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The potential of hydrogen for the chemical industry

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Contents

Executive summary

The chemical industry is a critical sector in developing innovative solutions to enable the shift towards a sustainable and circular economy, but it is facing a massive challenge to become net-zero. Only a portion of the net-zero target can be achieved through energy efficiency, bio-based feedstock and closing material loops, stressing the need for other solutions such as hydrogen, carbon capture, and electrification in the chemical industry.

Today, about 10 million tons of hydrogen is already used in the EU industry, mainly as feedstock for the production of ammonia and in the refining industry. Blue and green hydrogen are the two key low-CO2 alternatives that could replace the carbon-intensive grey hydrogen, which represents 95% of the hydrogen production today.

The energy transition and route to net-zero has also led to new potential roles for low-CO2 hydrogen, and therefore the hydrogen market is expected to exceed 100 million tons by 2050, resulting in hydrogen becoming a main energy carriers of the future EU energy system. There are three important demand drivers: industry (heat, steam, reducing agent in steel industry), sustainable fuels for transport (mainly shipping, long-distance road transport and aviation) and sustainable chemical feedstock (methanol, ammonia), and to a lesser extent hydrogen as a storage medium to enable the shift to renewable energy.

The emerging hydrogen economy is supported by initiatives of policy makers at a European and country level, estimating a required investment of €430 billion until 2030. The increasing number of hydrogen projects being initiated or announced in the chemical industry is a good indicator of the interest in hydrogen, and stress the urge to act now. Countries outside Europe are also catching up with formalising hydrogen strategies and projects, and demand for hydrogen in China is estimated to hit 60 million tons a year by 2050.

Chemical companies are uniquely positioned to tap into the opportunities of the emerging hydrogen economy, and can create a competitive advantage by doing so. A set of strategic choices cascading down from “aspiration” to “where to play” to “how to win” to “how to configure” helps to set the right corporate direction and strategy in a structured and thoughtful way.

Hydrogen is not only a key enabler to become net-zero for the industry, but also an important opportunity for chemical companies to generate new sustainable revenue streams. New business and pricing models can be deployed in a profitable way by making smart choices based on the potential and willingness-to-pay for different markets and by focusing on customer centricity. Chemical companies can leverage their strong global assets, interlinked supply chains, existing sales and distribution, and hands-on engineering knowledge etc. to kickstart their future role in the hydrogen economy, and make the shift to a more sustainable portfolio in a profitable way.

01

Transition to a net-zero EU chemical industry

The chemical industry is essential to develop innovative solutions to move towards a sustainable and circular economy, but it is facing a massive challenge to become net-zero

With over 1.1 million workers, €543 billion turnover and €9.3 billion R&I investments, the European chemical industry is a wealth-generating sector of the economy and a major contributor to building a sustainable future for Europe.

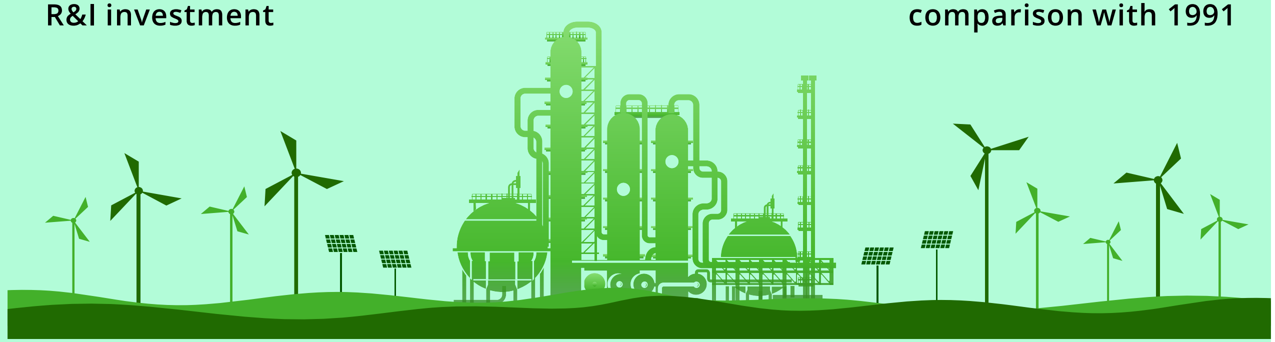
The European chemical industry is essential to develop innovative solutions to move toward a low carbon and circular economy (e.g. light-weight strong performance materials, components for batteries, enabling recycling of batteries etc.), but is also facing a massive challenge to become net-zero.

The industry has already decreased its carbon footprint by 50% compared to 1991 while the overall added value of the industry has increased. However, there is still a challenging road ahead toward 2030 and 2050 to further reduce the emissions with the low-hanging fruit already harvested.

Vital part of EU economy, and essential to achieve a low carbon and circular economy

€543 billion turnover & €9.3 billion R&I investment

Reduction of nearly 50% in CO_2 emissions in comparison with 1991



Sources: CEFIC, IEA, EEA, IHS Markit, Deloitte analysis

Only a part of the net-zero target can be achieved through energy efficiency, bio-based feedstock and closing material loops, stressing the need for solutions such as hydrogen, carbon capture and electrification

In addition to energy efficiency improvement measures, bio-based feedstock, and closing material loops, the EU chemical industry will have to consider other levers to reach net-zero, such as hydrogen, carbon capture, and electrification & the shift to renewable energy.

To ensure a successful transition toward climate neutrality, different angles and pathways will have to be combined in a smart way by leveraging existing assets while building up capacity to enable low-CO2 production systems.

In this landscape, low-CO2 hydrogen and derivatives will play a key role as sustainable fuel for the processes and applications that are hard to electrify and serve as a sustainable feedstock for the chemical industry.

It is already clear that this transition will have a huge impact on existing and new value and supply chains, including shipping of hydrogen, pipeline infrastructure network for hydrogen and CO2, international power transmission lines, reliable & qualitative supply of biomass and plastic waste etc.

Hydrogen

Low-CO2 hydrogen and derivatives will play a key role as sustainable fuel, and as sustainable feedstock for the chemical industry.

Carbon capture, storage and utilisation

Carbon capturing is an important pathway to reduce CO2 emissions, in a first phase storing the CO2, and in a second phase using the CO2 by bringing it back in the value chain through the combination with hydrogen to methanol for example.

Electrification and shift to renewable energy

There is potential for power-to-heat applications in electric steam crackers and electric boilers, for example, but also for power-to-chemicals via electrochemical reactors.

Improving resource and energy efficiency

This can be further accelerated by existing and emerging digital tools, such as predictive analytics, big data, advanced analytics & visualization, and energy management applications powered by artificial intelligence.

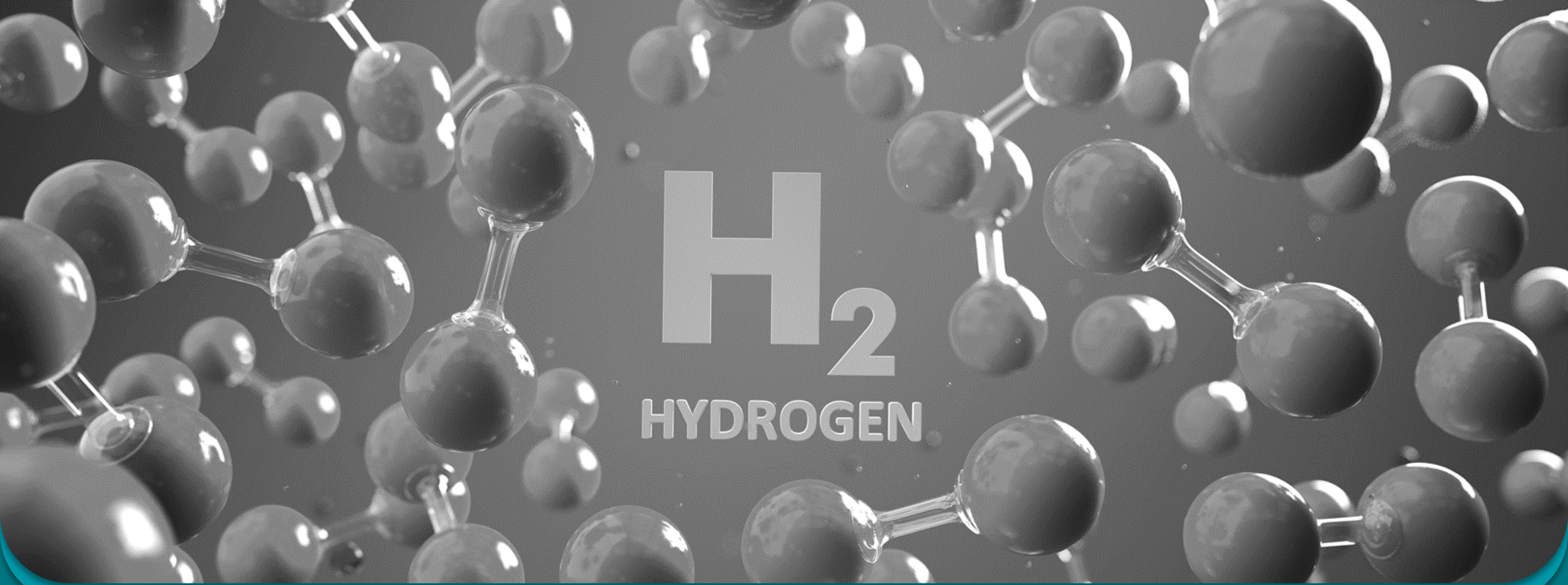
Sources: Deloitte analysis

Bio-based feedstock

These types of sustainable feedstock naturally lead to the production of bio-based chemicals (e.g. alcohols, organic acids and polyesters).

Closing material loops

Mechanical and/or chemical recycling with a qualitative collection and sorting of plastic waste as an important prerequisite, and new technologies such as blockchain & digital watermarking enabling traceability throughout the value chain.



02

Different roles of hydrogen in this transition

Today, about 10 million tons of hydrogen is already used in the EU industry, mainly as feedstock for the production of ammonia and in the refining industry

About 10 million tons of hydrogen is used in the European industry on a yearly basis, primarily as feedstock in the chemical and refining industries.

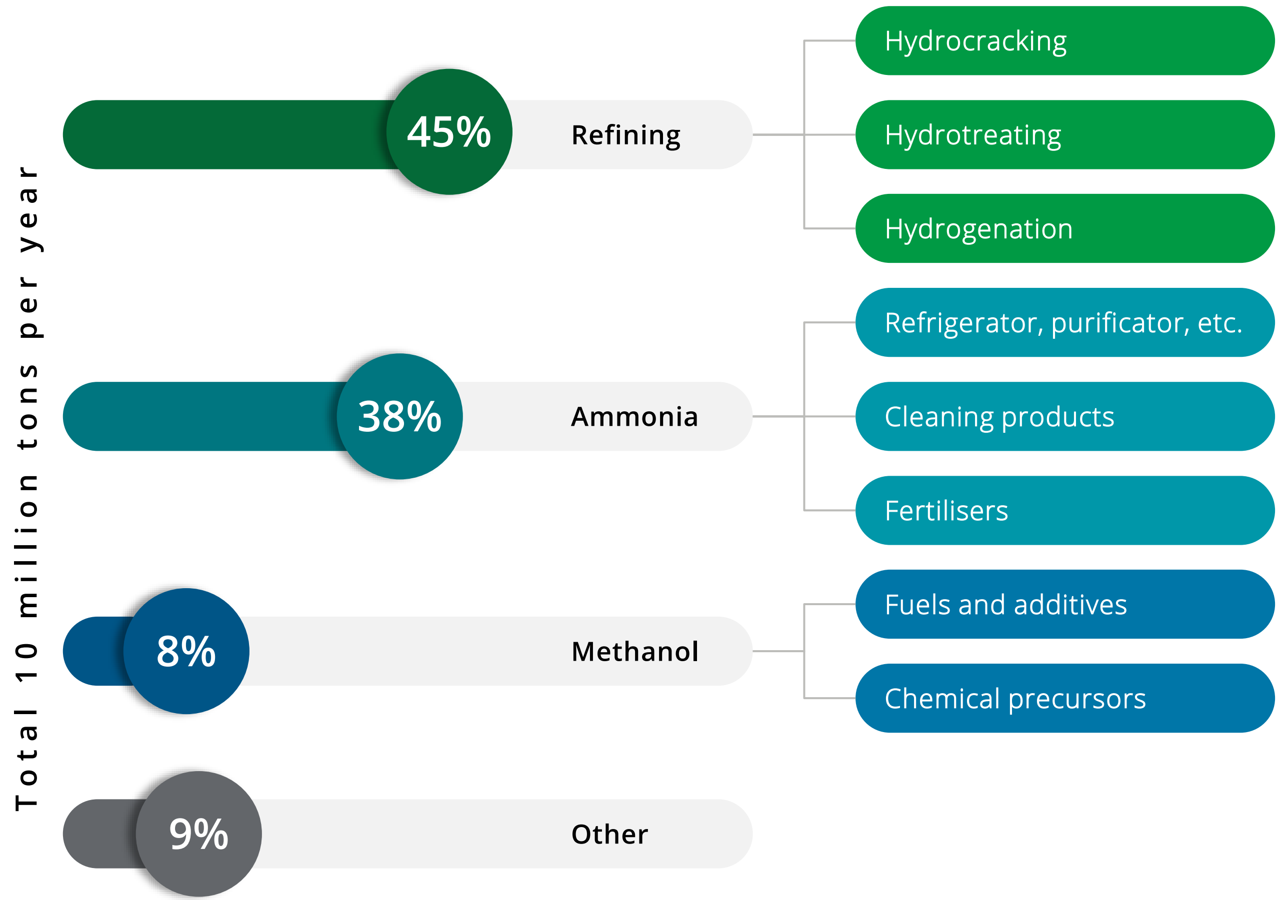
In the chemical industry, hydrogen is mostly used as feedstock to produce ammonia. Ammonia is mainly used as a fertiliser but it is also a key component of various household cleaning products under the form of ammonium hydroxide. In industrial processes, ammonia serves as a refrigerator, purificator and chemical stabilizer.

In addition to ammonia, hydrogen is involved in the production of methanol, which is mainly used as a chemical building block to produce other chemical compounds, fuels and additives.

In the refining industry, hydrogen is used in the conversion of crude oil for:

- Breaking large molecules into smaller molecules with higher added value (Hydrocracking)
- Removing contaminants such as sulfur, nitrogen and metals from crude oil fractions (Hydrotreating)
- Stabilizing some chemical products (Hydrogenation)

Current uses of hydrogen in the EU



Source: FCH, Linde Gas, IEA, Deloitte Analysis

Blue and green hydrogen are the two key low-CO2 alternatives that could replace carbon-intensive grey hydrogen, which represents 95% of the hydrogen production today

Today, EU hydrogen production is responsible for the emission of 70 to 100 million tons of CO2 annually. Nonetheless, low-CO2 alternatives—defined by specific colours—can be considered, namely blue and green hydrogen

Grey hydrogen: produced through the conversion of natural gas in the presence of steam with CO2 as a by-product. The overall process is referred to as steam methane reforming (SMR). The hydrogen produced is considered grey as fossil fuels are consumed and CO2 emissions occur.

Blue hydrogen: carbon capture technology is used in the SMR process. Even though the process still relies on fossil fuels, 90-95% of the CO2 emissions are captured.

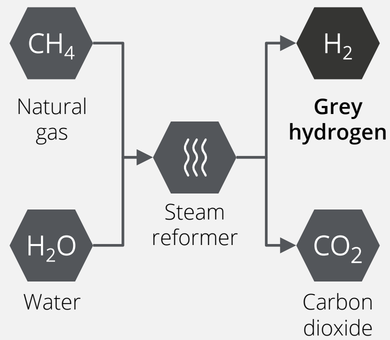
Green hydrogen: produced via electrolysis, where water is converted into hydrogen and oxygen using electricity. When renewable electricity is used as input, the hydrogen is indicated as green because there is no consumption of fossil fuels and no CO2 emissions.

Other production methods

Purple hydrogen is produced via electrolysis, but using nuclear energy instead of renewable energy.

Turquoise hydrogen is produced through the conversion of natural gas into hydrogen by means of methane pyrolysis generating solid carbon and avoiding CO2 emissions. This method is gaining traction.

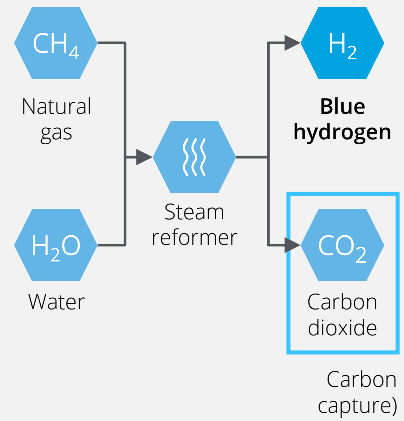
Grey hydrogen



Pros
- Low production cost
- Mature technology

Cons
- High CO2 emissions (7-8 kg CO2 /kg H2)
- Using fossil fuels

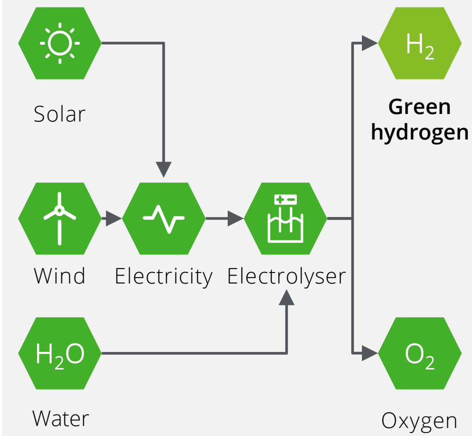
Blue hydrogen



Pros
- Leveraging existing SMR installations
- Capturing 90% to 95% CO2 emissions

Cons
- Need to store and/or re-use captured CO2
- Increased costs due to carbon capture infrastructure and energy need

Green hydrogen



Pros
- No CO2 emissions
- Using renewable energy

Cons
- Higher production costs compared to grey and blue hydrogen
- Scarcity of renewable energy

Source: Deloitte analysis, Hydrogen Council

The energy transition and route to net-zero has led to new potential roles for low-CO2 hydrogen, and subsequently huge opportunities for the chemical industry as a consumer and/or producer

There is potential to replace the existing grey hydrogen production with low-CO2 alternatives such as blue and green hydrogen. In practice, existing SMR installations can be adjusted to produce blue hydrogen by equipping the installations with carbon capture technology.

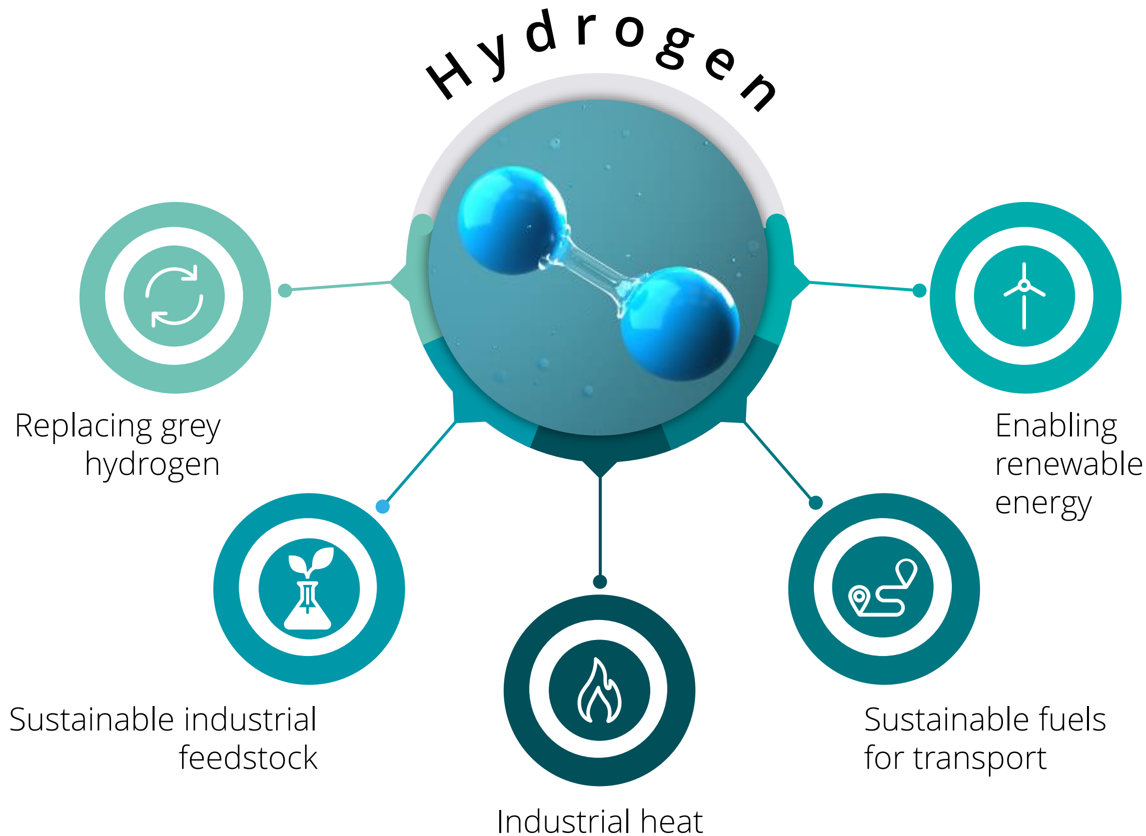
The energy transition and route to net-zero has also led to new potential roles for low-CO2 hydrogen, and subsequently huge opportunities for the chemical industry as a producer and/or consumer.

Sustainable industrial feedstock: hydrogen can serve as a feedstock to produce chemical building blocks such as methanol by combining hydrogen and CO2.

Industrial heat: hydrogen can replace natural gas or other fuels to fuel industrial burners and boilers to provide low carbon heat for industrial processes, and act as a reducing agent for the steel industry

Sustainable fuels for transport: hydrogen or derived synthetic fuels can serve as a sustainable fuel in those segments where electrification is more difficult such as shipping, long-distance transport and aviation

Enabling renewable energy: hydrogen can be used as a flexible offtake and storage medium to secure and balance renewable power supply.



03

Future demand for hydrogen in Europe

The EU annual demand for hydrogen is expected to exceed 100 million tons by 2050, resulting in hydrogen becoming a main energy carrier of the future EU energy system

The overall yearly demand for hydrogen is expected to grow more than tenfold in the EU from 2021 to 2050, mainly driven by the demand in transport and industry. Hence, hydrogen is supposed to become a main energy carriers of the future European energy system.

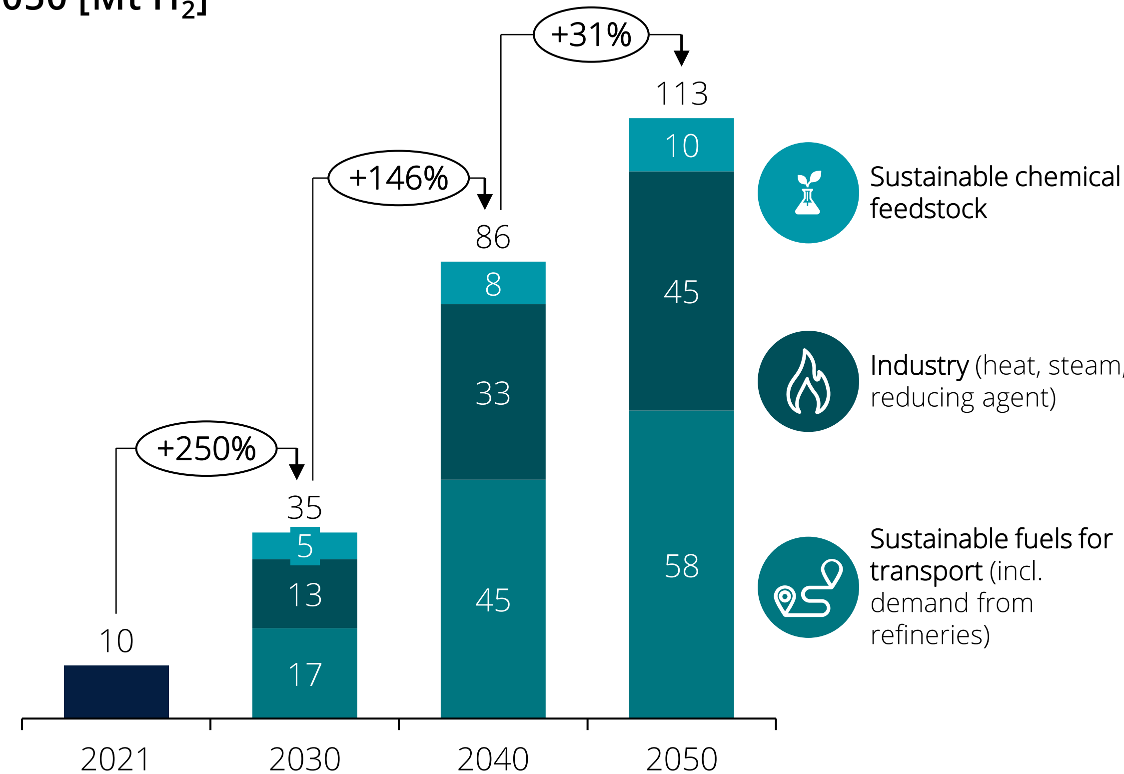
Today, the EU annual demand for hydrogen accounts for 10 million tons, of which about half is used for the production of ammonia and methanol and about half for oil refining.

Between 2021 and 2030, the demand for hydrogen is expected to increase from 10 to 35 Mt of hydrogen, leading to an additional demand of 25 Mt over a 10-year period.

Between 2030 and 2040, the demand is expected to significantly ramp up, leading to an exponential growth of 51 Mt by 2040, resulting in a demand of 86 Mt by 2040.

Between 2040 and 2050, the demand is expected to increase at a slower, but still significant rate with an average growth rate of 31% over 10 years leading to an expected demand of 113 Mt by 2050.

Expected annual demand for hydrogen in the EU over 2021-2050 [Mt H_2]*



Sources: Deloitte, Hydrogen4EU, Hydrogen Roadmap for Europe (FCH), Navigating through hydrogen

(*) Excluding potential of hydrogen in enabling renewable energy and in heating for buildings

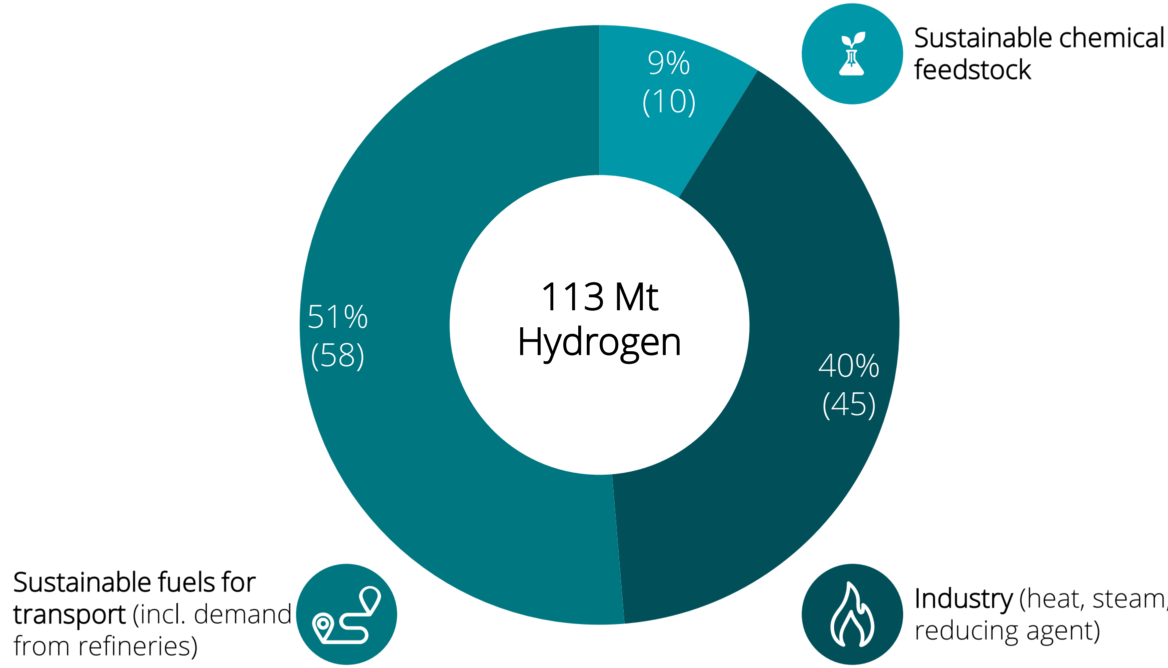
Moving forward, the industry and transport sector are clearly the most significant demand drivers representing more than 90%

Transport: representing more than 51% (58 Mt) of the demand, hydrogen used for transport is expected to be the #1 demand driver, either for consumption in fuel cells, as intermediary feedstock for the production of synthetic fuels, or for use in biorefineries. Hydrogen or derived synthetic fuels are energy-dense fuels to be used for heavy and long-distance road transport, shipping and aviation and hence addresses some of the limitations electric mobility faces in terms of energy density, weight, range and refueling.

Industry: 40% (45 Mt) of the overall hydrogen demand in 2050 is expected to come from industry for heat, steam and reducing agent (steel industry) purposes. 18 Mt is expected to come from the steel industry (heat and reducing agent), and 6 Mt is expected to come from the chemical industry.

Sustainable chemical feedstock: 9% of the hydrogen demand is expected to be related to sustainable chemical feedstock. The chemical industry is requiring green feedstock/precursor molecules such as ammonia and methanol, produced by means of low-CO2 hydrogen. These green chemicals are converted into high-value end-products for different sectors (e.g. automotive, electronics, pharmaceuticals etc.).

Expected EU hydrogen demand in 2050*



Sources: Deloitte, Hydrogen4EU, Hydrogen Roadmap for Europe (FCH), Navigating through hydrogen

(*) Excluding potential of hydrogen in enabling renewable energy and in heating for buildings

04

Europe taking a leading role in the transition to hydrogen

The emerging hydrogen economy is supported by initiatives of policy makers at a European and country level, estimating a required investment of €430 billion until 2030

The European Green Deal & Economic recovery plan highlight hydrogen as an investment priority in order to boost economic growth and resilience, create local jobs, and consolidate the EU's global leadership.

The European Clean Hydrogen Alliance is part of the efforts to accelerate the decarbonisation of industry and maintain leadership in Europe. It brings together industry, national and local public authorities, civil society and other stakeholders and is strongly anchored in the hydrogen value chain. It covers renewable and low-CO2 hydrogen from production, to transport, to end markets.

The alliance will establish an investment agenda and support the scaling up of the hydrogen value chain across Europe. An industry blueprint estimates investments of €430 billion until 2030.

As part of the Green Deal, the EU has also defined a EU hydrogen strategy; In the first phase, from 2020 up to 2024, the strategic objective is to install at least 6 GW of electrolysers in the EU and the production of up to 1 million tons of green hydrogen. From 2024 up to 2030, the ambition is to install 40 GW of electrolysers to produce 10 million tons of green hydrogen.

4GW of electrolyser capacity installed by 2030

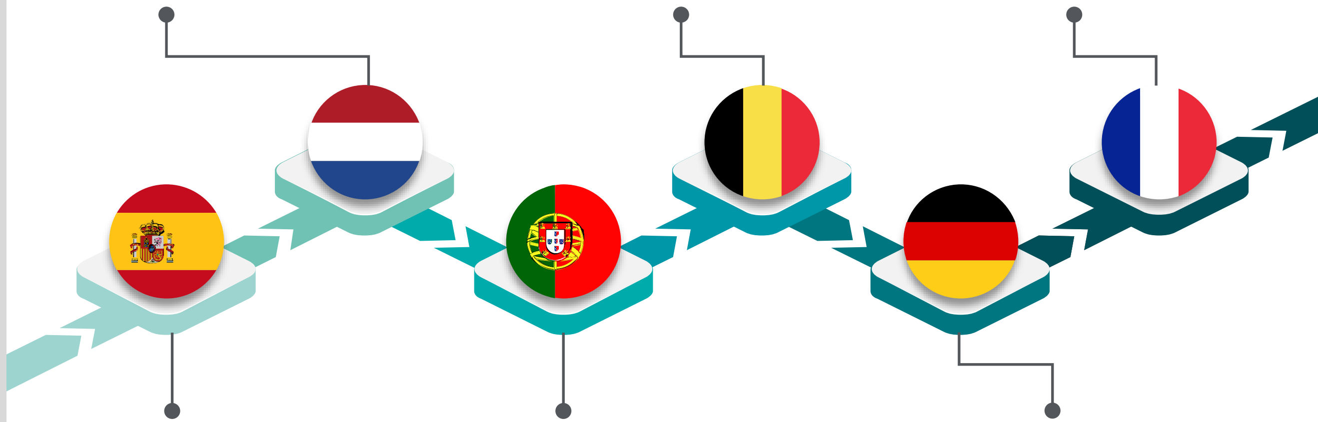
The plan includes investments adding up to €9 billion and should ensure a leading position in Europe.

Hydrogen strategy approved by government

The federal government has approved a national hydrogen strategy & vision, with an important focus on hydrogen import

6.5GW of green hydrogen by 2030

The plan is to spend €7 billion to support a decarbonised hydrogen economy.



4GW of electrolyser capacity to be installed by 2030

The programme would require an investment of €8.9 billion within the next decade.

2-2.5GW of installed capacity to produce hydrogen in the next decade

The government approved the hydrogen strategy with €7 billion investments.

5GW by 2030 and 10GW by 2040

€7 billion will be invested in new businesses and research.

Sources: European Commission, Clifford Chance, Visie en strategie waterstof, Deloitte analysis

Infrastructure is a key factor to enable the hydrogen economy. Concrete plans and projects are being developed at European and country level

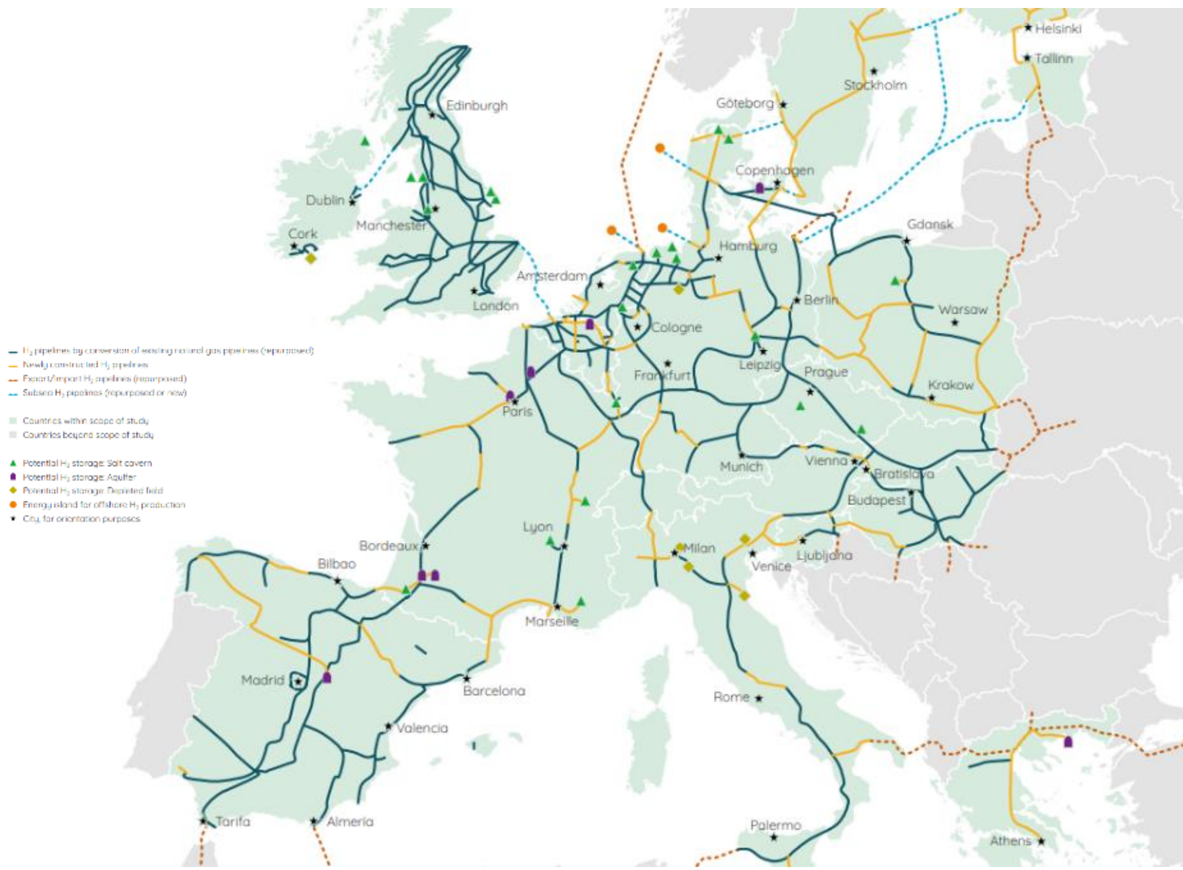
Initiated by a group of European gas transmission system operators (TSOs) in 2020 and reviewed this year, the European Hydrogen Backbone (EHB) initiative is a proposal for a dedicated hydrogen pipeline network infrastructure, largely based on the repurposing of existing natural gas pipelines. The EHB aims to accelerate the decarbonisation of the energy and industrial sectors on EU level by distributing low-CO2 hydrogen while securing energy supply and energy system resilience.

Concretely, the EHB initiative presents a scenario laying out a phased construction of the hydrogen backbone until 2040 in a viable way on both economic and technical levels.

By 2030, the EHB would be composed of 11,600 km of pipelines, connecting emerging hydrogen valleys. Then, the overall hydrogen infrastructure would gradually grow to become a pan-European network, achieving a total length of 39,700 km by 2040. Practically, the actual EHB construction pathway will depend on the future supply and demand dynamics of the integrated energy system.

Overall, the success of the initiative will strongly rely on a close and transversal collaboration between TSOs, EU Member States and neighbouring countries to set up the right regulatory, financial and technical framework.

Projected European hydrogen backbone in 2040



Sources: Extending the European Hydrogen Backbone initiative (2021), Deloitte Analysis

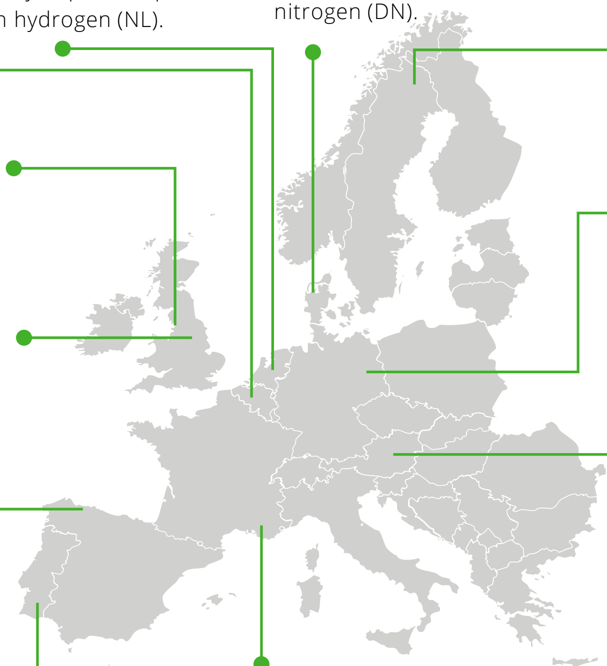
An increasing number of hydrogen projects being initiated or announced in the chemical industry is a good indicator of the interest of the sector, and stress the urge to act now

Several companies and consortiums have already started their journey toward low-CO2 hydrogen by announcing and initiating projects across Europe.

These projects cover a wide range of applications such as power-to-methanol, power-to-methane, green ammonia production and blue hydrogen production across Europe.

It is of crucial importance that chemical companies start now with their hydrogen journey & initiatives to build-up knowledge, assets & traction, and lay-out the foundations, to avoid missing out when the market will accelerate in the future.

Non-exhaustive overview of ongoing hydrogen projects in the chemical industry



Construction of "power-to-methanol" demo-plant in the port of Antwerp (BE).

NortH2

Setting up a 10GW offshore windfarm combined with an electrolysis plant to produce green hydrogen (NL).

HALDOR TOPSOE

Green Ammonia

Production of "green ammonia" based on green hydrogen and nitrogen (DN).

Liquid Wind

Power-to-Fuel

Production of e-methanol by combining green hydrogen with captured CO2 (SE).

Project Centurion

Feasibility study to look at new hydrogen generation and storage options, including a potential plan to build a 100MW power-to-gas energy storage facilities at Runcorn.

Offshore wind and hydrogen project

BASF and RWE propose 2GW offshore wind and hydrogen project. BASF plans to use approximately 300MW of the power produced by the wind farm to produce green hydrogen (DE).

ZEROCARBON HUMBER

Construction of a large-scale blue hydrogen production plant and a pipeline network connecting the industrial sites of the Humber region (UK).

Carbon2ProductAustria

Construction of an industrial scale carbon capture capacity where CO2 will be combined with green hydrogen to produce renewable hydrocarbons (AT).

800MW green hydrogen project

Spanish utility Iberdrola and chemical manufacturer Fertiberia have formed a new partnership that, with a €1.8 billion investment, aims to install 800MW of green hydrogen production capacity in Spain by 2027 (SP).

galp

Portugal's Galp Energia plans to install a 100MW electrolyser to power its refinery in Sines with green hydrogen by 2025 (PT).

Total, Engie team up on Green Hydrogen project

Total and Engie have signed a cooperation agreement to design, develop, build and operate the Masshylia project, France's largest renewable hydrogen production site in Châteauneuf-les-Martigues in the southern Provence-Alpes-Côte d'Azur region (FR).

Sources: Deloitte Analysis

Countries outside Europe are also catching up with formalizing hydrogen strategies and projects. Demand for hydrogen in China is estimated to hit 60 million tons a year by 2050

The International Energy Agency map shows that countries like Chile, Morocco, Oman or Australia will have low hydrogen costs from hybrid solar PV and onshore wind systems in the long term.

These countries usually have wind and sunshine levels that are high and constant throughout the year, making them suitable candidates for renewable energy import to Europe.

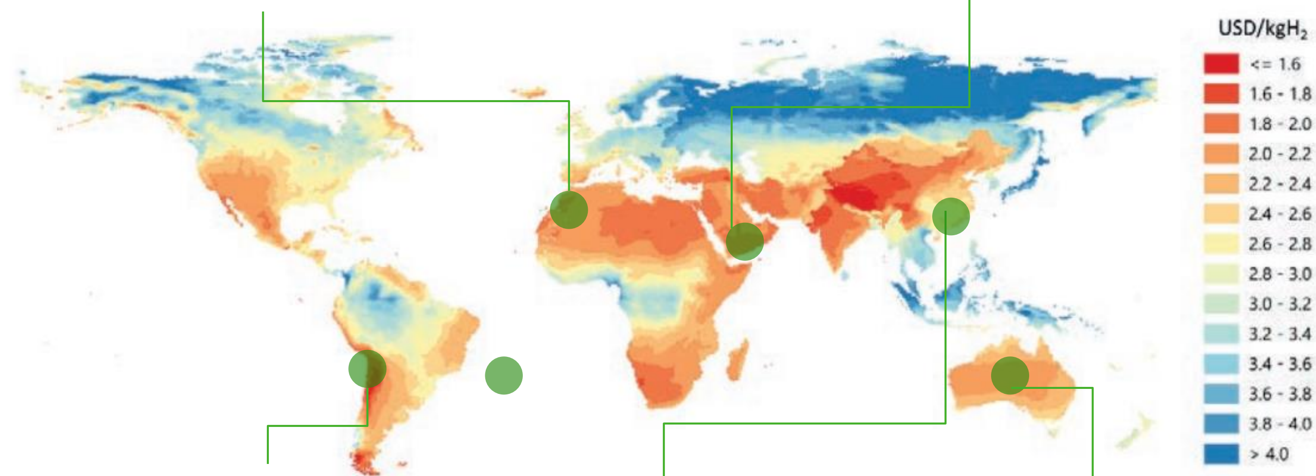
Cost of transport, different carrier options, and availability of seaport and infrastructure facilities need to be considered, but the first studies point out that importing hydrogen to Europe will be a feasible and an economically sound solution (e.g. Hydrogen Import Coalition, Belgium).

China was until recently a relative laggard in hydrogen, but now China is clearly catching up. Demand for hydrogen energy is estimated to hit 60 million tons/year by 2050, according to the China Hydrogen Alliance's data.

Hydrogen costs from hybrid solar PV and onshore wind systems in the long term

Morocco and the International Renewable Energy Agency (IRENA) will collaborate to advance the country's renewable hydrogen economy and accelerate the uptake of renewable energy as it seeks to become a major green hydrogen producer and exporter.

The government of **Oman** has announced plans to begin construction on what will be the largest green hydrogen plant in the world. Most of its production is intended for export to Europe and Asia. When complete, the facility is expected to produce 1.8 million tons of hydrogen and 10 million tons of green ammonia every year.



Chile presented its National Strategy for Green Hydrogen in November 2020, identifying three objectives:

- Have 5GW of electrolysis capacity under development by 2025
- Produce the cheapest green hydrogen in the world by 2030
- Be among the world's three largest hydrogen exporters by 2040

China
China's ambition to achieve carbon neutrality by 2060 will accelerate the development of hydrogen. Hydrogen was listed in the country's latest five-year plan (14th Five Year Plan, FYP, 2021-2025) under the emerging industries that decision-makers see as a priority. Given that these designations lead to state support in the form of capital and human resources, the focus on hydrogen bodes well for its development.

The **Australian** government had already authorized USD 355 million for hydrogen projects. Of that amount, USD 53.3 million is dedicated to hydrogen export hubs.

Sources: IEA, ICIS, Deloitte analysis

05

Key considerations in your strategy as a chemical company

Chemical companies are uniquely positioned to tap into the emerging hydrogen economy, and create a competitive advantage generating new revenue streams, by shifting to a more sustainable portfolio

A set of strategic choices cascading down from "aspiration" to "where to play" to "how to win" to "how to configure" helps to set the right corporate direction and strategy in a structured and thoughtful way.

Throughout this series of questions and strategic reflections, it is important to keep in mind external factors that have a big influence on the outcomes and considerations.

For chemical companies, hydrogen can be a key enabler to achieve net-zero, hence it is important to set the right strategy and foundation toward a sustainable future.

On the other hand, chemical companies are uniquely positioned to tap into the emerging hydrogen economy & value chain. Chemical companies can leverage their strong global assets, interlinked supply chains, existing sales and distribution, and hands-on engineering knowledge to kickstart their role in the hydrogen economy.

By entering in the most relevant markets, applying new and smart business and pricing models based on willingness-to-pay per market, and focusing on customer excellence and centricity, chemical companies can generate new revenue streams and make the shift to a more sustainable portfolio in a profitable way, and hence increasing their competitive advantage.

Aspiration

- What is the **potential and role of hydrogen to guide your business to net-zero** in line with the corporate sustainability strategy?
- Is there appetite to go beyond your own business, and **become a key player in the hydrogen value chain for other businesses and industries**?

Where to play

- For which **activities and processes is hydrogen most suited** in comparison to other options?
- **Which emerging markets are most interesting to tap into** based on existing assets, supply chains, sales and distribution channels?
- What is the **willingness-to-pay for hydrogen in different end markets** and how does this impact the **business case & profitability**?

How to win

- Which **new business and pricing models** will you implement to become more **sustainable in a profitable way**, or to enter new hydrogen markets?
- How to **position your business** in the fast-changing **hydrogen value chain and ecosystem,** and integrate and partner with the right players?
- Deciding on **import vs local production** (e.g. LCOH) and leveraging existing assets to maximize economic viability & return

How to configure

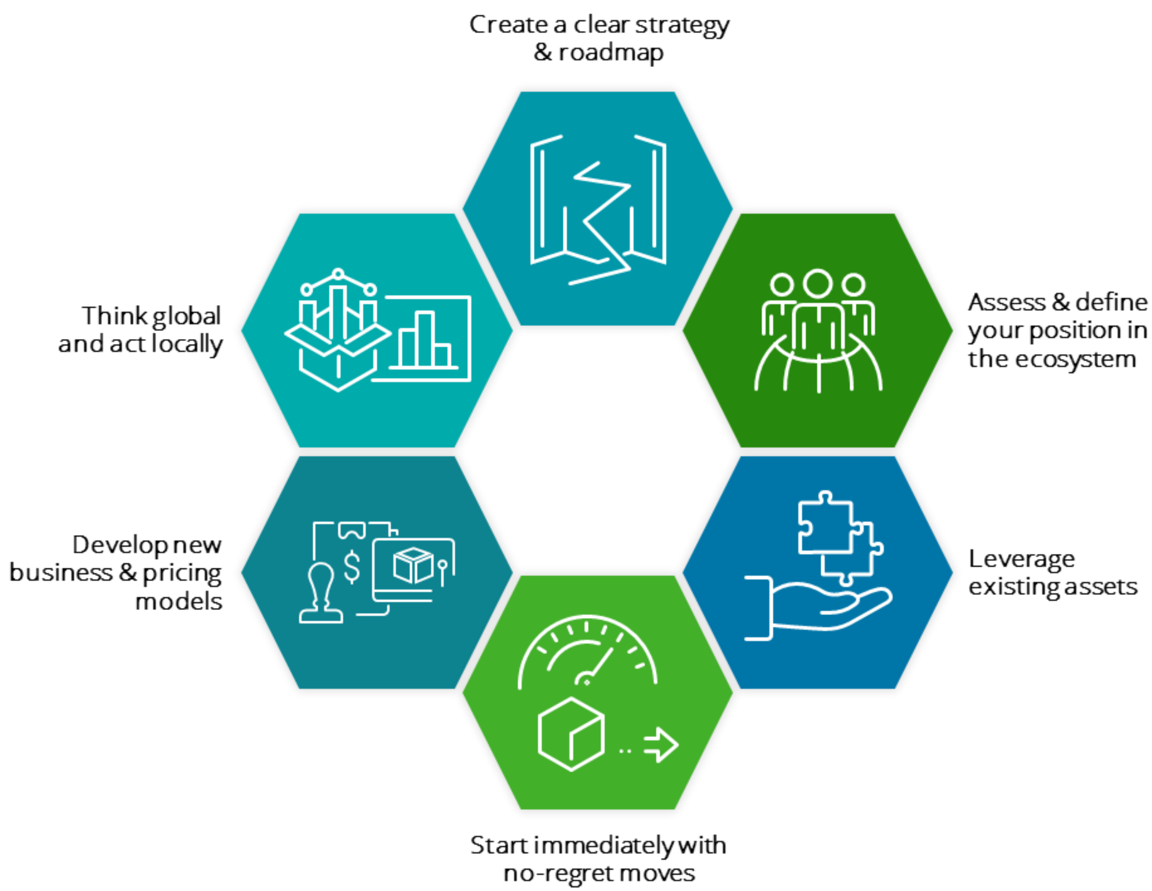
- How should you **organize your hydrogen business and governance** internally and externally in line with the overall sustainability strategy?
- How can you make optimal use of the **support mechanisms** available at EU and country level?

Economical viability | Reliability of supply | Technology readiness | Legislation & regulation | Environmental impact

External factors influencing these strategic choices

Key success factors for your hydrogen strategy as a chemical company

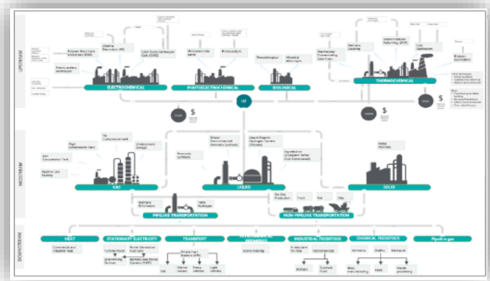
1. Create a clear strategy & roadmap: going through the set of strategic choices from aspiration, where to play, how to win, how to configure, to define a clear strategy and roadmap.
2. Assess and define your current and future position in the ecosystem: the chemical industry has a unique position to tap into the hydrogen economy, but companies need to think and rethink strategically how to position and interact with the hydrogen ecosystem and value chain to add value.
3. Leverage existing assets: the chemical industry has already specific assets, knowhow, sales and distribution channels etc. to create a competitive advantage in the hydrogen economy.
4. Start immediately with the no-regret moves: companies should start their hydrogen journey now, and already make no-regret moves and investments to secure their seat at the table and ensure a strategic position in the future.
5. Develop new business & pricing models: hydrogen is not only an enabler to become net-zero, but also a key opportunity for chemical companies to generate new sustainable revenue streams by deploying new business models in a profitable way based on the willingness-to-pay for different markets and looking at customer centricity.
6. Think globally and act locally: global chemical companies should leverage their global assets and capabilities looking at the LCOH and future supply chain, but act locally in developing new businesses and creating customer intimacy.



06

Our accelerating assets & tools

We have developed different hydrogen assets and tools to support our clients in their decision-making and transformation



Levelised cost of hydrogen tool (LCOH scenario modelling)

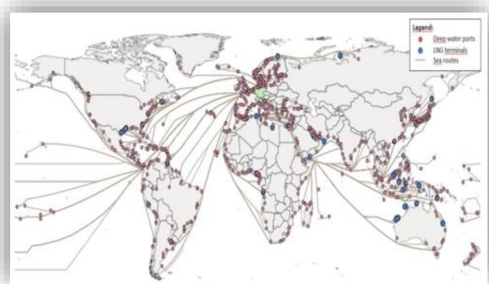
The Deloitte Hydrogen Model has been developed to assess all combinations of upstream production technology, midstream storage and transport along with customizable options for electricity and water source

Michael Wood

Energy System Model

Demand forecast and granular view on the future energy system (2030-2050), including hydrogen demand forecast by segment based on techno-economic analysis, company-level analysis and company interviews

Tarek Helmi & Michal Arament



Hydrogen import/export model

Assessing the best supply chain routes to import and export hydrogen across different countries taking into account transportation costs, existing gas infrastructure, etc.

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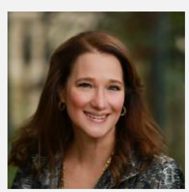

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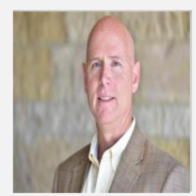

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