to be applied in order to increase and support energy efficiency in the production, transmission, distribution and consumption stages of energy, industrial establishments, buildings, electrical energy generation facilities, transmission and distribution networks and transportation, and to develop energy awareness throughout the country. With an amendment to this law, green

hydrogen can be evaluated within the scope of projects related to increasing energy efficiency and can be affected by the procedures and principles presented in the law and can benefit from support mechanisms. At this point, this law can be referred to in a framework law to be prepared by legislators.

In another case, while the German Federal Emission Control Act foresees regulations on hydrogen production, there is no corresponding law in Turkish legislation. Regulations in this respect can be implemented through the Regulation on the Functioning of Carbon Markets. However, there is no regulation on hydrogen energy in the current version of this Regulation, which is still in draft form and not in force.

Likewise, while Germany's Hydrogen Network Fees Regulation regulates the fees determined for the connection of hydrogen fuel cell vehicles to the grid and the use of the grid, benchmarking studies have shown that there is no legal regulation in this regard in Türkiye, nor has a hydrogen network and/or commodity market been established.

Recommendations on Hydrogen Production within the Framework of Turkish Legislation:

With the coordination of the Ministry of Energy and Natural Resources, a framework law should urgently be introduced into Turkish law by taking into account variables such as the production of hydrogen energy, the standards to be complied with during production, the characteristics of the production facilities, what the hydrogen produced will be produced with, whether the hydrogen will participate in the market to be formed after production or whether it will be used in consumption facilities connected to the production facility. In the framework law to be established regarding hydrogen energy, the following issues regarding production must be included:

- **Definitions and Scope:** Different types of hydrogen (grey, blue, green) and production methods should be clearly defined.
- **Licences and Permits:** Procedures and principles regarding establishing, operating, and supervising hydrogen production facilities should be determined. The necessary licences and permits, as well as the stages and with which documents to apply, should be clearly defined.
- **Safety and Environmental Impacts:** Safety standards and procedures to be followed in the operation of hydrogen production facilities should be determined. Environmental risks that may occur during the production, storage and transport of hydrogen and measures to prevent these risks should be regulated.
- **Incentives and Supports:** Tax reductions, subsidies and other financial support should be provided to encourage hydrogen production investments. Mechanisms should be established to support research, development and innovation activities.
- **International Co-operation:** Efforts should be made to harmonise with international standards and regulations. Cooperation and information sharing in the field of hydrogen energy with different countries should be encouraged.
- **Resolution of Legal Disputes:** Mechanisms for the resolution of legal disputes related to hydrogen production should be established.

In relation to the framework law to be established, references should be made to other existing legal regulations, and amendments should be made in the regulations. For example, regulations can be introduced such that distribution companies, whose areas of responsibility are regulated in the Natural Gas Market Law, can be responsible for the blending of the hydrogen produced with natural gas, even if it is in the internal installation. On the contrary, if the framework law does not include a regulation on the blending of the hydrogen produced and does not pave the way for this, it is necessary to make amendments to the legal legislation regarding the establishment and inspection of the installation that allows one hundred per cent hydrogen flow, for example, regarding the transportation of chemicals by pipeline.

In addition to the regulations that can be brought to the framework law on the prevention of damages that may occur in the **environment during production**, amendments should be made to the legislation, such as the Environmental Law, Environmental Impact Assessment Regulation and Environmental Permit and Licence Regulation, and the production of hydrogen should be incorporated into the standards within these legislations. Again, the EIA requirement for hydrogen production facilities is determined according to criteria such as the project's scope, size and location. There is generally no

EIA requirement for facilities that produce hydrogen by electrolysis. There is usually an EIA requirement for facilities that produce hydrogen from fossil fuels. The scope and size of the project determine the EIA requirement for hydrogen filling stations. The lack of EIA regulations for hydrogen energy can be seen as an obstacle to investments in this field. Therefore, a special EIA regulation for hydrogen energy is required.

Recommendations on Hydrogen Transportation within the Framework of Turkish Legislation:

There is no binding legal regulation on the transport of hydrogen in Türkiye specifically. However, the "Regulation On The Carriage Of Dangerous Goods By Road" prepared based on the Agreement on the International Carriage of Dangerous Goods by Road (ADR), to which our country is also a signatory, which sets international standards for the transport of dangerous goods, makes it practically possible to transport hydrogen. In the annexes of ADR, dangerous goods are classified and hydrogen is listed among them. However, some measurements to be applied by standard (such as test pressure) have been left incomplete here.

On the other hand, following the EU, Türkiye uses existing international standards developed by ISO and IEC as a reference point for hydrogen transport safety. As a result of the discussions with EMRA within the scope of the project, it has been brought to the agenda that the pipework carrying 100 % hydrogen can be considered a priority. This means a serious financial burden. Likewise, even if hydrogen transport with CNG tanks instead of fixed lines is on the agenda, we need to look at the Natural Gas Market Law, which regulates the responsibilities of distributor companies, since these tanks are also considered internal installations. At this point, there is no regulation on the transport of hydrogen. The following issues must be regulated in the legal arrangements to be made regarding the transport of hydrogen in the hydrogen energy framework law:

- **Safety:** Safety standards and procedures to be followed during transport should be defined. Specific safety measures for different modes of transport (pipes, tankers, trucks) should be defined. Emergency plans and response procedures should be established.
- **Infrastructure:** Arrangements should be made for the development and operation of the infrastructure (pipes, storage facilities) necessary for the transport of hydrogen. Essential standards for the safety and security of the infrastructure should be determined.
- **Licenses and Permits:** License and permit requirements for hydrogen transport companies should be determined. Documents and procedures to be followed during transport should be defined.
- **Liability and Insurance:** Responsibilities arising from accidents and damages that may occur during transport should be determined. Insurance of carriers and other related parties can be made compulsory.

The above-mentioned regulation implementing ADR provisions should be revised following the framework law. Thus, it will be possible to implement the procedures and principles determined by the framework law with the standards specified in the revised regulation.

In the meetings held with the EMRA Natural Gas Department within the scope of the project, it was understood that the regulations on transportation of the framework law on hydrogen energy are expected to proceed in parallel with the distribution of natural gas. It has also been added that instead of the transportation being carried out primarily as natural gas and hydrogen blended, a system where 100% hydrogen can be transported is envisaged. This means that the hydrogen energy framework law should regulate the responsibility of existing or independent installations and compressed hydrogen tanks to be used during transport.

It is also necessary to regulate **the liability for fault in accidents** that may occur during transport and to make additions and amendments to the regulations on the transport of chemical substances in this respect.

Except for the pilot projects carried out within the scope of EU projects, there is no similar **initiative regarding hydrogen pipelines** in Turkish legislation. In this context, detailed regulations should be made on the planning and approval processes of hydrogen pipelines with the regulations to be issued in addition to the framework law.

For **the compressed transport of hydrogen**, some standards and definitions should be prepared to be added to the framework law, similar to the regulations in the Natural Gas Market Law on the compressed transport of natural gas. In addition, **qualification standards and authorisation procedures** that will enable the safe and efficient transport of these tanks in Turkish territory should be added to the legislation.

Environmental impacts should also be taken into consideration during the transport of hydrogen. In case of leakage or leakage of hydrogen, there is a potential for environmental pollution. Therefore, it is important that environmental regulations related to hydrogen transport are meticulously followed and environmental risks are minimized. In this context, standards regarding the transport of hydrogen should be added to the legislation, such as the Environmental Law, Environmental Impact Assessment Regulation, and Environmental Permit and Licence Regulation.

Recommendations on Hydrogen Storage within the Framework of Turkish Legislation:

Although storage activities have gained momentum within the framework of the Electricity Market Storage Regulation in Turkish legislation, this text does not include any statement regarding hydrogen energy storage. In fact, it can be said that hydrogen compressed for transport by the Regulation on the Carriage of Dangerous Goods by Road, which implements the ADR provisions described in the "Recommendations on Hydrogen Transportation within the Framework of Turkish Legislation" section above, functions as a storage activity as long as the transport action is not carried out. Comprehensive, up-to-date and in line with international standards, legal regulations on hydrogen storage will ensure the security and sustainability of investments in this field.

The following issues must be regulated in the legal arrangements to be made regarding the storage of hydrogen in the framework law:

- **Safety:** Procedures and principles regarding establishing, operating, and inspecting storage facilities should be determined. Specific safety measures should be defined for different storage methods (underground storage, pressurised tanks). Emergency plans and response procedures should be established.
- **Infrastructure:** Arrangements should be made for the development and operation of the infrastructure (storage facilities/tanks) required for the storage of hydrogen. Necessary standards for the safety and security of the infrastructure should be determined.
- **Licenses and Permits:** License and permit conditions for hydrogen storage facilities should be determined. Documents and procedures to be followed during storage should be defined.
- **Liability:** Responsibilities arising from accidents and damages that may occur during storage should be determined.

Although it can be argued that the current regulation on the transport of dangerous goods mentioned above actually covers storage, as explained in the previous section, this regulation should be revised in line with the reference to the framework law to be established. Since a separate regulation is not issued to regulate the implementation of the procedures and principles determined for the storage of hydrogen in the framework law, the standards regarding transport made in the current regulations can also be applied to storage.

In addition to the framework law, it should be included in the scope of **the Occupational Health and Safety Law to be applied especially in storage facilities**. Likewise, hydrogen is a potentially dangerous substance that can be stored in different forms (gas, liquid).

As obtained during the meetings with the Ministry of Industry and Technology within the scope of the project, it is envisaged that the Ministry will take an active role in the legal legislation to be enacted to determine **technical standards such as storage fuels and connections**.

An additional regulation should be made to the framework law regarding **the mechanisms that will reduce the costs of storage tanks and especially incentivise domestic investors**. For example, during the meetings held with the General Directorate of Energy Affairs of the Ministry of Energy and Natural Resources within the scope of the project, it was discussed

that hydrogen storage tanks can be included in *domestic component incentives*. Hydrogen energy should also be included in the related Communiqués and regulations made by the Ministry within the scope of this mechanism, within the scope of projects to increase energy efficiency and within the scope of renewable energy incentive mechanisms.

Issues such as site selection and environmental impacts of storage facilities should also be considered when storing hydrogen. In site selection, for example, for a facility to be used for an Organised Industrial Zone (OIZ); it will be able to find an application area by passing through the General Assembly of the relevant OIZ and will be able to benefit from some incentive mechanisms in this context. In addition, in a scenario where 100% hydrogen energy use is on the agenda in OIZs which do not use natural gas, the existence of an OIZ-specific storage facility will be sought in order to ensure sustainability, and a legal regulation specific to OIZs will increase the motivation for industrialists to use hydrogen energy..

Suggestions on the End User of Hydrogen within the Framework of Turkish Legislation:

Currently, no specific regulation focuses on the end-use sector of hydrogen energy in Türkiye. Since hydrogen is an energy source that can be used by end-users in various fields (energy production, transport, heating), the following issues must be regulated in the legal regulations that should be included in the framework law on the use of hydrogen by end-users:

- **Safety:** Standards and procedures should be established to ensure end users' safe use of hydrogen. Specific safety measures should be defined for different areas of use (homes, workplaces, vehicles).
- **Technical Compatibility:** Arrangements should be made to develop and operate the necessary infrastructure (hydrogen filling stations and connection equipment) for end users' use of hydrogen. Necessary standards for the technical compatibility and safety of the infrastructure should be determined.
- **Economic Incentives:** Tax reductions, subsidies, and other financial support should be provided to encourage end users to use hydrogen. Tax reductions and incentives can be applied to hydrogen-powered devices and systems.
- **Consumer Rights:** Regulations should be made regarding the rights and protection of end-users using hydrogen. Users should be provided with access to accurate and transparent information. Standards for the safety and quality of products and services should be set. In addition to the framework law, it should be regulated, for example, that consumers of hydrogen energy can benefit from the rights granted to consumers in the Law on the Protection of Consumers.

It is also necessary to amend the Environmental Law, the Regulation on Environmental Impact Assessment, the Regulation on Environmental Permits and Licences, the Regulation on Combating Air Pollution, the Regulation on Water Pollution Control, and the Regulation on Waste Management, or to make additional **legal regulations to the legal framework in which air pollution and wastewater emission standards are not set for hydrogen-using facilities**.

Suggestions for the PPP hydrogen initiative:

In the context of transitioning the ceramics sector to green hydrogen, several steps need to be addressed, including technical considerations, legal framework and permits related to the production, storage, and utilization of green hydrogen in kilns. Summarizing the findings of the study can be done by examining each link of the hydrogen value chain—production, storage, and end-use—individually.

For green hydrogen production, ensuring the electrolyzer system's adherence to standards, implementing safety measures at the installation site, and verifying compliance with required standards for hydrogen quality at the electrolyzer outlet is crucial. Additionally, the electricity source powering the electrolyzer units must be renewable, and the hydrogen produced should be "green certified."

Attention must also be given to hydrogen storage units to ensure safe application. This involves ensuring compliance of storage cylinders with technical standards, conducting periodic maintenance, and appropriately considering the lifetime and location of the cylinders. Transportation of hydrogen to kilns via pipelines requires careful consideration, with different

standards applicable for establishing new pipelines for pure hydrogen, retrofitting existing pipelines to carry 100% hydrogen, or blending hydrogen with natural gas.

At the end-use point, burning hydrogen in kilns requires burner technology compatible with blended natural gas or pure hydrogen. Collaboration with kiln and burner manufacturers is essential for a successful hydrogen transition project.

Currently, there is no specific permitting process for hydrogen in Türkiye. However, implementing a facility for producing and using explosive gases could impact factory safety and require permits. While existing fire competency and occupational health and safety regulations are currently sufficient, explaining industrial requirements to relevant stakeholders is crucial for establishing a streamlined permitting procedure.

Primary stakeholders, such as distribution companies, need to be engaged to accelerate the enactment of rules governing the distribution, storage, and use of hydrogen blended with natural gas. Bilateral relations with regulatory authorities and government bodies, such as EMRA, TENMAK, and the Ministry of Energy, can facilitate the process of establishing these rules.

While it is anticipated that legal measures will be taken in the realm of hydrogen energy in the foreseeable future, leveraging input from stakeholders outlined in the project report, the utilization of natural gas-hydrogen blends within internal installations remains impractical without the establishment of comprehensive legislation and the redefinition of responsibilities for natural gas distribution companies. Ultimately, governmental bodies and regulatory agencies assess investment opportunities and initiate legal proceedings, aiming to introduce new-generation energy sources like hydrogen to the Turkish market. Therefore, fostering strong bilateral relationships with these stakeholders and actively participating in shaping the legal framework for hydrogen energy will expedite the realization of desired outcomes for this project. Given the absence of technical standards, developing both technical readiness and legislation for green hydrogen simultaneously in Türkiye is crucial for regulating hydrogen applications effectively.

4 Annexes

Annex 1: List of Hydrogen Valley Projects – Germany and Türkiye

Annex 2: All European Hydrogen Standards based on CEN CENELEC, ISO and European Standards

Annex 3: H2020 Project List - Germany and Türkiye

Annex 4: Hydrogen Production and Consumption Project Germany

Annex 5: Germany Hydrogen Production in 2022 by Process Type

Annex 6: Meeting Minutes and Meeting Log

Annex 6.1 Meeting Minutes 2702024 (Ministry of Trade)

Annex 6.2 Meeting Minutes 2802024 (The Ministry of Energy and Natural Resources)

Annex 6.3 Meeting Minutes 0103024 (TENMAK)

Annex 6.4 Meeting Minutes 2103024 (EMRA)

Annex 7: Pre-Feasibility Study for a Green Hydrogen Plant in a ceramic's facility, Fichtner GmbH&Co KG

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