Why does Europe need green molecules?

Accelerating the decarbonisation of industry and heavy transport is key to Europe’s energy independence and industrial competitiveness

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Welcome letter

The energy transition is one of the most important transformations of our time. In 2025, global energy consumption grew by 3%, driven by rising demand from electric vehicles and data centers. That same year, solar energy became, for the first time in history, the main driver of growth in global energy supply, accounting for more than a quarter of the increase in global energy demand, according to the International Energy Agency (IEA). The energy transition offers an opportunity to activate three key levers for Europe's future: decarbonizing the economy, gaining energy independence, and boosting industrial competitiveness; in fact, thanks to renewables, the EU saves €30 billion annually in energy costs. To activate these three levers, not only are electron-based renewable energies (solar and wind) necessary, but, as we will see in this report, they also depend largely on the rapid production and adoption of new energies based on green molecules, such as green hydrogen and its derivatives, 2G biofuels, biomethane, and other sustainable chemicals. At Moeve, we foresee these energies representing between 25% and 33% of the European energy mix by 2050. To achieve these goals, the energy transition requires unprecedented collaboration between the private sector, public institutions, and civil society. The era of setting targets is over; now the era of taking action begins.

Currently, the greatest global challenge lies in the risks posed by growing geopolitical conflicts and disruptions to energy supply chains, as seen in the cases of Ukraine and Iran. In this context, security of supply and energy independence come to the forefront as strategic necessities to reduce external vulnerability and ensure a reliable, competitive energy supply.

At Moeve, we forecast that by 2040, green molecules could replace approximately 20% to 40% of current fossil fuel demand in Europe. The deployment of green molecules would reduce the European Union's external energy dependence by 50%, bringing it down to 28%. Reducing this dependence could not only strengthen the continent's energy stability but also help develop a new industry that, according to ManpowerGroup, will generate 1.7 million new jobs and a €145 billion increase in European GDP.

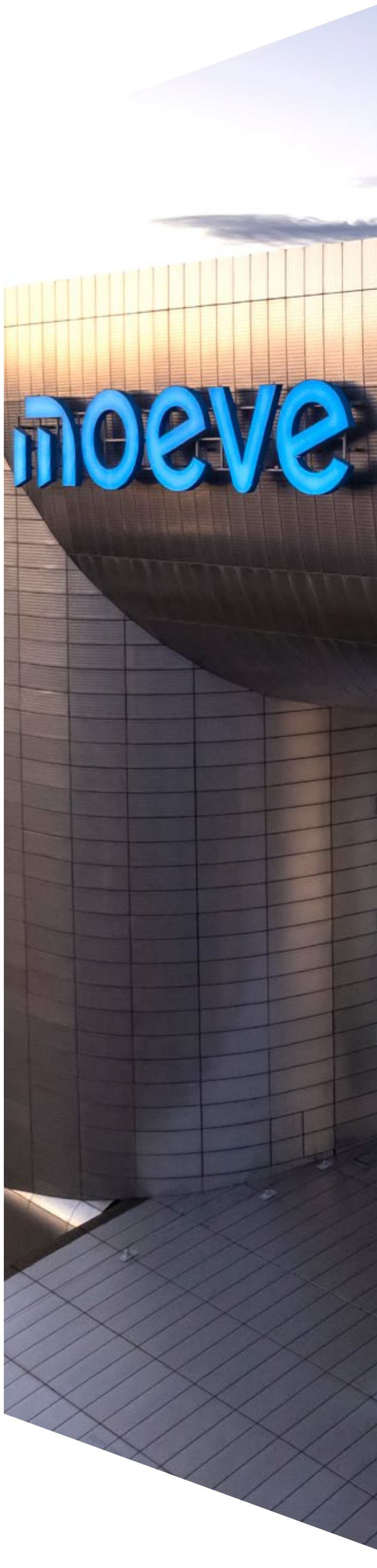
Additionally, the World Economic Forum's 2026 Global Risk Report noted that, over a ten-year horizon, 5 of the top 10 global risks are related to climate change and the environment. In this regard, without the integration of green molecules into the energy mix, it will be impossible to meet the goals of the Paris Agreement and achieve carbon neutrality by 2050. Green molecules are crucial for hard-to-abate sectors (such as energy-intensive industries, aviation, maritime transport, and long-haul trucking), where electrification alone is not viable.

In this report, we present a compilation of the latest reports from consulting firms and international organisations on the development of green molecules and the range of available solutions, highlighting their fundamental role and the European Union's strategic position to lead these technologies and thereby achieve a cost-effective and secure energy transition.

This decade, we are laying the necessary foundations to build a solid platform that will enable the accelerated deployment of hydrogen in the next. Acting now is key to developing the infrastructure needed to achieve the scale that will be required in the future. In this regard, at Moeve, we are developing what will be the largest green hydrogen project in Europe, and 2G biofuels complex in southern Europe, acting as true "market makers" capable of staying ahead of the market and paving the way for other players to join.

Our commitment is clear: to rely on facts, build alliances, and develop projects that have a positive impact on people and the planet through the development of value chains for the creation of a new industry that not only enables emissions reductions but also lays the groundwork for Europe's energy independence and competitiveness.

Maarten Wetselaar, CEO of Moeve



Executive summary

The world is at a pivotal moment in the global energy landscape, marked by geopolitical conflicts and disruptions to energy supply chains that have exposed the vulnerability of many countries stemming from their external dependence. In this context, the energy transition no longer responds solely to the need to advance the fight against climate change, but also to a strategic imperative: strengthening security of supply, reducing exposure to fossil fuel price volatility, and consolidating a competitive and resilient domestic industry.

The European Union is leading this global energy transition strategy as an opportunity to also gain independence and boost the competitiveness of its industry. This is because, in this constantly changing environment of geopolitical tensions, Europe will not be able to grow or compete globally without an industry that can develop using energy produced locally. Green molecules would make it possible to meet the emerging needs for energy sovereignty and transform decarbonisation into an engine of industrial growth, enabling Europe to gain a competitive advantage.

There is a growing consensus: Europe's competitiveness will not be able to take off as long as it maintains external dependencies that third parties can use as instruments of political or strategic pressure, as has been made evident in the most recent conflicts. As Enrico Letta has stated, "there is no Europe without industry, there is no security without financial resilience, and there is no security without energy independence."

This vision takes shape in a context of accelerating

international commitments to the energy transition, including the gradual phase-out of fossil fuels, a fourfold increase in the use of sustainable fuels by 2035, a tripling of global renewable energy capacity by 2030, and efforts to limit global warming to 1.5°C, reinforcing the need to move toward a safer, more competitive, and more sustainable energy model.

Aligned with these global goals, the European strategy can be seen in initiatives such as the "Green Deal," the "Clean Industrial Deal," and more recently the "Industrial Accelerator Act," which promote not only the production but also the demand for low-carbon products and technologies, based on three fundamental principles: Energy Affordability, Security of Supply, and Environmental Sustainability. This transformative process largely depends on the growing contribution of green molecules, particularly in hard-to-abate sectors, where direct electrification may not be a viable solution or, even when it is, it may not be the most advantageous option for the consumer. In this regard, renewable energies and green molecules play a crucial role in decarbonisation and are essential to achieving net-zero emissions targets.

To achieve this reduction in energy dependence and cut fossil fuel imports, the European Union aims to increase the share of renewable energy in the mix from 25.4% in 2024 to 42.5% (with an additional 2.5%) by 2030, according to the latest Renewable Energy Directive (RED III). This approach ensures more stable and competitive prices compared to resources affected by fossil fuel volatility in the global market, while contributing to environmental sustainability. However, this will not be enough; the European Union (EU) will not be able to meet the decarbonisation goals of the Paris Agreement without also promoting the rapid deployment of green molecule-based energies capable of decarbonizing sectors that may be difficult to electrify. Geopolitical conflicts, such as those involving Ukraine, Israel, and Iran, are accelerating the reform of the European Union's energy system, with green molecules playing an increasingly important role in this evolving energy transition landscape. In recent years, the EU has enacted several policies, such as the "Green Deal," REPowerEU, the Fit for 55 Package, the Clean Industrial Deal, the Renewable Energy Directive (RED III), the EU Competitiveness Compass, and

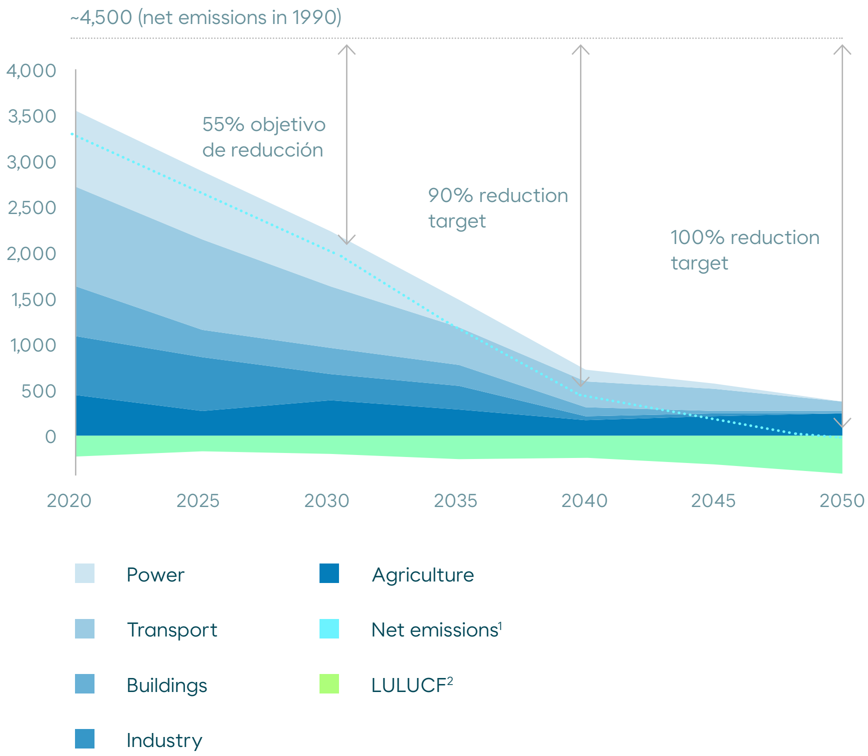
the Affordable Energy Action Plan, among others, to provide the necessary guidelines to advance decarbonisation and achieve the emissions reduction target of 55% by 2030 and 90% by 2040 compared to 1990 levels, as well as climate neutrality by 2050. Now, the urgency is focused on translating these policies into action to accelerate the transition toward a sustainable energy future.

The 2040 climate target, approved in early 2026, highlights the need for the energy transition to advance at an increasingly rapid pace. In this context, green molecules help accelerate the transformation by leveraging part of the existing energy infrastructure and, in doing so, reducing a significant portion of the investments that would be necessary in a scenario based exclusively on electrification[1]. This not only facilitates a faster and more efficient transition but also helps mitigate its economic impact on consumers.

2G biofuels represent an immediate and practical solution for decarbonizing the European Union, serving as a bridge in the transition toward synthetic fuels until they are mature enough for implementation in the medium and long term.

[1] "Market Activation Strategy", (2025), Global Hydrogen Mobility Alliance

Chart 1 Projected CO_2 emissions in the European Union by sector (Mt)

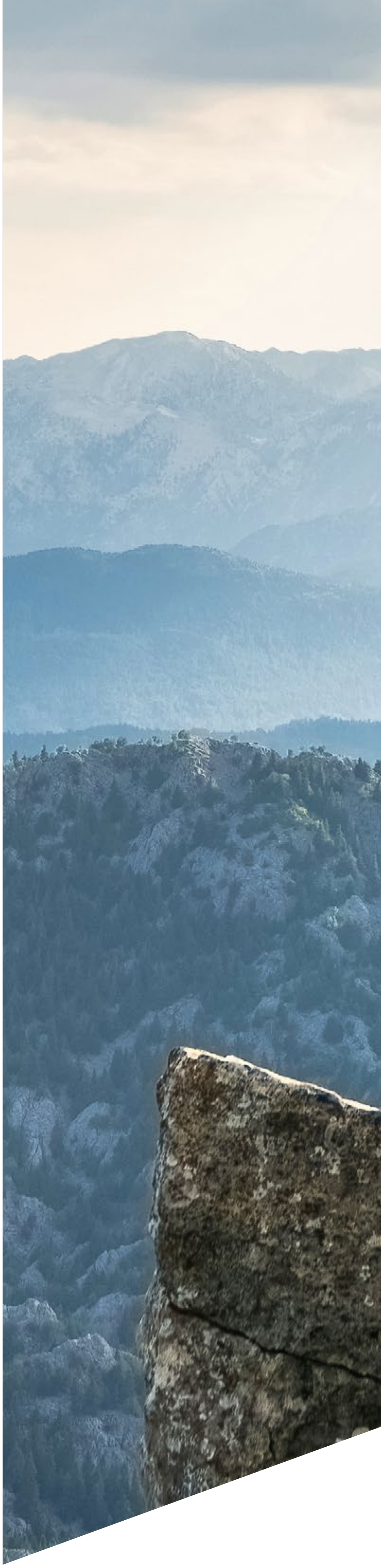


Main decarbonisation drivers

- Demand-side measures and circularity
- Biomass as fuel or feedstock
- Energy efficiency
- Carbon capture and storage or use
- Electrification and carbon-neutral power
- Land use or agricultural practice changes
- Carbon-neutral H2 as fuel or feedstock
- Other innovations

Notes: 1) Includes absorption technologies; 2) Refers to land use, land-use change, and forestry, which encompasses all the ways in which atmospheric CO_2 can be captured or released as carbon in vegetation and soils of terrestrial ecosystems.

Source: Moeve análisis based on McKinsey



The green molecule revolution

In 2024, fossil fuels accounted for approximately 68%[2] of the energy mix, and fossil raw materials for more than 90% of chemical supplies. Green molecules will be essential not only to replace them, but also to reduce the European Union's energy dependence, which in 2024 reached 57% of total demand.

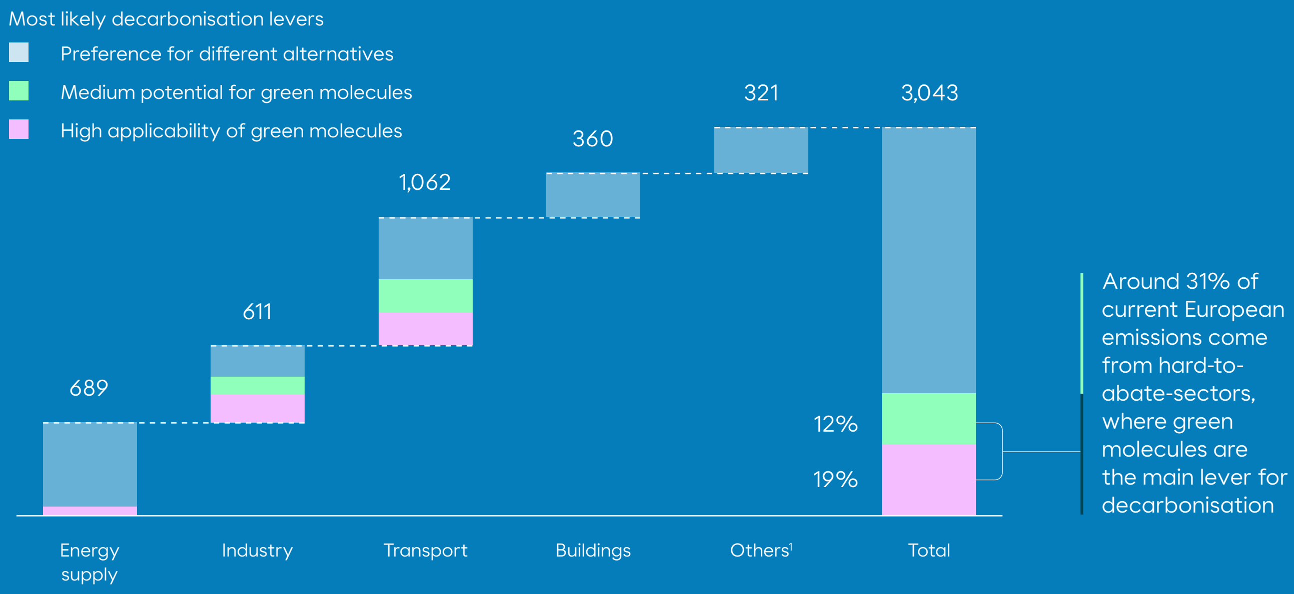
Direct electrification, which encompasses solutions such as solar photovoltaic energy, heat pumps, electric boilers, heaters, and electric vehicles, among others, is distinguished by its high energy efficiency and advanced degree of technological maturity. On the other hand, green molecules, used both in 2G biofuels and in synthetic fuels through indirect electrification (green hydrogen and its derivatives), possess specific characteristics that make them particularly suitable for decarbonizing sectors where direct electrification is not a viable option. These hard-to-abate sectors include, for example, certain industries such as chemicals, non-metallic minerals, steel, and refining, as well as long-distance transport—primarily aviation, maritime transport, and heavy-duty road freight—which account for approximately one in three (31%) of the European Union's total emissions and 20–25% of European primary energy demand, according to data from Eurostat and the European Environment Agency.

Greenhouse gas (GHG) emissions from hard-to-abate sectors have a proportionally greater impact in the European Union than at the global level, underscoring the urgency of accelerating the energy transition in the European context.

[2] "Energy Balance", (2024), Eurostat

While the European Union is making significant progress in the development of solar and wind energy, thereby reducing greenhouse gas emissions from electricity and heat generation by 48% in 2023 compared to 1990, the rest of the world still largely depends on coal, oil, and natural gas for electricity and heat generation, with a 97% increase in emissions over the same period, according to Our World in Data[3]. Given this context, accelerating the development of green molecules is key for the European Union to achieve its established decarbonisation targets and facilitate the transition toward a carbon-neutral economy.

Chart 2 **European Union emissions by sector ($MtCO_2eq$, 2024)**



Sectors with high-medium applicability of green molecules for their decarbonisation

- Oil refining
- Chemicals
- Iron and steel
- Non-metallic minerals
- Maritime shipping
- Aviation
- Heavy-duty trucks

Notes: (1) Agriculture and other minor sectors

Sources: European Environment Agency

Green molecules offer a transformative pathway to decarbonise hard-to-abate sectors, which currently account for approximately 31% of the European Union's total emissions.

[3] "Breakdown of carbon dioxide, methane, and nitrous oxide emissions by sector", Our World in Data

Green molecules can be sorted into two main categories: biomass-based and hydrogen-based (also known as synthetic fuels), depending on the compounds needed for synthesis. Second-generation biomass-based green molecules, which are already in use, give rise to more sustainable fuels or chemical raw materials such as biomethane, biomethanol and renewable diesel, and are obtained from raw materials such as organic waste, biomass or agricultural and livestock farming waste.

Green molecules based on hydrogen or synthetic fuels are compounds of non-biological origin produced using green hydrogen from renewable energy[4], together with CO_2 or N_2. Although still in the early stages of development compared to biofuels, rapid advances are expected to position hydrogen-based compounds as a relevant alternative for medium-to-long-term decarbonisation. They are often referred to as "power to X", as they are carriers of both energy (for fuels) and chemical raw materials.

Green molecules are the main lever for decarbonisation in hard-to-abate sectors and have the potential to cut Europe's emissions by up to 22% by 2050.

Uses of green molecules in hard-to-abate industries can be grouped into two. The first use relates to green molecules as a raw material, harnessing the chemical properties of green hydrogen to facilitate the production of compounds such as e-ammonia, fertilisers and green methanol (both biomethanol and e-methanol), as well as in refining processes and as a reducing agent in steel manufacturing. Secondly, green molecules are used as fuels, encompassing both hydrogen and its derivatives and biofuels, particularly in sectors where electrification is not technically or economically viable. These new-generation fuels made from green molecules offer high energy density and greater power capacity, making them suitable for heavy-duty transport and intensive thermal industries, such as the production of non-metallic minerals (cement, glass, ceramics) and chemical products, among others.

Despite the recent reductions, the European Union still has to make further efforts to achieve its target of cutting emissions by 55% below 1990 levels, which is necessary to meet the 2030 targets. To achieve these ambitious goals, significant transformations will be required across all industries by triggering five main levers: (i) reducing demand, (ii) enhancing energy efficiency, (iii) switching to low-carbon fuels and raw materials, (iv) capturing, utilising and storing carbon (CCUS), and (v) other measures, such as sustainable land use and farming practices.

While electrification is the main pathway to decarbonisation, green molecules are emerging as the second most significant lever, with the potential to mitigate approximately 22%[5] of emissions in Europe by 2050.

[4] Green hydrogen can be generated by means of electrolysis using renewable electricity such as solar photovoltaic or wind power, as well as by using biomethane and the steam methane reforming (SMR) process. This report will focus specifically on the electrolytic hydrogen route.

[5] Moeve analysis based on McKinsey "Net-Zero Europe"

Chart 3 Potential of emissions reduction mechanisms and share by 2050

Decarbonisation lever	Share of reduction by 2050	Description
Demand reduction and circular economy measures	7%	Seeks to **reduce** overall energy and resource consumption by **promoting circularity through recycling and product reuse.**
Technological efficiency	11%	Energy efficiency enhancement through **technological advances**, such as in power generation, or **through infrastructure improvements**, such as heat recovery for industrial uses.
Fuel change – Electrification	44%	Transitioning from fossil fuels to renewable power sources (such as **solar PV, onshore and offshore wind, etc.**) for various applications, such as **electricity generation and electric vehicles.**
Fuel change – Green molecules	22%	Switching from traditional fossil-based feedstock to **low-carbon alternatives, referred to as green molecules** (such as **ammonia, methanol, biogas,** etc.).
Carbon capture, usage and storage	6%	**Capturing CO_2 emissions and storing them underground or using them to make synthetic fuels,** particularly in industries where fuel switching is challenging.
Others	10%	**Sustainable land use practices,** including reforestation and the adoption of sustainable farming practices, can also help to trim emissions and preserve biodiversity.

Sources: Moeve analysis based on McKinsey

In the European Union, the maritime shipping, aviation, heavy-duty road transport and industrial sectors play a pivotal role in economic growth, global trade and international exchange. But, as mentioned above, these industries are also major contributors to the European Union's emissions. In this context, innovative solutions are emerging, spurred by regulatory initiatives such as the FuelEU Maritime and ReFuelEU Aviation policies, among others. This comprehensive strategy entails embracing biofuels, green hydrogen and synthetic fuels, all aimed at reshaping transport and industrial practices while meeting the stringent emissions reduction targets set by European Union regulations.

Gradual adoption of green molecules

The adoption of green molecules will be influenced by factors such as the type of molecule, the intended end-use sector, resource availability, funding availability, market acceptance, the cost and intensity of decarbonisation, and competition from other decarbonisation alternatives. However, the European Union is well equipped to accelerate adoption across the region.

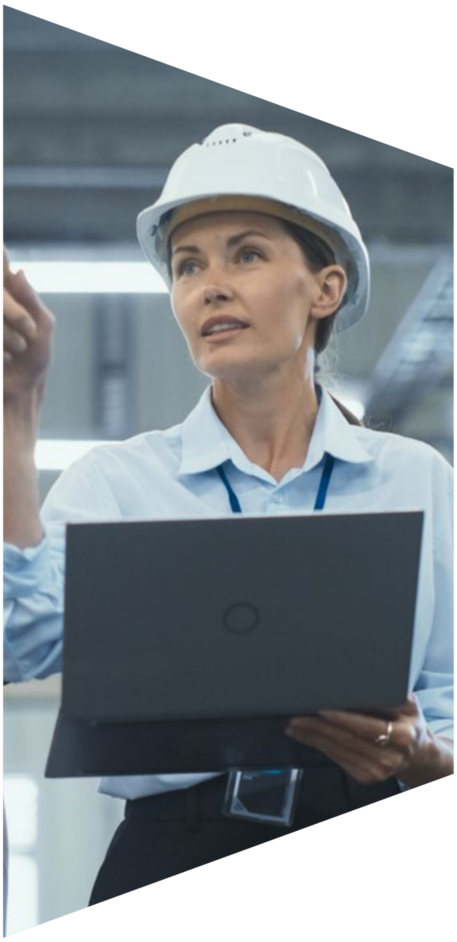
Nowadays, biofuels are at the head of the pack in the energy transition drive and are expected to remain there in the short-to-medium term. An example of this is Moeve's 2G biofuels development project in Huelva, which is expected to begin operations in early 2027. The plant will have a flexible production capacity of 500,000 tonnes of SAF and renewable diesel, making it the largest 2G biofuels industrial complex in southern Europe. Projects like this not only reinforce the role of biofuels today but also help pave the way for the transition towards other renewable alternatives in the future.

As technology advances and infrastructure consolidates, hydrogen-based synthetic fuels, sustainable feedstock and pure hydrogen are expected to play a more prominent role in the medium-to-long term. These renewable alternatives could replace up to half of the demand for fossil fuels, accounting for between 25% and 33% of the European Union's final energy demand in 2050.

According to the Hydrogen Council, half of global hydrogen demand by 2030 could come from Europe, reaching 5 Mtpa, driven by regulatory requirements such as RED III[6]. In this context, the forecasts from the "Clean Hydrogen Monitor 2025" indicate that Europe would reach 2.3 Mtpa of this demand by 2030 through local renewable hydrogen production, which would cover approximately 60% of its estimated regulatory demand. While these estimates fall short of the REPowerEU target of achieving an internal production capacity of 10 Mtpa by 2030, they reflect real and essential progress in developing the infrastructure needed to accelerate hydrogen production in the years ahead.

Furthermore, the current international landscape is led by China, which is at the forefront of electrolyser deployment for renewable hydrogen generation and accounts for more than half of the global committed capacity[7], with the aim of reducing its dependence on fossil fuels. Europe, for its part, holds second place in committed renewable hydrogen capacity, with around 20% of the global total. This push by China highlights an increasingly clear reality: strengthening energy security and industrial competitiveness through the energy transition is no longer just an option, but a strategic priority for Europe. Sustaining and accelerating this progress will be key not only to covering domestic demand with local production, but also to laying the foundations of a market that will define the next decade.

Green molecules could replace up to 50% of fossil fuel demand by 2050 and form approximately one-third of the European Union's energy mix, a crucial step towards climate neutrality.



[6] "Global Hydrogen Compass 2025", McKinsey

[7] Projects that have either reached a final investment decision, are under construction, or have commenced operations.

Within Europe, Spain is recognised as a leader in the Power-to-Hydrogen (PtH) project pipeline and has the most ambitious electrolysis target in the European Union for 2030. According to Hydrogen Europe, this leadership is attributed to Spain's favourable conditions related to energy resources and ambitious government initiatives[8]. In Iberia (Spain and Portugal), renewable hydrogen production of 0.39 Mtpa is forecast for 2030, associated with a generation capacity of 3 GW in Spain and 0.9 GW in Portugal. Although this figure falls below the 12 GW initially envisaged in Spain, the long-term vision remains intact and continues to underscore the country's commitment to this technology. The gradual ramp-up in the commissioning of projects in newly emerging sectors is commonplace and is expected to accelerate as the regulatory framework is consolidated, with the transposition of RED III or the binding adoption of the emissions reduction targets approved by the IMO in the maritime transport sector. Furthermore, progress in grid access and connection procedures, as well as the materialisation of public funding that facilitates final investment decisions, will drive the execution of a greater number of projects. In this context, Spain holds a leading position in Europe, ahead of other benchmark markets such as Germany, where a deployment of 2.2 GW[9] is expected.

This Spanish leadership is due, in part, to the deployment that has already begun to materialise, with multiple players having reached a final investment decision on their hydrogen projects. This is the case of Moeve, which has approved the first phase of the Andalusian Green Hydrogen Valley, Onuba, with 300 MW, is the largest green hydrogen project in the EU dedicated to the energy industry. Repsol, for its part, recently installed its second 100 MW electrolyser at Petronor, aimed at strengthening industrial decarbonisation. Initiatives in the final construction phase are also noteworthy, such as the BP and Iberdrola project in Castellón, with 25 MW.

At the European level, other cases where this trend is also gaining momentum are worth highlighting, such as the Stegra project in Sweden, the largest FID project in Europe, which completed the installation of 740 MW of electrolysers in April 2026, to be used for the manufacturing process of green steel.

In terms of recent developments, many biofuel projects are focusing on Sustainable Aviation Fuels (SAFs). The European Union anticipates approximately 53 production plants by the end of the decade. This represents around 43% of global projects currently under way (~125) with a capacity of 3.5 million tonnes, accounting for approximately 15% of the total projected capacity, estimated at around 23 million tonnes[10].

EU regulations incentivising green molecules need to focus on actions with high emissions reduction potential, prioritising biomass-based fuels for immediate decarbonisation, supplemented by hydrogen solutions in the medium-to-long term.

[8] "Clean Hydrogen Monitor 2023", Hydrogen Europe

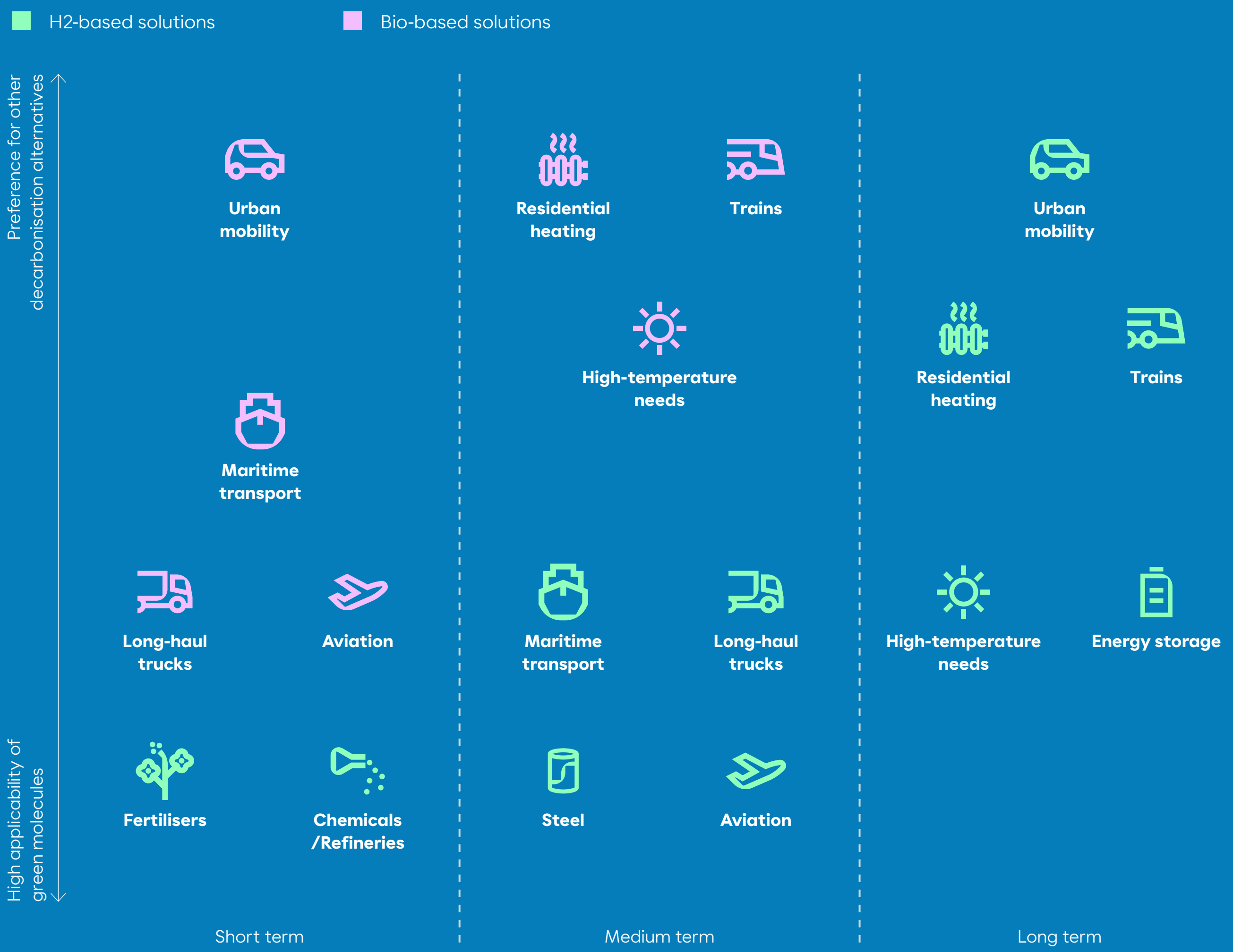
[9] "Clean Hydrogen Monitor 2025", Hydrogen Europe

[10] Moeve analysis

A prioritised adoption hierarchy for green molecules should focus on the most efficient reduction cases, considering factors such as decarbonisation intensity, resource efficiency and economic feasibility. The European Union benefits from robust infrastructure and widespread availability of resources, giving it a competitive edge over other regions in the transition to green molecules.

Biomass-based fuels are expected to drive decarbonisation efforts, while hydrogen-derived alternatives will gain prominence in the medium and long term as their competitiveness improves. Adoption across sectors will depend on factors such as public subsidies, adaptation costs, fuel cost competitiveness, resource availability, the required level of decarbonisation, and the implementation of regulations that set clear decarbonisation targets. Ultimately, these elements will shape the transition toward a greener economy in the European Union.

Chart 4 Hierarchy of green molecule solutions



Sources: Moeve analysis based on Ramboll Group

Second-generation biofuels could reach cost parity with fossil fuels in the 2030s, while green hydrogen could achieve parity in the 2040s, according to different scenarios based on public sources.

The cost gap between conventional fossil fuels and green molecules is expected to narrow as the cost of CO_2 emissions increases, biomass- and hydrogen-based fuel production becomes more efficient, and renewable energy prices, which account for 70-80% of the price of hydrogen, fall. According to various price scenarios prepared by the IEA (International Energy Agency), the WEF (World Economic Forum), the Mærsk Mc-Kinney Møller Center and IRENA (International Renewable Energy Agency), among others, biofuels are the first solution projected to achieve cost parity with conventional fuels, potentially by the 2030s. In contrast, hydrogen-based fuels are expected to reach cost parity during the 2040s.

Besides efforts to ensure cost competitiveness, offtakers are being forced to explore ways to decarbonise their production processes and Scope 3 emissions by means of mandatory regulatory measures and voluntary decarbonisation pledges. The main players in this field include car manufacturers and food and beverage companies, which are working with various industries to decarbonise products and processes.

Exploring the impact of the green premium

An assessment of the impact of the green premium on different products from 2030 onwards shows that the premium tends to dissipate along the product's entire value chain[11]. For example, the impact on the price of a car of using green steel instead of conventional steel is less than 2%. Similarly, the price increase associated with the use of green ammonia for green fertilisers could result in a 1% and 5% rise in wheat production costs. Also, when considering the additional cost of using vessels powered by green fuels to carry products, it is estimated that the impact on the price of each item varies between 1% and 4%. This is because freight costs represent only a small portion of the final price charged to consumers. The adoption of SAFs reflected in the regulatory targets is expected to trigger a limited increase in passenger ticket prices, ranging from €1 to €40, depending on the type of flight.

The green premium impact declines along the product value chain, reducing its effect on end-user prices to moderate increases of 1–5% from the 2030s onwards.

[11] Price analysis based on current price estimates and forecasts. The effect of the green premium on these products will be felt the most in the short term, as technological advances continue to bring down the cost of green molecules in the medium-to-long term, while CO_2 costs push up fossil fuel prices.

Chart 5 Assessment of the green premium for key hard-to-abate industries in 2030

Hard-to-abate industries	Steelmakers	Fertilisers	Maritime transport	Aviation
	Metallurgical coal	**Grey H2**	**Marine fuel**	**Kerosene**
Decarb. alternative	Green H2 for DRI-EAF route	Green H2 / Ammonia in urea plant	Biofuels (methanol, LNG or diesel) with e-methanol and ammonia vessels	Bio-based such as HEFA, FT, AtJ and green hydrogen-based such as PtL
Green premium impact	**1-2%** Passenger car	**1-5%** Wheat and maize	**1-4%** Retail price increase	**1-5%** Ticket price increase

Sources: Moeve analysis based on Hydrogen Europe, IEA, Mærsk Mc-Kinney Møller and WEF

Ensuring the adoption of green molecules

Europe is ready to drive global decarbonisation and promote a broader use of green molecules. The region has several levers supporting a green transition, including the ability to produce hydrogen-based fuels at a competitive cost thanks to abundant renewable power generation. European backing for the reuse of waste to produce biofuels, coupled with the availability of biomass and forestry waste, provides the necessary raw materials. Europe also benefits from state-of-the-art infrastructure, diverse consumption patterns and a robust industry, making it a global leader in industrial, logistics and aviation hubs.

Although these efforts are commendable, concerns have been voiced by European institutions and associations about a possible “raw material supply crisis” based on current trends, as evidenced by the sharp growth in imports of used cooking oil into the EU from non-EU countries since 2015. This highlights the importance of diversifying the biofuel feedstock envelope through innovation, reducing reliance on imported waste oils, and strengthening Europe’s domestic supply chains. Despite these challenges, continued promotion of and regulatory support for sustainable practices in Europe remain strong, driven by the region’s need for energy security and independence, combined with the limitations of the electricity grid.

The role of green molecules is becoming key to securing future energy supplies and facilitating an efficient electricity system, particularly amid concerns regarding potential bottlenecks and grid saturation. Once the necessary green hydrogen infrastructure is in place, green hydrogen can contribute to managing the intermittency of an electricity system based on renewables, by turning green electricity into green hydrogen when there is a surplus of renewable generation, and converting it back into electricity when there is a deficit. Green molecules can therefore help against grid saturation, highlighting the importance of identifying the combination of solutions with the greatest potential.

Europe is at the global forefront in the adoption of green molecules, boosting its energy security and autonomy while facilitating a resilient, sustainable transition to a low-carbon economy.

Hydrogen is one of these solutions, and Southern Europe, particularly the Iberian Peninsula, is emerging as a region with considerable potential for achieving a highly competitive Levelised Cost of Hydrogen (LCOH). This potential is driven by a competitive Levelised Cost of Electricity (LCOE) thanks to abundant solar photovoltaic and onshore wind resources. According to the Goldman Sachs analysis entitled "Carbonomics: The Clean Hydrogen Revolution", projections suggest that, by 2030, Spain and Portugal could produce green hydrogen at approximately half the cost compared to Central Europe and the Nordic countries, becoming a potential large-scale supplier of green molecules in the region. The synergy between the abundant wind resources in northern Europe and the solar radiation in southern Europe reflects optimal conditions for the development of efficient wind farms and solar facilities. These renewable sources play a pivotal role in ensuring the lowest LCOE and facilitating the roll-out and scaling of hydrogen-based green molecules across the region.

Southern Europe, particularly the Iberian Peninsula, has exceptional potential for producing green hydrogen at highly competitive costs, achieving prices almost half those of Central and Northern Europe.

According to the “Clean Hydrogen Monitor 2025” report by Hydrogen Europe[12], and in line with studies by the Hydrogen Council and the European Hydrogen Backbone, announced projects in the European Union total 12.7 Mtpa of green hydrogen production by 2030, although currently only 5% of these projects are in the development phase. The study identifies southern Europe, highlighting regions such as Iberia, as well as northern Europe, including the Nordic countries and the United Kingdom, as the main future producers. These regions are anticipated to contribute more than 70% of hydrogen supply by 2040, leveraging their abundant natural resources. To maintain a competitive edge in synthetic fuels, southern Europe must focus on harnessing the cost advantages of raw materials. While subsidies and incentives can provide support, regions with access to low-cost hydrogen and CO_2 sources will lead in synthetic fuel production, with the cost of renewable electricity being the primary factor influencing green hydrogen production costs. Proof of this is that, in the European Hydrogen Bank auction, promoters submitted surprisingly low premium bids. The aid needed to cover the difference between the cost of producing hydrogen and the price that offtakers are willing to pay was set at a maximum of €4.5/kg, while all winning bids ranged between €0.37/kg and €0.48/kg. This highlights the importance of cost-effective renewable electricity to remain competitive in the synthetic fuels market.

Also, Europe’s commitment to a circular economy and the reuse of waste is key to ensuring a sustainable supply of biomass, which is crucial for the development of biofuels and the transition to clean energy. The continent’s diverse climates and ecosystems offer a rich variety of biomass resources for bioenergy (for biofuels such as SAFs or biomethane). Through innovative practices such as the reuse and recycling of organic waste from agriculture, livestock farming or municipal sources, together with sustainable forestry methods, Europe is harnessing these resources to drive its renewable energy agenda. According to several publicly available studies, such as those conducted by Concawe and Imperial College London[13], together with scenarios prepared by the European Commission[14], the availability of second-generation biofuels could exceed 2,000 TWh (terawatt-hours) by 2050. This projection implies a tenfold increase in demand for biofuels compared to current levels, according to the latest Eurostat data.

[12] “Clean Hydrogen Monitor 2025”, Hydrogen Europe

[13] “Sustainable biomass availability in the EU, to 2050”, Concawe

[14] “Development of outlook for the necessary means to build industrial capacity for drop-in advanced biofuels”, European Comission

Consumption patterns across Europe will also play a decisive role in shaping the adoption of green molecules. Regions such as Spain, among others, with high demand in the maritime shipping and aviation industries, have the potential to become strategic hubs for the sustainable production and supply of SAFs and green molecules.

Despite this promising outlook, there are a number of barriers and challenges to the adoption of green molecules. Critical factors such as investment needs, resource availability and the willingness to pay for decarbonisation-related cost increases are significant obstacles to the integration of green molecules into the European energy landscape. However, a number of support measures and enablers are being actively developed to prevent these challenges from becoming hindrances, such as ambitious regulatory targets and technology R&D alongside government subsidies and incentives, among others. Key stakeholder partnerships are helping in a joint effort to overcome obstacles and promote the adoption of green molecules across the board.

> Comprehensive measures are being developed, including ambitious regulatory targets, advanced R&D, government subsidies and strategic incentives, to overcome barriers to the widespread adoption of green molecules.

Chart 6 **Key challenges and enablers for accelerating the adoption of green molecules**

Sources: Moeve analysis

The challenges associated with implementing these technologies underscore the importance of combining strategic investment and collaborative efforts with regulatory frameworks that not only stimulate production but also drive demand. Alongside regulatory support and financial incentives, partnerships between public and private stakeholders are essential for scaling up production, aligning it with to market demand, and reducing the risks taken by early investors. In this context, the transition will be accelerated through European policies that support, in a coordinated manner, the development of supply, the creation of demand, and the deployment of infrastructure, ensuring balanced progress among the different market actors.

The adoption of green molecules throughout the European Union is set to drive considerable economic growth and job creation by 2040. According to projections by Moeve and ManpowerGroup[15], the development of green molecules could generate up to 1.7 million new jobs in the EU and the United Kingdom, averaging around one hundred thousand (100,000) jobs per year. Spain is projected to lead the other EU countries in job creation, creating 181,000 new posts by 2040, closely followed by the United Kingdom and Germany. This growth in employment will also bring substantial economic benefits by increasing GDP in the area (European Union and the United Kingdom) by up to €145 billion by 2040, of which €15.6 billion will come from Spain.

Major investments will also be needed within the European Union to achieve carbon neutrality and decarbonise the economy. As underlined in the reports "New Energy Outlook: Europe" by BloombergNEF[16], "Net-Zero Europe: Decarbonization pathways and socioeconomic implications" by McKinsey[17] and "Road to Net Zero" by the Rosseau Institute[18], Europe's transition to a net-zero economy by 2050 will require more than €29 trillion[19] in cumulative investment, of which approximately 20%, or around €5 trillion, will be incremental investment compared to a scenario devoid of climate action, as the remaining €23 trillion will come from redirecting investments that would traditionally have funded fossil fuel technologies. BloombergNEF also estimates that the required hydrogen supply side investments will increase steadily over the years, expecting around €300-400 billion in the period 2022-2050.

To drive green industrialisation in Europe, it is essential that policies promote not only supply but also demand in a coordinated manner, to ensure synchronized progress among the different market players.

The need to decarbonise our economy so as to curb the rise in greenhouse gas emissions and limit global warming must not be postponed. Ignoring this challenge would have serious, irreversible consequences for the planet, such as rising temperatures and sea levels, melting polar ice caps, more frequent heat waves, floods and other extreme events.

A European Commission study[20] reveals the economic implications of climate change. Higher temperatures trigger a further decline in well-being, affect economic output and impact household well-being. In a 3 °C-warming scenario, the annual loss of well-being in the European Union could reach at least €54 billion. In contrast, limiting warming to 1.5 °C will reduce the additional well-being loss by 89% down to €6 billion per year. The implications of not decarbonising will be economically significant, including much greater well-being losses in southern regions compared to northern areas.

[15] "Green Molecules: The Imminent Labor Market Revolution in Europe". The impact was assessed using the EHB's green hydrogen projections. These projections anticipate approximate output ranging between 1,200 TWh and 1,400 TWh of green hydrogen by 2040, spanning the European Union and the United Kingdom.

[16] "Energy sector investment requirements in Europe under BNEF Net Zero Scenario", BloombergNEF

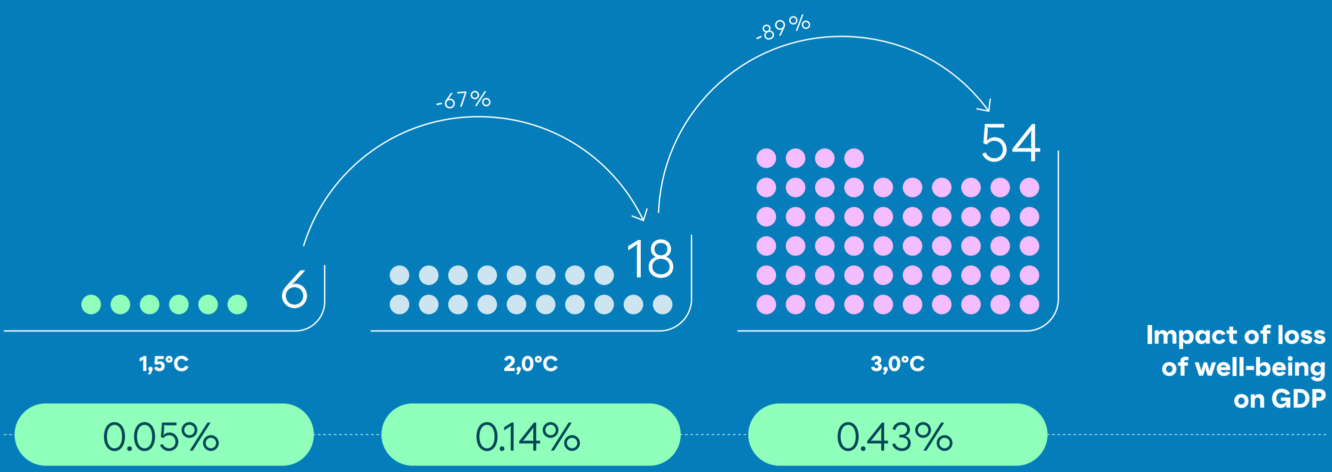
[17] "Net-Zero Europe, Decarbonization pathways and socioeconomic implications", McKinsey

[18] "Road to Net-Zero, Bridging the Green Investment Gap", Institut Rousseau

[19] "De-risking the energy transition in Europe", PwC

[20] "Welfare loss from climate change impacts", European Commission

Chart 7 Annual loss of well-being due to the impacts of climate change (€bn)



Fuentes: Comisión Europea y PESETA IV.

Failing to act on climate change could also lead to a substantial decline in GDP. In Europe alone, the cumulative economic effects are estimated to exceed €6 trillion over the next 50 years. In contrast, achieving global climate targets could bring considerable economic benefits, with an estimated potential of up to €730 billion in Europe. Acting now is not only crucial for our health and the environment, but also to drive new opportunities for economic growth.

So, climate inaction would have adverse consequences not only for the environment and public health, but also from an economic viewpoint. Compared to the estimated additional investment of €5 trillion[21] needed to achieve climate neutrality by 2050[22], the economic impact of failing to decarbonise would exceed the required investment by 10–20%, amounting to over €6 trillion in the next 50 years.

Without climate action, the European Union faces potential losses of €6 trillion, a cost that well exceeds the €5 trillion needed to achieve a carbon-neutral economy by 2050.

[21] The additional investment needed to achieve Net Zero refers to the incremental investment required compared to a climate inaction scenario

[22] “New Energy Outlook: Europe” de BloombergNEF

Green molecules driving European strategy

The adoption of green molecules is key to Europe meeting its energy transition, supply security, energy sovereignty, reindustrialisation and industrial competitiveness goals. Replacing up to 40% of fossil fuel demand with locally produced green molecules will reduce the European Union's energy dependence by 50%, from the current 57% to 28% by 2040, bolstering the continent's energy stability.

For this to be possible, Europe must harness its potential and commit to innovation and the local manufacturing of the technology needed to meet energy needs autonomously, competitively, and sustainably. In this context, green hydrogen will play a key role, as it will enable greater penetration of renewables into the electricity system, while providing demand and flexibility to the system. Thus, becoming a key opportunity for reindustrialisation, competitiveness, and job creation.

This will be a catalyst for more competitive reindustrialisation in Europe, attracting industries such as chemicals and steel, which are capable of embracing hydrogen and biofuels as clean energy sources. So decarbonisation must become a driver of growth in European industries and position our continent as a leader in the green economy of the future.

The first step along this path is to develop the necessary infrastructure, such as H2Med or the Hydrogen Valleys, which will lay the groundwork for the first projects and facilitate subsequent scaling-up until a single, integrated market can be established at the European level. Regulation is key at this point in time and must provide a clear, stable framework that facilitates investment and ensures a fair, efficient transition.

The groundwork must be laid during this decade for a solid platform that will enable the accelerated deployment of hydrogen in the following decade. Acting now is essential to develop the infrastructure needed to achieve the scale that will be necessary going forward.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01

Driving European decarbonisation: the rise of green molecules

1.1.

Humanity faces the energy revolution of the century in an uncertain macroeconomic arena

The world is going through a pivotal stage in the global energy landscape, marked by geopolitical conflicts and disruptions to energy supply chains that have exposed the vulnerability of many countries stemming from their external dependence. In this context, the energy transition no longer responds solely to the need to advance the fight against climate change, but also to a strategic imperative: strengthening security of supply, reducing exposure to fossil fuel price volatility, and consolidating a competitive and resilient domestic industry.

This stage is the result of multiple historic global agreements, such as the one reached at COP28 in 2023, which some international media identified as the “beginning of the end” of the fossil fuel era. At this conference, nations agreed to advance the gradual phase-out of fossil fuels, which still account for approximately 80% of global primary energy demand.

Following this decision, international commitments have been progressively strengthened, for example at COP30, where the imperative to maintain the goal established in the Paris Agreement was reinforced, limiting the temperature increase to 1.5°C above pre-industrial levels by the end of the century. To achieve this goal, the need to quadruple the use of sustainable fuels by 2030 was emphasized. Additionally, COP30 also underscored the need to triple global renewable capacity and double the annual rate of energy efficiency improvements by 2030, along with accelerating efforts to reduce unabated coal use, among other objectives.

During the conference, the European Union, in association with its Member States, championed the need to raise climate ambitions and emphasised the need to set new global energy targets.

> “The window of opportunity to act and avoid irreversible impacts on humanity and nature is closing rapidly. The existential threat posed by climate change in particular drives the European Union’s unwavering commitment to the Paris Agreement.”

Antonio Costa, President of the European Council, at COP30, in November 2025[23]

[23] “COP30 climate summit, Belém, Brazil, 6-7 November 2025”, European Council

Energy transformation is at the forefront of the European Union's agenda and is becoming one of the main priorities for all Member States. Geopolitical events, such as the conflict in Ukraine and more recently the conflict in Iran, have driven the EU to accelerate the reform of its energy system. Against this backdrop, striking the right balance between energy affordability, security of supply and environmental sustainability is crucial for the European Union and policymakers. This transformative voyage depends on a growing contribution from green molecules, particularly in industries where electrification may not be a viable option, emerging as a major force for achieving decarbonisation and net-zero emissions targets. Achieving this balance is essential to ensure economic progress while advancing energy policies:

- **Security of supply:** green molecules can significantly enhance European energy independence by promoting technologies, fuels and processes that use locally-sourced renewable energy. This helps stabilise supply amid international energy trade volatility, particularly at a time when geopolitical factors highlight the need for reliable, domestically-sourced energy. Although development may take time, the potential of agricultural, forestry, municipal and other waste in the EU is vast, offering a substantial improvement in security of supply compared to the current reliance on oil and gas.

- **Energy affordability:** diversification in energy supply and fuel production thanks to green molecules will bring greater energy affordability in the medium-to-long term, together with increased price stability and predictability compared to resources exposed to global market volatility. This benefits industries, consumers and the economy at large by providing a more predictable pricing framework.

- **Environmental sustainability:** the decarbonisation of the economy is among the most significant challenges facing humanity today, as emphasised by reputable sources such as Forbes in "Time to Tackle Humanity's Greatest Challenge: Climate Change". As demonstrated in the report, green molecules are expected to play a pivotal role in the transition to a net-zero economy and in decarbonisation targets.

Green molecules are essential for achieving European decarbonisation targets and complying with the Paris Agreement, particularly in industries in which electrification is not feasible.

There is an increasingly consolidated idea: Europe's competitiveness will not be able to take off as long as it maintains external dependencies that third parties can use as an instrument of political or strategic pressure, as has been made evident in the most recent conflicts. As Enrico Letta pointed out at the 34th Faconauto Congress, "there is no Europe without industry, there is no security without financial resilience, and there is no security without energy independence."

In seeking to ensure a fair and competitive energy transition, the European Union has developed several policies and legislative packages in recent years, particularly over the last seven years with the Green Deal, the Fit for 55 Package, REPowerEU, the Renewable Energy Directive (RED III), the EU Competitiveness Compass and the Affordable Energy Action Plan, among others. These initiatives consistently set more ambitious decarbonisation targets. Consequently, green molecules will play an increasingly important role in this evolving landscape.

The launch of the Green Deal in 2019 is one of the European Union's most significant milestones in the fight against climate change, setting the ambitious target of achieving a 55% reduction in greenhouse gas emissions by 2030 compared to 1990 levels. The Green Deal comprises a set of policy initiatives designed to establish the European decarbonisation strategy that will lead to climate neutrality by 2050. This policy package encompasses specific initiatives in sectors within the European economy, as well as more holistic initiatives that together chart the course for Europe's green transition.

The most remarkable Green Deal initiatives include the Fit for 55 package, launched in 2021. This comprehensive package encompasses several proposals to meet the greenhouse gas reduction targets and climate goals set by the European Union.

The Fit for 55 package brought in some of the European Union's most significant initiatives for decarbonisation and the transition to green molecules. They include the EU Emissions Trading System (ETS), the Carbon Border Adjustment Mechanism (CBAM), FuelEU Maritime, ReFuelEU Aviation and RED III, among others.

Introduced in early 2022 in response to the war in Ukraine, the REPowerEU plan aims to accelerate European decarbonisation and the green transition while reducing reliance on Russian fossil fuels. The plan focuses on generating clean energy and diversifying energy supply, emphasising the growing use of green molecules such as hydrogen and its derivatives, along with biomethane. The ambitious objectives include the availability of 20 million tonnes of green hydrogen by 2030 (of which 10 million will be produced in the European Union and the remaining 10 million will be imported), together with 35 billion cubic metres of biomethane, among others.
One of the European Union's recent policy initiatives is the update of the RED, which raises the renewable energy consumption target for 2030 from 32.0% to 42.5% (with an additional 2.5%), with the aim of reducing energy dependence and fossil fuel imports. It also sets more ambitious specific targets for the transport sector, industry, as well as the building heating and cooling sectors, in a coordinated effort to advance the integration of renewable energy across various areas.

Furthermore, the recent revision of the European Climate Law further reinforces this trajectory by establishing a new intermediate target as a key step towards climate neutrality by 2050. This target consists of a 90% reduction in greenhouse gas emissions by 2040 compared to 1990 levels. Additionally, progress towards this new target will be periodically assessed based on technological developments, industrial competitiveness and energy price trends, in order to ensure an effective, competitive transition that protects the prosperity and social cohesion of the European Union.

1.2.

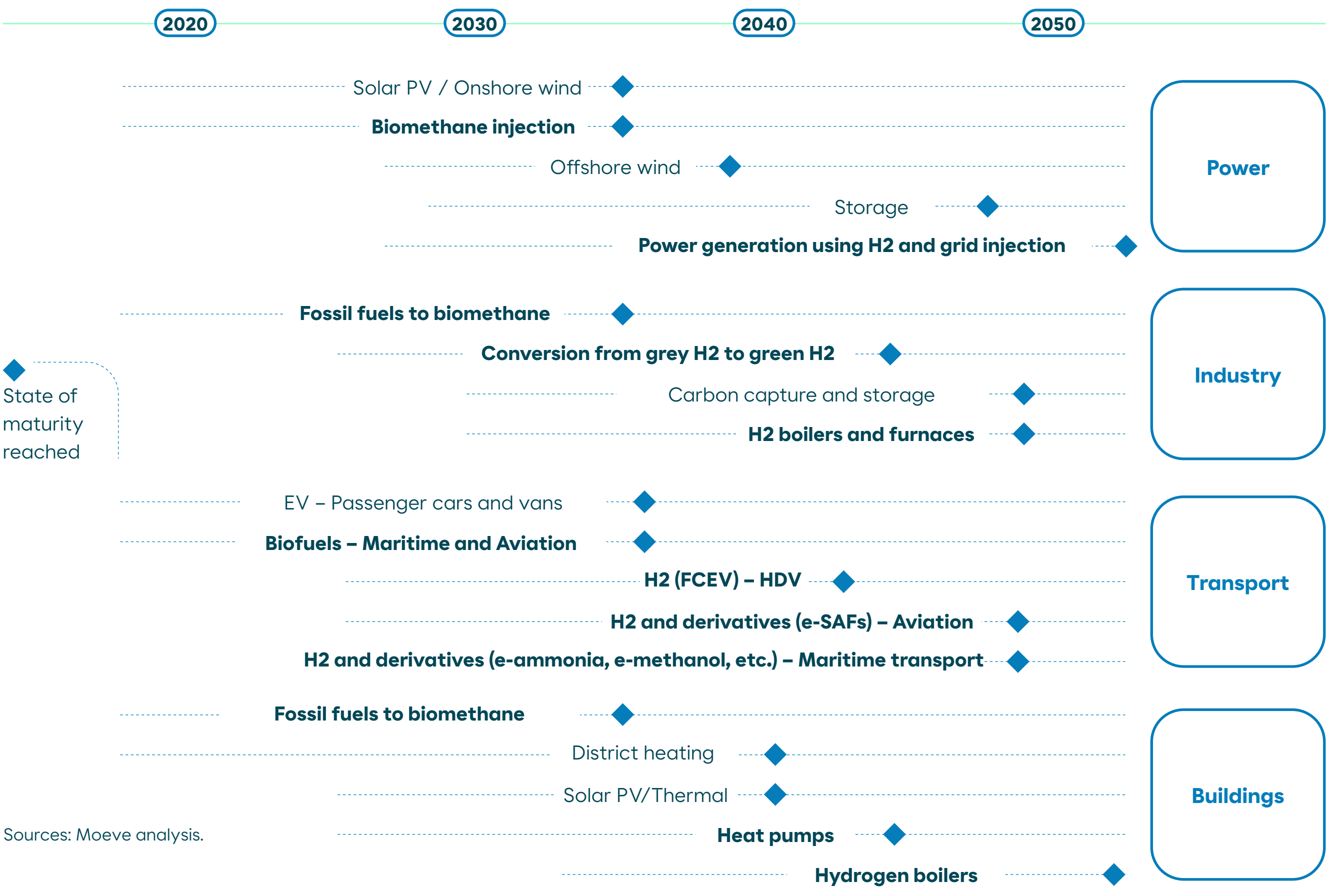
A problem of this magnitude requires a combination of technology solutions tailored to each end use

Energy use in different economic sectors calls for a broad variety of technology solutions, ranging from commercial aircraft to industrial furnaces and boilers, as well as trucks and cargo ships. So the technological alternatives available to decarbonise these industries vary according to the end use, the power required, energy density needs and other factors.

The alternative technologies required for decarbonisation can be placed in two main groups based on the type of technology. There are those that depend on electrification (such as photovoltaic solar energy, battery electric vehicles, heat pumps, etc.) and others based on green molecules, including sustainable aviation fuels (SAF), ammonia or methanol for maritime transport, etc.

To execute the energy transition and meet decarbonisation targets, a mix of technologies will be required, with the aim of identifying the most effective combination to decarbonise the specific requirements of each end use. Therefore, EU energy policies advocate for the electrification of the economy and a growing role for green molecules, as they allow for the leveraging of part of the existing energy infrastructure and, with it, a significant reduction in the investments that would be necessary under a scenario based exclusively on electrification[24]. This not only facilitates a faster and more efficient transition, but also helps to mitigate the economic impact on consumers. All the technologies needed for decarbonisation are on the table; however, their adoption will depend on both the cost of the technology and its technological maturity, factors that will influence industrial production and scalability.

Chart 8 Overview of decarbonisation technology development



Sources: Moeve analysis.

[24] "Market Activation Strategy", (2025), Global Hydrogen Mobility Alliance

Hard-to-abate industries include sectors or segments of the economy that face substantial challenges if they are to cut greenhouse gas emissions. These industries generally have processes that rely heavily on fossil fuels, making it difficult to bring down emissions. Heavy industries such as iron and steel, chemicals, refineries and non-metallic minerals such as cement, along with specific transport sectors such as aviation, long-distance maritime transport and heavy-duty road transport are hard to abate. Green molecules are emerging as a key alternative for decarbonising these sectors. Depending on its end use, they can be classified into two main groups:

- **Green molecules as a raw material:** green hydrogen has the necessary chemical properties that electrification cannot offer to decarbonise specific sectors. These uses include hydrogen as a raw material to make various chemicals, such as ammonia, fertilisers and methanol, among others. It is also essential in refining processes, such as hydrogenation and hydrocracking for fuel production. Hydrogen also serves as a suitable reducing agent in steel manufacturing processes, where electrification is not a viable solution.

- **Green molecules as fuel:** Both hydrogen and its derivatives and biofuels have a high energy density and greater power capacity, and can withstand higher temperature peaks, making them suitable for industries in which electrification may not be technically feasible. These applications are gaining relevance in heavy-duty transport sectors such as maritime shipping, aviation and long-distance trucking, as well as in specific industries with intensive thermal processes, such as non-metallic mineral production.

Hard-to-abate sectors include heavy industries —iron, steel, chemicals, refineries, and cement— and key areas of transport such as aviation, long-distance maritime shipping, and heavy-duty road transport.

Conversely, electrification is a highly competitive solution in high-energy-efficiency sectors, with most solutions showing remarkable technological maturity.

1.3.

Exploring the nature of green molecules: a deep dive

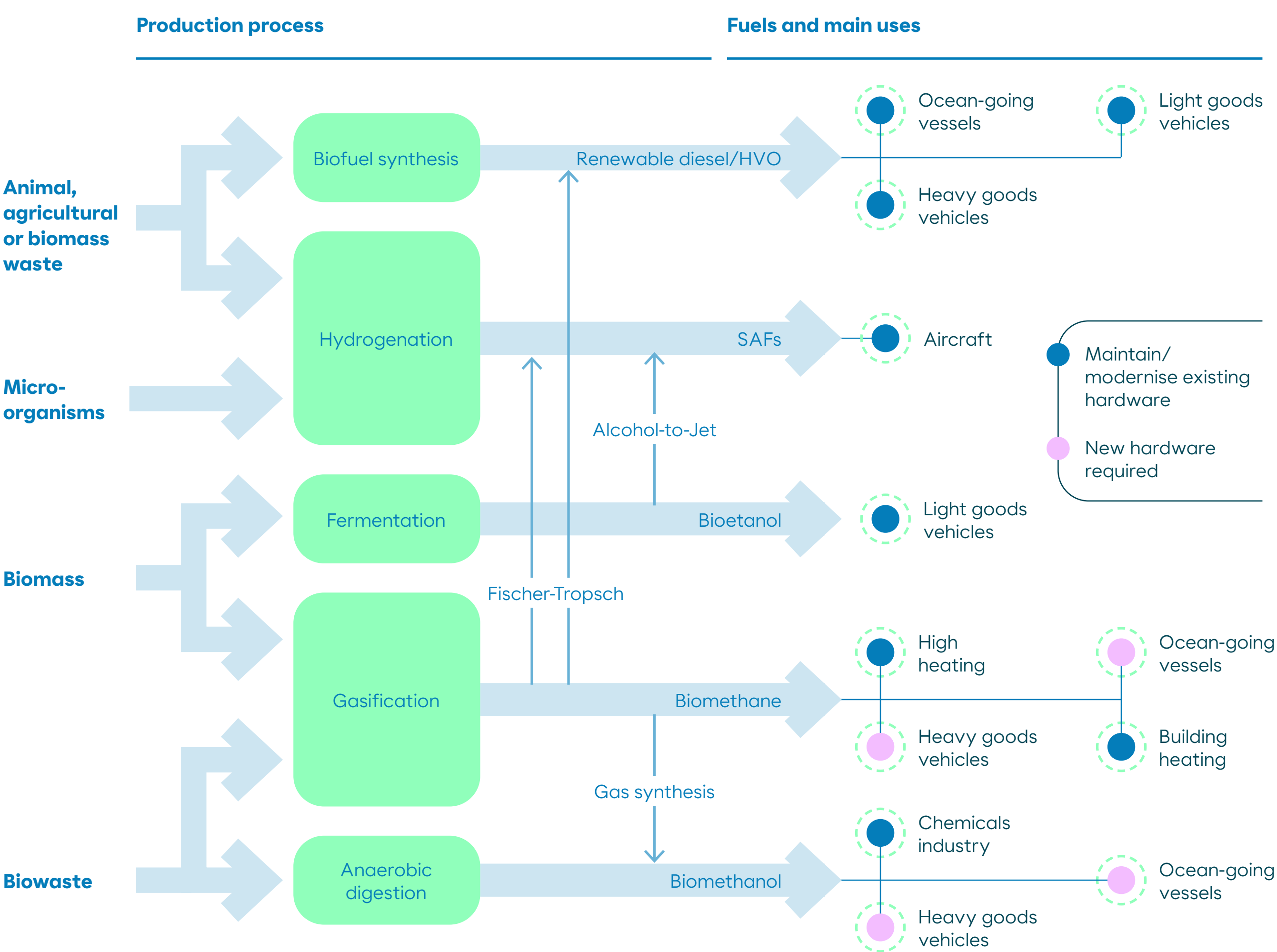
Green molecules are liquid or gaseous chemical compounds that are key to achieving decarbonisation targets and can contribute to a green transition through low-carbon solutions. Green molecules can be broadly categorised into two main groups: **biomass-based** and **hydrogen-based**, depending on the nature of the production process.

Biomass-based molecules such as biomethane, biomethanol, renewable diesel and SAFs are green fuels obtained from organic waste, biomass, agricultural waste and livestock waste. These organic compounds undergo advanced processes (anaerobic digestion, hydrogenation, etc.) to produce sustainable fuels and offer clean alternatives for heating, transport and industrial applications.

Biomass-based fuels can in turn be categorised into two main groups. Firstly, there are first-generation biofuels obtained from agricultural crops such as maize, sugar cane or vegetable oils. These types of biofuels are currently the most widely used worldwide. However, the EU is placing restrictions on their use due to concerns about potential adverse effects of uncontrolled practices on competitiveness in the food industry and on biodiversity.

Then there are second-generation biofuels derived either from organic waste not associated with the food industry or from microorganisms. These biofuels are obtained from a number of organic compounds such as municipal solid waste, manure, biomass or used cooking oils, among others. The use of waste to produce these second-generation fuels promotes a circular economy and reduces the volume of waste sent to landfills.

Chart 9 Overview of the various biofuel production technologies

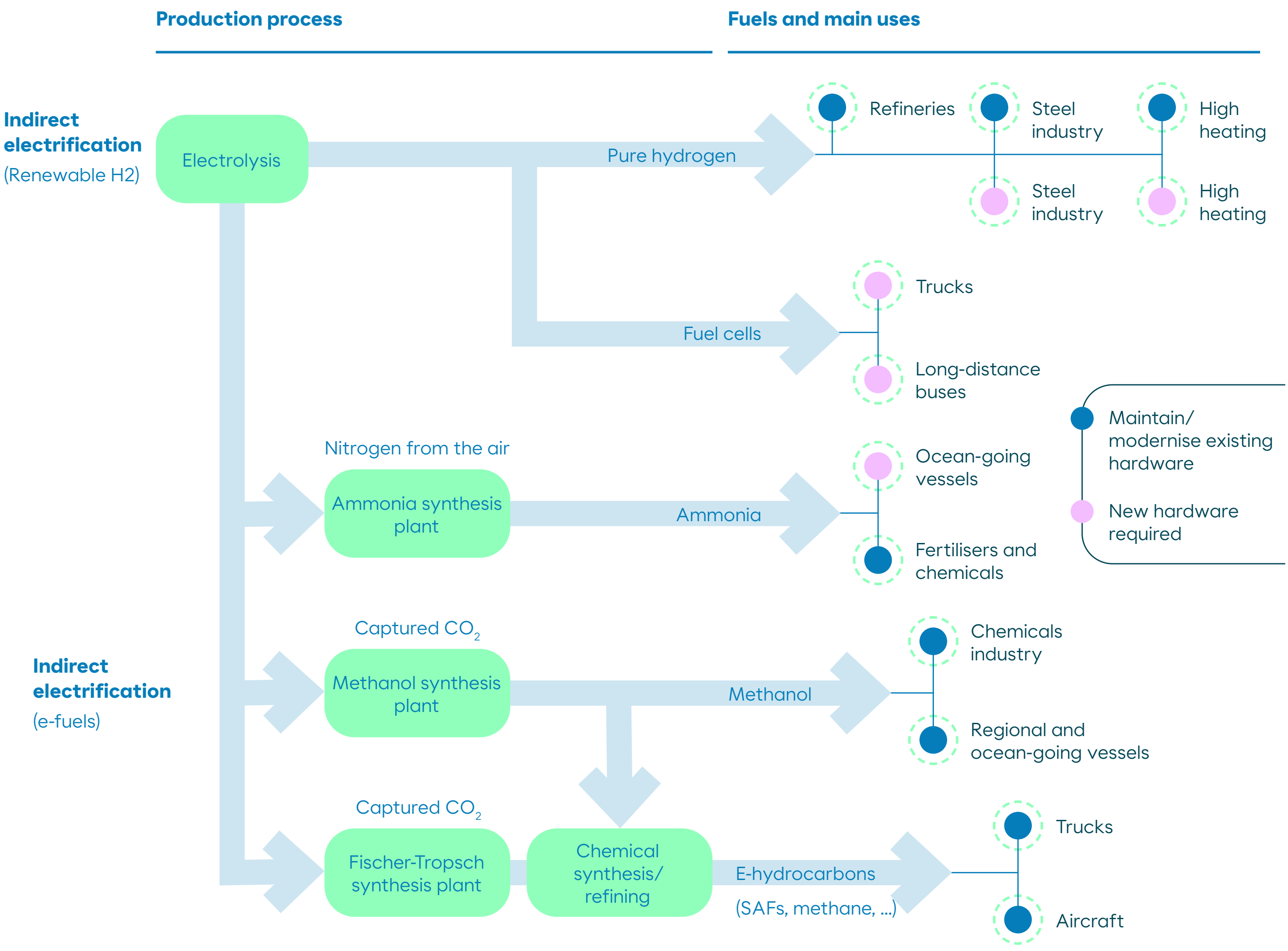


Sources: Moeve analysis.

Hydrogen-based green molecules (also called synthetic fuels, hydrogen derivatives or e-fuels), which include pure green hydrogen[25], green methanol, green ammonia or Power-to-Liquid (PtL) fuels such as e-kerosene, are synthetic compounds made from green hydrogen together with CO_2 or N_2. These compounds undergo advanced processes such as FT (Fischer-Tropsch), methanol synthesis, ammonia synthesis, etc. to produce synthetic green fuels. Thanks to renewable energy sources and carbon capture technologies, these molecules offer efficient solutions for achieving decarbonisation using natural resources.

When evaluating both categories, biomass-based green molecules show greater maturity compared to hydrogen-based alternatives. But hydrogen derivatives show huge potential for future development and growth that will unlock the full potential of decarbonisation using green molecules. Advances in green hydrogen production and cost reduction efforts will be key to establishing these technologies as competitive alternatives to fossil fuels.

Chart 10 Overview of the various technologies for producing green H2 and its derivatives



Sources: Orsted; IRENA; Moeve analysis.

[25] Green hydrogen can be generated through electrolysis using renewable power, such as solar photovoltaic or wind energy, and by means of biomethane and the Steam Methane Reforming (SMR) process. This report will focus specifically on the electrolytic hydrogen route.

02

Unlocking the power of green molecules

2.1.

A pathway to replace 30-50% of fossil fuel demand and decarbonise 20-25% of the European Union's emissions by 2050

The transition towards green molecules in the decarbonisation effort involves replacing the currently dominant fossil fuels, which constitute approximately 68%[26] of the existing energy mix. In the short term, biofuels are anticipated to lead this transition, accelerating the green transition towards intermediate decarbonisation targets. An example is Moeve's project in Huelva, which is expected to come into operation in early 2027.

The project will scale up to have the capacity to produce 500,000 tonnes per year of synthetic fuels, mainly HVO for road and maritime transport, as well as SAF for aviation. Projects like this not only consolidate the role of biofuels today but also facilitate the transition towards other renewable alternatives in the future. The plant will have a flexible production capacity of 500,000 tonnes of SAF and renewable diesel, creating the largest 2G biofuels industrial complex in southern Europe. Projects like this not only consolidate the role of biofuels today but also facilitate the transition toward other renewable alternatives in the future.

In the medium and long term, e-fuels are expected to contribute alongside 2G biofuels, helping to increase the demand for green molecules and achieving long-term energy transition goals. These alternatives are projected to help displace around 30–50% of fossil fuel demand by 2050, representing approximately 20–35%[27] of the European Union's final energy mix. A report by Engie titled "Achieving Europe's Energy Transition" indicates that the potential by 2050 could be 32%[28].

Biofuels are an immediate carbon abatement solution for the European Union, while e-fuels will tackle decarbonisation in the long term.

On assessing the European Union's GHG emissions, the region emerges as one of the main contributors, accounting for approximately 10% of the global total. In 2019, before the impact of COVID-19 and the lockdowns, the European Union's emissions totalled around 3.8 billion tonnes of CO_2[29], according to the European Environment Agency. While this is significantly lower than earlier years (13% down on 2010 and 17% and 23% down compared to 2000 and 1990, respectively), it still falls short of the 55% reduction targeted to meet the emissions reduction objectives set for 2030 and the net-zero targets for 2050.

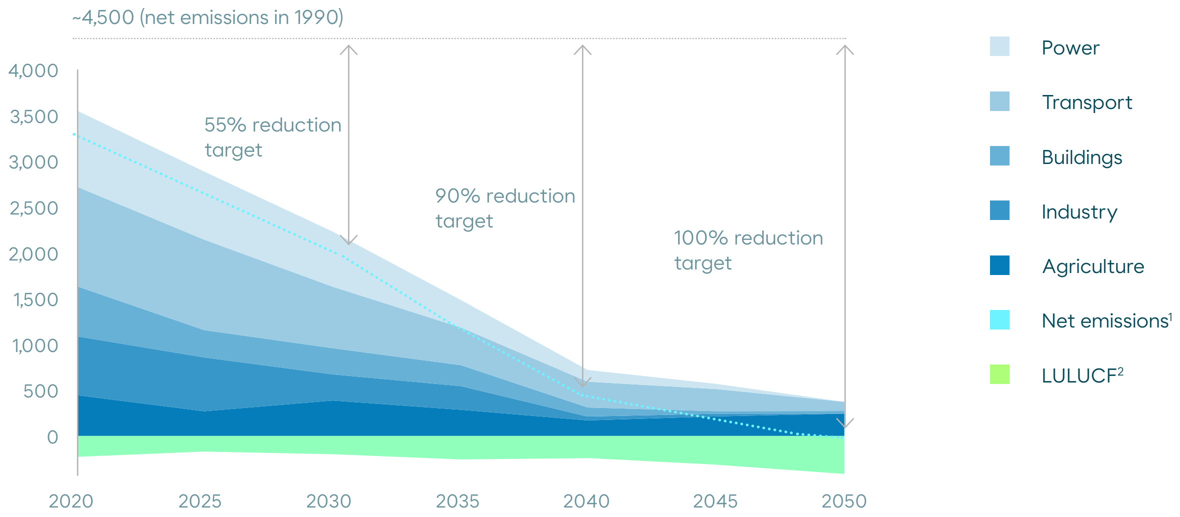
[26] "Energy Balance", (2024), Eurostat

[27] "The role of hydrogen in energy decarbonization scenarios", (2022), European Commission JRC

[28] "Achieving Europe's Energy Transition", Engie

[29] "Greenhouse gas emissions", Our World in Data

Chart 11 Expected EU CO_2 emissions by segment and share of reduction (Mt)



Main decarbonisation drivers

- Demand-side measures and circularity
- Biomass as fuel or feedstock
- Electrification and carbon-neutral power
- Land use or agricultural practice changes
- Energy efficiency
- Carbon capture and storage or use
- Carbon-neutral H2 as fuel or feedstock
- Other innovations

Notas: 1) Includes absorption technologies; 2) Refers to land use, land-use change, and forestry, which encompasses all the ways in which atmospheric CO_2 can be captured or released as carbon in vegetation and soils of terrestrial ecosystems.

Source: Moeve análisis based on McKinsey

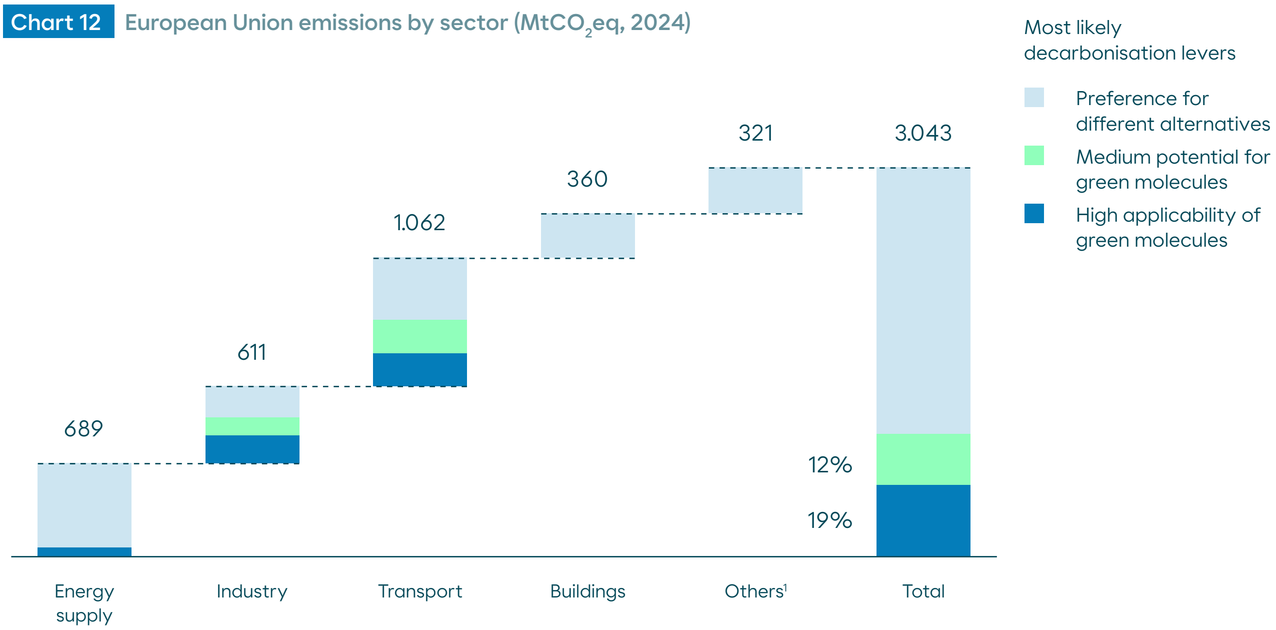
Green molecules are forecast to play a pivotal role in hard-to-decarbonise sectors where electrification may not be a feasible solution. These industries account for approximately 31%[30] of current GHG emissions in Europe and 20-25%[31] of European primary energy demand and are key domains where the presence and embracing of green molecules will be particularly relevant.

Similarly, green molecules such as ammonia could also play a significant role in storage and power generation, helping to balance the power system and serving as a carrier to facilitate international trade in renewable energy.

[30] European Environment Agency, (2024)

[31] "Energy Balance", (2024), Eurostat

Chart 12 European Union emissions by sector ($MtCO_2eq$, 2024)



Sectors with high-medium applicability of green molecules

- Oil refining
- Chemicals
- Iron and steel
- Non-metallic minerals
- Maritime shipping
- Aviation
- Heavy-duty trucks

Notes: (1) Agriculture and other minor sectors

Sources: European Environment Agency

Emissions from hard-to-abate industries have a more pronounced influence within the European Union compared to global emissions. This can be explained mainly by the European Union's accelerated decarbonisation efforts, particularly in the energy supply sector, where significant progress has been made in solar and wind energy in recent decades, reducing GHG emissions from power and heat generation by 42% by 2020 compared to 1990, according to Our World in Data[32]. This contrasts with a greater global dependence on fossil fuels, including coal, oil and natural gas, with GHG emissions from electricity and heat generation growing 76% over the same period. Consequently, the European Union has to speed up the advancement of green molecules to attain the abatement targets and facilitate the transition to a carbon-neutral economy.

[32] "Breakdown of carbon dioxide, methane, and nitrous oxide emissions by sector", Our World in Data

But green molecules alone will not suffice to achieve emissions reduction objectives. Further substantial transformations will be necessary in all economic sectors by means of five main levers:

- **Demand reduction:** measures to bring down overall energy and resource consumption, coupled with circularity actions to boost waste reduction through recycling and product reuse.
- **Energy efficiency:** improvements in this lever will be achieved in two main ways: firstly, through the technologies employed, such as power generation, heat pumps and electric and fuel cell vehicles; and secondly, through improvements in infrastructure, including heat recovery in industrial applications and insulation in residential buildings.
- **Shift towards low-carbon alternatives for fuel and raw materials:** the transition from fossil fuels to low-carbon alternatives is the key lever for triggering and attaining a considerable reduction in emissions, as established at COP28. This fuel change will be led by renewable power sources (solar photovoltaic, onshore and offshore wind, etc.) and green molecules (ammonia, methanol, biogas, etc.).
- **Carbon capture, usage and storage (CCUS):** CCUS technology captures CO_2 emissions from intensive industrial facilities or directly from the air to store them underground in geological formations or use them to make synthetic fuels. This lever is key to reducing GHG emissions in industries in which switching to low-carbon alternatives is more challenging, such as cement production.
- **Other measures:** sustainable land-use practices, such as reforestation, can play a pivotal role in CO_2 capture while preserving biodiversity. Adopting sustainable farming practices can also help cut emissions in one of the most challenging sectors.

Green molecules are emerging as the second most significant decarbonisation lever after electrification, with the potential to mitigate approximately 22% of emissions in Europe by 2050[33].

Chart 13 Potential contribution to emissions reduction by 2050 by reduction lever

Decarbonisation lever	Share of reduction by 2050	Description
Demand reduction and circular economy measures	7%	Seeks to **reduce** overall energy and resource consumption by **promoting circularity through recycling and product reuse.**
Technological efficiency	11%	Energy efficiency enhancement through **technological advances**, such as in power generation, or **through infrastructure improvements**, such as heat recovery for industrial uses.
Fuel change – Electrification	44%	Transitioning from fossil fuels to renewable power sources (such as **solar PV, onshore and offshore wind, etc.**) for various applications, such as **electricity generation and electric vehicles.**
Fuel change – Green molecules	22%	Switching from traditional fossil-based feedstock to **low-carbon alternatives, referred to as green molecules** (such as **ammonia, methanol, biogas,** etc.).
Carbon capture, usage and storage	6%	**Capturing CO_2 emissions and storing them underground or using them to make synthetic fuels,** particularly in industries where fuel switching is challenging.
Others	10%	**Sustainable land use practices,** including reforestation and the adoption of sustainable farming practices, can also help to trim emissions and preserve biodiversity.

Sources: Moeve analysis based on McKinsey

[33] Moeve analysis based on McKinsey "Net-Zero Europe"

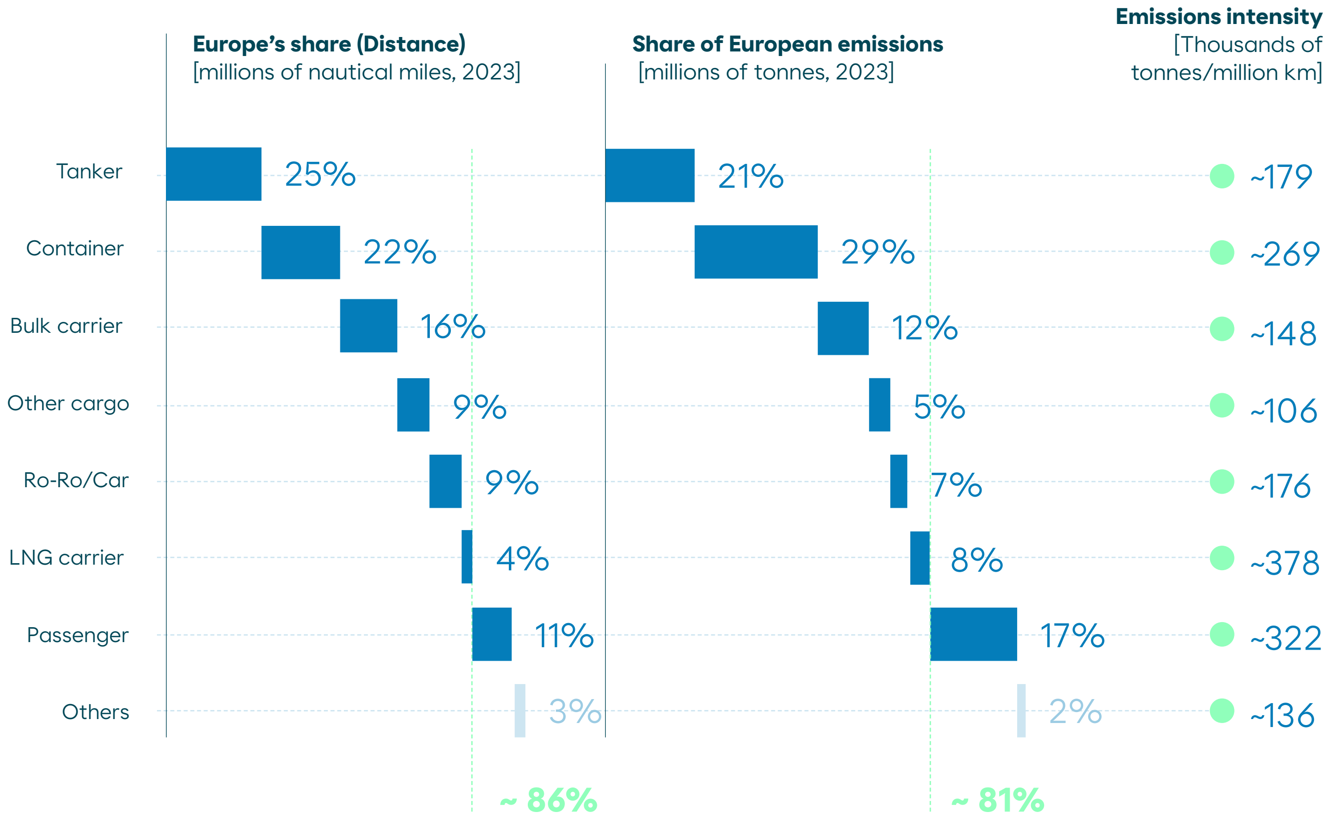
2.2.

Sailing towards sustainable seas with green maritime transport

Maritime transport is pivotal to global trade volume, contributing 80% of the total, according to the United Nations Conference on Trade and Development, and serving as the backbone of international supply chains. This industry spans a wide range of segments designed to meet specific transport requirements, taking account of factors such as vessel size, cargo type (containers, bulk cargo, etc.), transport distance (short, medium or long distance) and the nature of the route (regular or tramp services). The main types of vessels include bulk carriers, oil tankers, container ships, LNG carriers and passenger ships, among others.

The majority of vessels within the sector are large ships designed for the transport of goods and different types of cargo over medium to long distances. These vessels collectively account for approximately 86% of the distances travelled (nautical miles) and contribute around 81% of the sector's global emissions, as shown in the figure below.

Chart 14 Main technologies in the maritime shipping sector



Sources: European Commission's 2024 report on maritime transport

Around 98% of the existing global fleet relies on traditional fuels such as fuel oil or marine diesel, while the remaining 2% consists of vessels that use dual fuels, allowing them to make use of hydrocarbons or alternative fuels such as LNG (liquefied natural gas), LPG (liquefied petroleum gas), batteries, methanol and others. These alternative fuels are becoming more common in newly commissioned ships. According to DNV (Det Norske Veritas)[34] and AFI, from 2023 to 2024 there was a 38% year-on-year increase in orders for vessels powered by alternative fuels. In 2024, 264 ships were powered by LNG, a fuel that can reduce CO_2 emissions by 20-30% compared to conventional fuels, according to IRENA[35].

Given its extensive role in global trade and predominant use of fossil fuel-powered technology, the maritime industry contributes 5%[36] of Europe's total emissions and is hard to abate, with inherent decarbonisation challenges. The long service life of vessels, spanning 25-30 years, entails lengthy investment payback periods, delaying the adoption of new environmentally friendly technologies. The industry also has a complex commercial structure involving numerous stakeholders, including ship owners, technical managers, vessel operators, cargo owners, ports and terminal operations.

The maritime shipping sector has undergone a global transformation in recent years to tackle environmental pollution and reduce emissions that undermine air quality, such as sulphur dioxide, nitrogen oxide and carbon dioxide. This transformation initially sought to reduce sulphur emissions, a major pollutant from ships. The International Maritime Organisation (IMO) approved a regulation that came into force in 2020 requiring ships to use fuels with a maximum sulphur content of 0.5% and 0.1% in emission control areas, as compared to the 3.5% previously permitted. In line with these IMO regulations, the use of fuels with lower sulphur content, mainly Low Sulphur Fuel Oil (LSFO) and Marine Gas Oil (MGO), has been promoted in recent years. In parallel, new alternative and more environmentally friendly fuels such as LNG, methanol, etc. are being explored, as well as the use of scrubbers, which are atmospheric emission purification systems.

Despite the efforts of recent years in the decarbonisation of the maritime sector, even more significant changes are expected with the approval of the emissions reduction targets established by the IMO in April 2025. The emissions reduction targets are 8%–21% by 2030 and 30%–43% by 2035, compared to 2008 levels. The regulation includes economic penalties for operators that fail to meet these targets and rewards for those that exceed them, in addition to incentivising the use of ZNZ (Zero or Near Zero) fuels through the IMO Net Zero fund. While the legally binding adoption of these measures was planned for October 2025, the final adoption decision has been postponed to 2026.

Before the IMO's emissions reduction targets were approved, the European Union approved FuelEU Maritime in July 2023, setting ambitious targets for decarbonising the industry. But those targets fall short of the new objectives set by the IMO. FuelEU Maritime established an emissions reduction target of 2% by 2025 and 6% by 2030 compared to 2020 levels, and targets of 31% and 80% by 2040 and 2050, respectively. As part of these goals, a lower sub-target has been set for Non-Biological Renewable Fuels (NBRF), aiming for a 2% share by 2034 if the share in 2031 is less than 1%.

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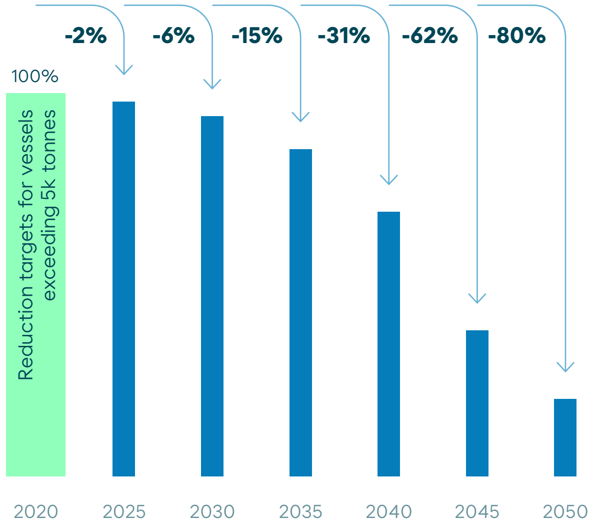
[34] "Maritime Forecast to 2050", DNV

[35] "A pathway to decarbonize the shipping sector by 2050", IRENA

[36] European Environment Agency, (2024)

Chart 15 ReFuelEU Marítimo

EU maritime industry regulation [%]



Key factors in emissions regulation

1. **The EU's emissions reduction targets apply to vessels with a gross tonnage of over 5,000** (c.55% of all ships, c.90% of maritime sector emissions) calling at European ports[1]
2. **Sub-target of a 2% share for RFNBO by 2034**
3. **Mandatory access to electricity in EU ports as from 2035** for ship power needs
4. **Multiplier in which RFNBO energy counts double until 2034**
5. **First-generation biofuels will not be eligible** for emissions reduction obligations

Notes: (1) Excluding fishing vessels
Sources: European Commission; Moeve analysis

Concerns have been voiced that European targets are insufficient to attain carbon neutrality by 2050. It is suggested that these targets should be more closely aligned with the new standards approved by the International Maritime Organisation (IMO). Also, by focusing on an emissions reduction target rather than setting specific goals for the use of green fuels, there is a risk that the use of transition fuels, such as liquefied natural gas (LNG), will be favoured rather than fully fostering the adoption of green molecules.

In a significant step taken in April 2023 to reduce CO_2 emissions, the European Union included the maritime industry in the European Union Emissions Trading System (ETS). Since 1 January 2024, the maritime shipping sector has been forced to bear the cost of CO_2 emissions, helping to undermine the competitiveness of fossil fuels compared to renewable alternatives.

> The implementation of stricter emissions regulations in the maritime industry, an essential component of global trade, could face significant challenges and impact the flow of international commercial traffic.

To achieve emissions reductions in the maritime shipping sector, three main levers must be addressed, according to public sources such as IRENA: reducing demand, enhancing technological efficiency and transitioning to green molecules. This switch could lead to a 60-70% reduction in emissions from the sector.

Technological assessment

As mentioned previously, the maritime shipping industry encompasses various types of vessels depending on transport needs. In turn, these vessels have a wide range of abatement alternatives, based on the type of fuel used. In 2023, Mærsk already launched the first ship powered by green methanol, while Japan plans to commission ships powered by green ammonia in 2026.

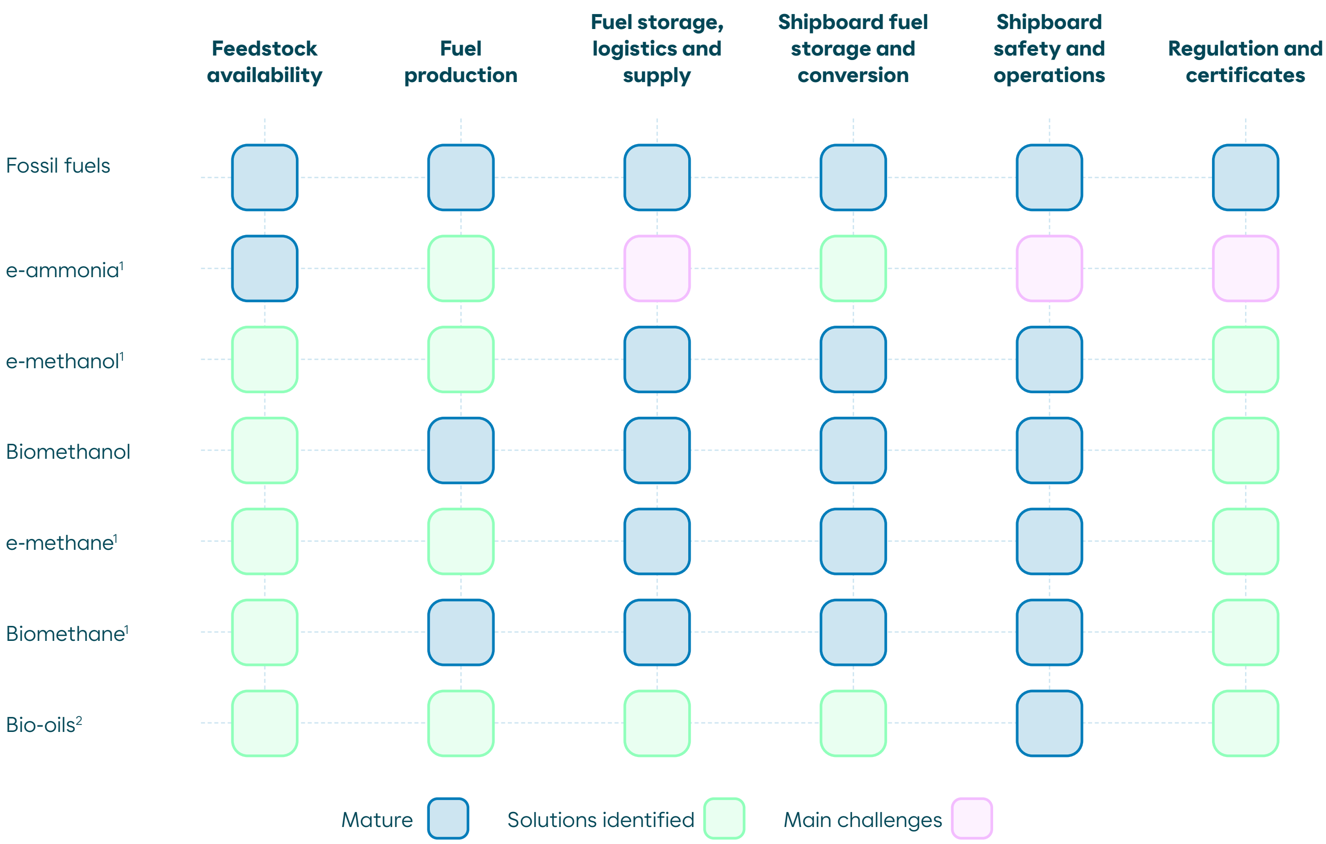
When examining decarbonisation options for large cargo vessels, which contribute around 80% of global maritime emissions, green molecules emerge as the leading alternatives. Biofuels are already playing an active role in the maritime industry's decarbonisation process and are poised to lead the sustainable transition in the short term. Fuels such as biomethanol, biomethane and biodiesel show potential. Meanwhile, e-fuels such as e-ammonia and e-methanol are expected to expand in the medium-to-long term in pursuit of decarbonisation.

Thanks to their high energy density and power requirements, green molecules appear to be the only viable alternatives for decarbonising large vessels (except for pure hydrogen as a fuel). Direct electrification through battery-powered electric ships or indirect electrification using pure hydrogen and fuel cells may only be feasible for ferries, cruise ships on short routes (50-100 km) or smaller vessels such as recreational boats and tugs, accounting for a small portion of the reduction in maritime CO_2 emissions.

Green molecules are expected to lead decarbonisation in the maritime shipping industry, as they are the only viable technology for large vessels, accounting for around 80% of total maritime transport emissions.

The green molecule alternatives available for maritime shipping decarbonisation form a complex landscape characterised by varying levels of maturity and challenges, as illustrated in the following chart based on the Mærsk Mc-Kinney Møller Center for Zero-Carbon Shipping's assessment of marine fuels.

Chart 16 Maturity and challenges of fuel routes



E-ammonia and methanol are positioned as the most favourable technologies, but each route has specific challenges in terms of cost, scalability and technological security.

1) These fuel production technologies are mature, but scaling production is constrained by limited electrolyzer manufacturing capacity and access to biogenic CO_2
2) Bio-oils produced by hydrothermal liquefaction (HTL) and fast pyrolysis (FP)
Sources: MMM Center for Zero-Carbon Shipping

Despite the regulatory challenges, ammonia is emerging as a promising candidate for decarbonisation. Its hazardous properties have been effectively managed for over a century, and the first ammonia-powered vessels are expected to enter service throughout 2026[37]. This development represents a significant milestone in harnessing renewable ammonia, highlighting its potential as a viable green energy option. Ammonia is already a widely traded commodity, transported by the same tankers that carry LPG and other similar liquid chemicals. Currently, the first two-stroke engine powered by ammonia for use as fuel has already been developed. This achievement requires overcoming the safety challenges associated with ammonia, in particular its toxicity at low concentrations and its corrosive nature. The pungent smell of ammonia, even in minimal quantities, can cause significant olfactory discomfort. Furthermore, its combustion must be carefully controlled to minimise nitrous oxide (N_2O) emissions, a greenhouse gas with a global warming potential 273 times greater than that of CO_2. The low energy density of ammonia, approximately one third that of conventional fuel oils, further limits the cargo-carrying space on board ships.

[37] "The world's first complete commercial ammonia fueled engine has been accomplished", (2025) J-ENG

The world's first ammonia supply was completed in Singapore in March 2024, and several studies have provided initial data on the associated risks and possible safety measures. But further work is needed to fully enable ammonia as a solution during the industry's transition. This includes more risk assessments, operational safety protocols, port guidelines and real-world trials and pilots.

Methanol, as the preferred and most technologically advanced alternative, has favourable chemical properties and requires minimal supply infrastructure modifications. Handled as a liquid at atmospheric pressure and stored in conventional tanks like traditional diesel, methanol is a promising solution. However, challenges related to the availability of resources, such as biogenic CO_2 and biomass, pose potential long-term scalability and adoption issues. Methanol is also a toxic chemical and is more flammable than ammonia, burning with an almost invisible flame, so strict safety protocols are needed. Nonetheless, since the first methanol-powered ship was launched more than a decade ago, supply experience has accumulated and now a multitude of ports worldwide offer this service.

Regulatory frameworks have been developed to promote the supply of methanol, including the IMO's IGC Code and several port-specific guidelines and operational checklists. The reuse of existing infrastructure emerges as a key consideration for the development of these fuel technologies going forward. For example, biomethane could leverage existing LNG infrastructure, while diesel infrastructure could be reused for ethanol. Studies by the International Energy Agency (IEA) suggest that LNG infrastructure can be converted to ammonia without excessive costs or significant modifications. This highlights the adaptability and potential profitability of reusing existing infrastructure to accommodate the evolving green molecule landscape in maritime decarbonisation efforts.

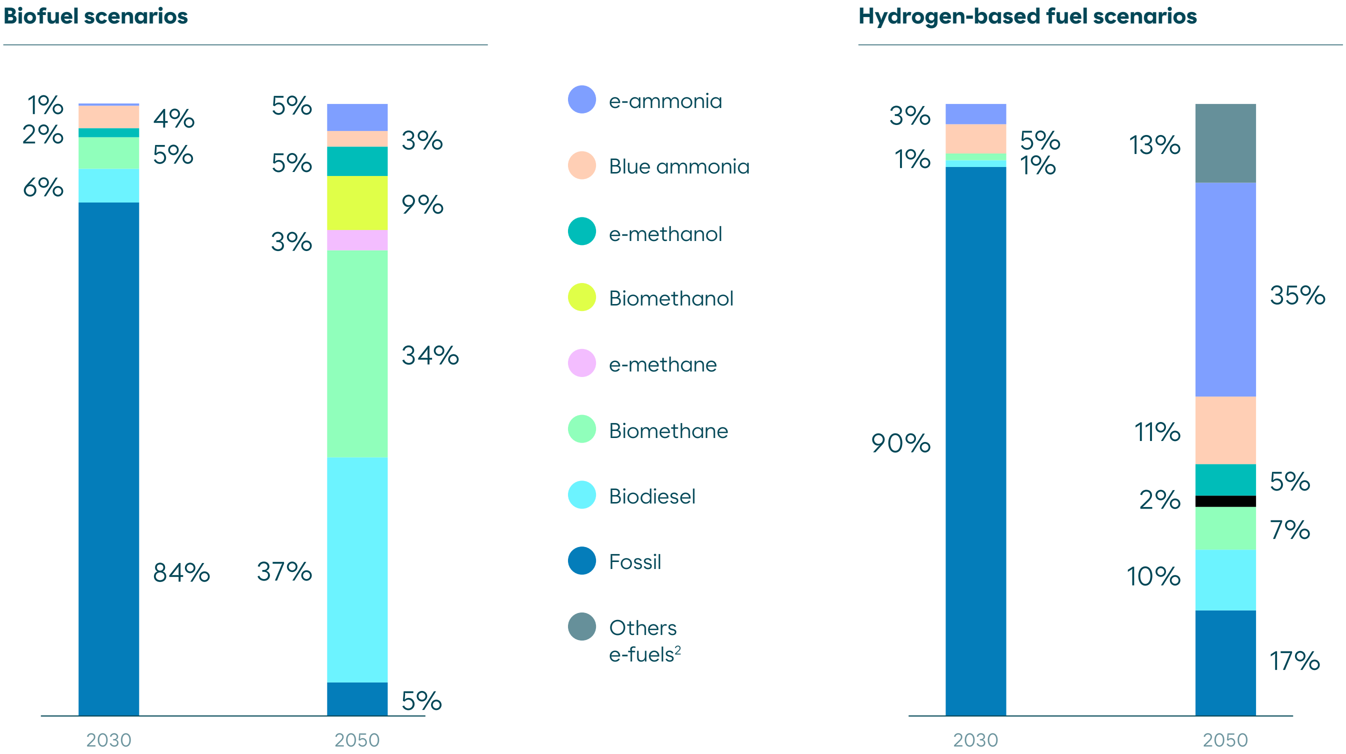
Future demand

The future scenario for green molecules in the maritime shipping sector will be significantly influenced by several key factors, fanning a certain degree of uncertainty. The drivers of future demand, shaped primarily by fuel price competitiveness, regulatory frameworks and resource availability, aggravate the complexities due to ongoing developments in the necessary technologies. The future availability of essential resources, such as biomass or biogenic CO_2, could also sway future fuel adoption scenarios.

In a comprehensive study analysing future fuel projections from key market players such as DNV, IRENA, IEA and the Mærsk Mc-Kinney Møller Center for Zero-Carbon Shipping, among others, Lloyd's[38] highlights two predominant trends: hydrogen-based scenarios and biofuel scenarios. Although hydrogen-based scenarios are more prevalent, the study suggests that the future fuel mix will probably not be dominated by a single fuel source. Most scenarios project that no single fuel will have a share of over 50% by 2050, which points to a diversified, balanced approach between biofuels and hydrogen-based fuels in the maritime shipping industry.

[38] Lloyd's Register Maritime Decarbonization Hub. (2023). The future of maritime fuels.

Chart 17 Breakdown of Lloyd's fuel mix based on average values taken from the scenarios analysed[1]



Notes: (1) 9 biofuel scenarios and 14 e-fuel scenarios from DNV, IRENA, IEA, Mærsk Mc-Kinney Møller Center for Zero-Emission Shipping, Clarksons Research, Ricardo Energy & Environment, ABS, UMAS & E4tech; (2) Hydrogen and e-MGO
Sources: Lloyds Register; Moeve analysis

> The marine fuel mix of the future will be diverse, led by green molecules such as biofuels and hydrogen derivatives. No single alternative is expected to dominate, with no fuel exceeding a 50% share by 2050.

Although market alignment points to the limited adoption of methanol in the maritime shipping sector, recent order trends for new vessels suggest heightening interest and investment in this alternative fuel. This apparent disparity underlines the complex challenges associated with accurately forecasting the industry's path, as inputs such as evolving technology costs and regulatory landscapes introduce dynamic elements that can impact market preferences and decisions.

The lower forecasts for methanol adoption are significantly shaped by perceived economic barriers related to CO_2 capture. As the maritime shipping industry contends with the economic feasibility of adopting green molecules, particularly those involving carbon capture technologies, it is clear that the industry's future choices will be intrinsically linked to evolving cost dynamics and technological advances in sustainable fuels for maritime transport. Market scenarios point to green ammonia becoming the most popular marine fuel in the long term, driven by the broad availability of N_2 , fuel competitiveness and TCO (total cost of ownership).

So the maritime shipping industry is navigating uncertain waters as regards the future adoption of decarbonisation technologies, as there are several alternatives available. But it is clear that a mix of solutions will be needed, each contributing to the industry's goal of carbon neutrality by 2050. Although some fuels and solutions may need more time to scale up, a common thread in all scenarios is the indispensable role of green molecules, both biofuels and synthetic solutions, emerging as the most promising and practically feasible solution for abatement in the maritime shipping sector.

2.3.

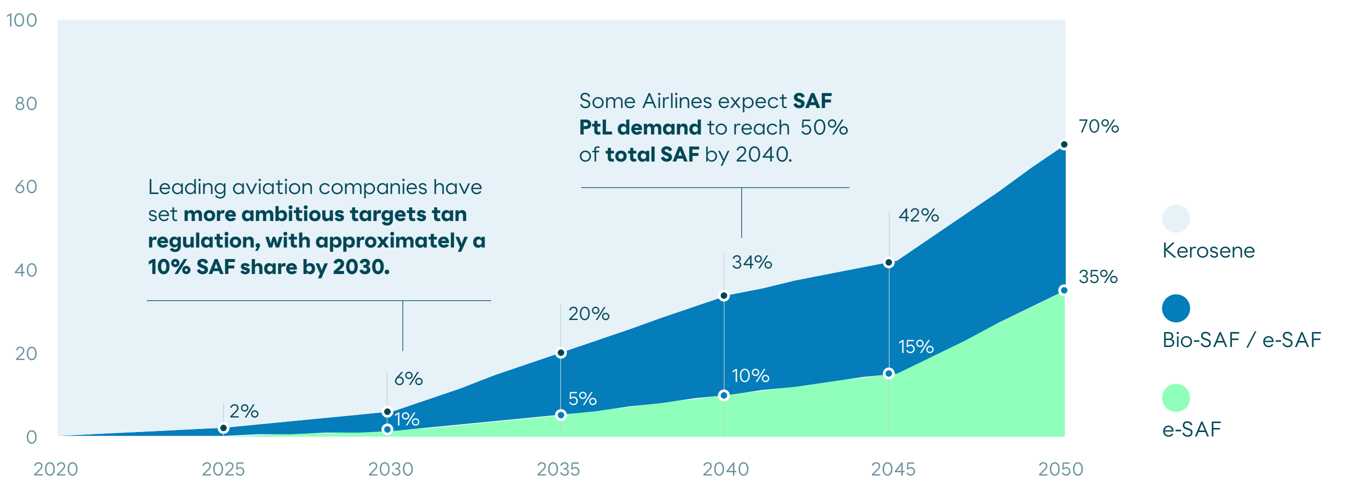
SAF solutions for greener aviation

The aviation industry is a highly significant sector that plays a fundamental role in the advancement of modern society by facilitating tourism, global business and trade. According to the European Commission, its significant contribution to european economic growth is underscored by the fact that more than 1 billion passengers fly to, from and within the European Union each year, constituting one third of the global market[39]. The European aviation sector, recognised as one of the best-performing segments of the European economy, holds a leading position on the global stage.

However, the substantial impact of aviation on emissions cannot be overlooked. Accounting for approximately 16% of CO_2 emissions from the transport sector and 5% of total European Union[40] emissions, aviation faces the challenge of being a hard-to-abate sector.

European regulatory policies have set ambitious decarbonisation targets for the sector through the ReFuelEU Aviation initiative, adopted in October 2023. The adoption of SAF is a key component of these targets, with goals to increase the share of SAF to 6% by 2030, 34% by 2040 and an ambitious 70% by 2050. Specific targets have also been set for e-SAF, aiming to reach 35% by 2050, highlighting the industry's commitment to adopting innovative solutions to reduce its carbon footprint. Furthermore, since 2024, the allocation of free CO_2 emission allowances under the ETS is gradually decreasing until 2026, with the aim of providing incentives for the progressive phase-out of fossil fuels.

Chart 18 Evolution of ReFuelEU Aviation's SAF regulatory objectives



ReFuelEU Aviation target

	2025	2030	2035	2040	2045	2050
SAF	2%	6%	20%	34%	42%	70%
o/w e-SAF	-%	1,2%	5%	10%	15%	35%

Sources: IEA; ReFuelEU Aviation; Moeve analysis

[39] "Number of air passengers up 8% in 2024", Eurostat

[40] European Environment Agency, (2024)

The International Civil Aviation Organisation (ICAO)'s objectives are aligned with those of the European Union, sketching a path to increasingly implement SAFs. The ICAO forecasts a share of 5.2% by 2030, 39% by 2040 and an ambitious 65% by 2050[41]. These targets aligning the industry with regulatory bodies reflect a shared commitment to make the aviation sector more sustainable and environmentally aware, tackling the challenges of emissions growth in the context of its global economic significance.

Several European countries have set national SAF targets exceeding those laid down in European regulations. For example, the United Kingdom is aiming for 10% SAF adoption by 2030, while the Nordic countries (Norway, Sweden and Finland) have their sights on 30%. The Netherlands has set a target of 14% SAF adoption by 2030. Outside Europe, countries such as Singapore and Canada have targeted a SAP share of 5% and 10%, respectively, by 2030. But the ReFuelEU Aviation regulatory targets will not suffice to attain climate neutrality in the industry. According to the Air Transport Action Group (ATAG)'s Waypoint 2050 report[42], achieving emissions reduction and climate neutrality in the aviation sector entails activating four different levers. These four lines of action encompass a holistic approach to addressing the multidisciplinary challenges of decarbonizing the aviation sector:

- **Advances in technology and efficiency:** this lever has the potential to cut aviation emissions by up to 22%. Innovations in propulsion systems, materials and aerodynamics help reduce fuel consumption and emissions. Key aspects of this strategy include developing and espousing new technologies, such as electric and hydrogen-powered aircraft for short-haul flights.

- **Operational improvements:** improving the operational efficiency of airlines, optimising flight routes and upgrading logistics and airport and air traffic management systems all contribute to lessening the environmental impact of air transport. This lever highlights the need for more sustainable practices across the aviation ecosystem and could bring down the industry's emissions by up to 10%.

- **Adoption of SAFs:** this lever points out the need for substantial investment in the production, distribution and adoption of SAFs, spanning both biomass-based and hydrogen-based alternatives. At present, there is no EU roadmap on how to scale up its production, while the US has given support for SAFs by means of the Inflation Reduction Act. Facilitating research and development into alternative fuel sources, supporting the expansion of SAF production facilities and implementing policies that encourage it's use are key components of this strategy. This is a key enabler for achieving substantial emissions reductions. Estimates indicate a potential reduction of over 60% in aviation industry emissions, particularly on medium- and long-haul flights, which account for more than 90% of emissions according to EuroControl[43].

- **Other market and regulatory measures:** activating this lever involves implementing market measures and regulations to incentivise and enforce sustainable practices in the aviation industry. This includes setting emissions reduction targets, rolling out carbon pricing mechanisms and updating regulations to ensure environmental standards are met. Market-based approaches, such as emissions trading, can be effective tools to push the industry towards climate-neutral operations.

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41 "Third Conference on aviation and alternative fuels (CAAF/3)", International Civil Aviation Organization

42 "Waypoint 2050", Aviation Benefits Beyond Borders

43 "Eurocontrol data snapshot CO_2 by distance", Eurocontrol

So the aviation sector recognises SAFs to be the main feasible alternative for decarbonising medium- and long-haul flights, which account for 80-90% of emissions. These fuels offer practical solutions for immediate emissions abatement.

The aviation industry acknowledges that Sustainable Aviation Fuels (SAFs) are the only viable solution for decarbonising medium- and long-haul flights, which account for 80-90% of emissions.

For short-haul flights, which contribute less than 10% of the industry's emissions, the spotlight is on exploring potential long-term alternatives. Hybrid or hydrogen-electric aircraft could play a role in decarbonising short-haul flights, while other transport options such as railways are seen as competitors in providing sustainable travel over shorter distances.

A notable advantage of SAFs is their compatibility with existing infrastructure. This means that embracing SAFs does not require significant technical changes to aircraft, engine fuel systems, distribution or storage facilities. This is an advantage and facilitates a smoother integration of sustainable practices into the aviation industry without the need for a full infrastructure overhaul.

Chart 19 Overview and maturity of aviation decarbonisation technologies for 2050

	Technology features
Sustainable aviation fuels	• SAFs are already in use and can operate in the same aircraft as conventional aircraft fuel. • There are 4 SAF production technologies: HEFA, FT, AtJ and PtL. • Fuel costs are high but are expected to fall sharply in the medium-to-long term.
Hydrogen	• Hydrogen aircraft use hydrogen by means of FCEV technology or direct combustion. • The fleet is likely to be renewed, so companies such as Rolls-Royce are testing modifications to existing engines so they can run on H2.
Fully-electric	• Fully-electric aircraft use battery-powered electric propulsion systems. • Fuel costs compared to jet fuel are low, but a new fleet of smaller aircraft would have to be developed.

Sources: Moeve analysis

Technological assessment

The aviation industry faces significant challenges in integrating new technologies, driven mainly by two key factors. Firstly, the extended service life of current aircraft, which averages around 25 years and is a considerable obstacle. Secondly, the complex process of developing technologies that meet rigorous requirements and safety tests for commercial passenger flights further complicates these challenges.

When exploring alternative emissions abatement technologies for the sector, three possibilities emerge. SAFs are the main alternative in the short and medium term. Meanwhile, electric or hydrogen solutions are seen as promising alternatives for specific types of long-haul flights. But the entry barriers for electric and hydrogen technologies are substantial, given their current absence from the market and the need for completely new designs.

Electric and hydrogen solutions, though promising, show inherent limitations. These technologies are primarily designed for short-haul flights and may face challenges related to energy density limitations when applied to longer-haul flights. For short-haul flights, they have to compete with well-established alternative modes of electric transport, such as high-speed trains, which are a credible, proven alternative for decarbonising short-haul flights throughout the European Union.

Positioned as the only viable alternative for fossil fuel abatement in the sector, SAFs specifically target medium- and long-haul flights, which account for 80-90% of CO_2 emissions. As aviation operates almost entirely on fossil fuels, SAFs, and particularly bio-based SAFs, which are already available and show a high degree of technological maturity, are an immediate solution for advancing decarbonisation. Existing certifications allow SAFs to be blended with conventional fuel at up to 50%, facilitating the immediate kick-off of the abatement process. Anticipating stricter long-term decarbonisation targets, SAFs are poised for a smooth transition to full adoption as the exclusive aircraft fuel, reaching 100% usage in the medium-to-long term without significant technical issues.

Chart 20 Technologies available for the aviation industry

	Queroseno	Alternativas sostenibles: SAF	Alternativas sostenibles: H_2	Alternativas sostenibles: Aviones eléctricos
Technological development	Technology currently used	No need to adapt engines	Highly reactive Difficult to store Low maturity	Low range High weight Slow charging
Economic feasibility	Low cost	High short-to-medium term cost	High short-to-medium term cost	In testing phase. High cost of manufacturing and replacing batteries
Environmental impact	High CO_2 emissions	80-100% reduction in CO_2 emissions	Zero CO_2 emissions if green H2 is used	Zero CO_2 emissions if green H2 is used
Potential use	Available for short, medium and long haul	Available for short, medium and long haul	Available for short-to-medium haul	Available for short haul
Potential development	**Unfavourable**	**Favourable**	**Medium**	**Unfavourable**

Source: Moeve analysis

Two distinct SAF groups can be identified based on the origin of the resources required for production and synthesis. They are bio-based SAFs, made from organic compounds, and synthetic SAFs or PtLs, derived from green hydrogen and CO_2 captured from industrial sources or directly from the air. The characteristics of the various SAFs vary in terms of emissions reduction throughout the life cycle.

Bio-based SAFs are emerging as the primary alternative for decarbonising the aviation sector. A high degree of technological maturity, coupled with the wide availability of raw materials, makes them a strategically positioned option for swift scaling and increasing integration. Three different types of fuels can be distinguished in the bio-based SAF group:

- **HEFA (Hydroprocessed Esters and Fatty Acids) process:** this is currently the most advanced aircraft biofuel production route. It involves the processing of vegetable oils, waste and residual lipids. Hydrogen is used to remove oxygen and break down the compounds into suitable hydrocarbons, which are then isomerised to create SAF. The HEFA process is certified for a 50% blend ratio.

- **AtJ (Alcohol-to-Jet) process:** this is an alternative to FT technology, although it does not currently meet ReFuelEU standards. The AtJ process converting sugar-rich or lignocellulosic biomass feedstocks into alcohol. An isobutanol or ethanol dehydration process is then carried out, followed by oligomerisation, hydrogenation and fractionation. The AtJ process is certified for a 50% blend ratio.

- **FT process:** this route can be used for the production of bio-SAF by transforming biomass and municipal solid waste into biofuels using the FT (Fischer-Tropsch) synthesis technology. During this conversion process, Biomass is gasified to produce synthesis gas, which is then converted into paraffinic and olefinic hydrocarbons. These compounds are cracked and isomerised to produce SAF. FT SAF is certified to be blended with up to 50% conventional jet fuel. Additionally, while bio-SAF production from biomass and municipal solid waste remains challenging, the FT process can also be applied to more mature production routes, such as the production of e-SAF through Power-to-Liquid pathways.

Power-to-Liquid (PtL) technology allows green hydrogen, obtained through electrolysis, and CO_2 to be converted into aviation fuel and other hydrocarbons through processes such as Fischer-Tropsch synthesis or the methanol synthesis route. The methanol process is not yet certified for use in aircraft, while the PtL FT synthesis process is already certified for blending with Jet A1 in a 50% ratio.

	Bio-SAF			E-SAF / PtL
Technological routes	HEFA	AtJ	FT	FT / Methanol synthesis
Feedstock	Vegetable oils, waste lipids and waste	Agricultural and forestry waste, sugar-rich biomass and cover crops	Biomass (agriculture, municipal and forestry)	Renewable hydrogen and CO_2
Description	Raw material treated with hydrogen to remove oxygen, converting the compounds into suitable hydrocarbons and then isomerising them to create SAFs. This process is certified for blends of up to 50%.	The AtJ process involves converting sugar-rich or lignocellulosic biomass feedstock into alcohols, followed by an isobutanol or ethanol dehydration process. The AtJ process is certified for blends of up to 50%.	The FT route transforms biomass and municipal solid waste into biofuels. Biomass is gasified to produce synthesis gas and then converted, cracked and isomerised to produce SAFs. It is certified for blends of up to 50%.	It converts green H_2 from electrolysis and green CO_2 into jet fuel and other hydrocarbon products using either the FT route or the methanol synthesis route. FT synthesis is certified for a 50% blend ratio. The methanol process is not yet certified.
Greenhouse gas emissions reduction	74-84%	40-70%	85-95%	89-100%
Technology Readiness Level (TRL)	8-9	7-8	6-8	5-8

Sources: EASA; Moeve analysis

Future demand

The European Union currently consumes around 45 million tonnes of kerosene, rising to nearly 60 million tonnes if the United Kingdom and Norway are included. Going forward, the industry's decarbonisation is expected to be driven primarily by SAFs, as set out in European regulations. European Commission[44] projections point to an increase in consumption to 50 million tonnes (EU-27) by 2050, while the World Economic Forum (WEF)[45] anticipates further growth up to approximately 70 million tonnes, including the UK and Norway. But SAF production is currently more costly than conventional kerosene. Despite recent macroeconomic events that have pushed up kerosene prices, incentives are still insufficient to make SAFs cost-competitive.

As a result, SAFs currently account for less than 1% of aviation fuels. Globally, SAF production is low at the present time, at around 4.4 Mtpa. This is well below the voluntary commitment of 16.3 million tonnes made by airlines for 2030 and even further away from the overall target of 17.1 million tonnes set by governments. However, ongoing and announced projects suggest a significant increase to reach global SAF production of 23 million tonnes per annum by 2030, according to the World Economic Forum's February 2025 report. Of this future output, the 11.3 million tonnes figure is regarded as nearly certain, thanks to capacity expansions and post-FID projects, although 5.8 million tonnes will still be needed to meet government targets. Added to this is an announced pre-FID capacity of 12 million tonnes, although it is not guaranteed to materialise. The capacity forecast for 2030 ranges between 11.3 and 23.3 million tonnes.

Similar growth is expected in Europe, which now produces around 1.7 million tonnes of SAFs each year, with output expected to increase to 3.5 million tonnes in more than 50 plants in the coming five years. According to the ReFuelEU regulation, Europe's 2030 SAF obligation is estimated at 5.1 million tonnes, which will require a determined effort to increase production capacity at the regional level.
This increase in SAF production is primarily driven by the voluntary sustainability market and regulatory policies with ambitious targets for its use from 2025 onwards. The SAF sector is emerging as an immediate alternative for decarbonising the aviation industry, attracting investment and fostering the development of sustainable fuel production plants. The voluntary sustainability market, spurred by Environmental, Social and Governance (ESG) commitments and the net-zero aspirations of airline customers, plays a pivotal role in decarbonisation efforts and CO_2 emissions reduction. Leading aviation companies, such as International Airlines Group (IAG), which owns airlines such as British Airways, Iberia, Vueling, Aer Lingus and Level, have set ambitious targets. IAG was the first to target a 10% SAF share by 2030, well above the mandatory 6%, and has earmarked a major investment of €865 million to achieve this goal. Some airlines have set their own voluntary targets, such as Ryanair, SAS and Norwegian, with SAF targets of 15% by 2030, while companies such as DHL, FedEx and UPS are aiming for 30%.

[44] "Study supporting the impact assessment of the REFuelEU Aviation initiative", European Union

[45] "Guidelines for a sustainable aviation fuel blending mandate in Europe", World Economic Forum

Along with voluntary decarbonisation efforts, regulatory initiatives have become a core driver of SAFs, calming investment uncertainty and providing planning security for fuel producers and airlines alike. In the European Union, individual countries have enacted regulations to incentivise the use of SAFs by means of fuel blending mandates. But the major turning point came in 2023 with the ReFuelEU Aviation Regulation.

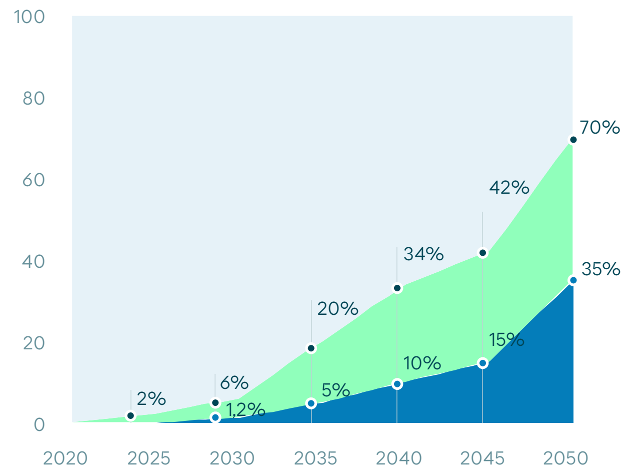
The ReFuelEU Aviation initiative makes it mandatory for fuel suppliers throughout the European Union to ensure that all fuel available to aircraft operators at European Union airports contains a minimum percentage of SAFs since 2025. A minimum share of synthetic fuels by 2030 will also be required, with both shares growing progressively until 2050. This regulatory framework is expected to considerably boost the adoption of sustainable fuels in the region, in line with the aviation industry's decarbonisation and climate neutrality goals. The ReFuelEU Aviation initiative sets the main scenario for SAF adoption in the European Union, representing the minimum share of these fuels legally required . Alternative adoption scenarios have been considered, using projections from reputable sources such as the IEA and the WEF.

The chosen scenarios include the IEA Net-Zero Pathway. This approach proposes a more rapid adoption on the way to meeting the Paris Agreement climate goals. This scenario stands out for its comprehensive vision, backed by a broadly accepted, recognised source, focusing on efficiency at the economic sector level and prioritising emissions reductions in industries in which the greatest impact can be achieved at the lowest cost.

Chart 22 Escenarios de adopción de SAF

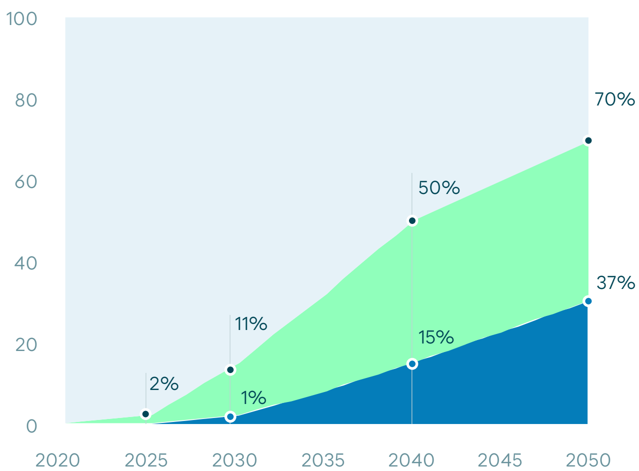
Kerosene | Bio-SAF / e-SAF | e-SAF

ReFuelEU Aviation



IEA Net Zero

The IEA Net Zero scenario describes a more ambitious pathway, particularly in the short and médium term, with the goal of reaching 11% SAF by 2030 and 50% by 2040.



Sources: European Commission; IEA; Moeve analysis

2.4.

Transforming road transport thanks to renewable diesel and fuel cells

Road transport, which includes both light and heavy vehicles, is a key component of today's society. It does not only move people and goods, but is pivotal to economic activity, connecting communities and global trade. This method of transport not only improves the quality of life but also promotes trade and facilitates international cooperation.

It is key to driving the economy and keeping us connected, but the transport industry also poses significant environmental challenges, particularly in view of the contribution it makes to greenhouse gas emissions. Road transport accounts for 73% of total transport emissions and 20% of total European emissions, according to the European Environment Agency. Heavy-duty vehicles (HDVs) are the most hard-to-abate segment, contributing nearly 20% of total transport emissions and 5% of European emissions, so they have a significant share of greenhouse gas emissions. This highlights the urgent need to address the transport industry's environmental impact and implement effective measures to cut carbon emissions.

Delving deeper into heavy-duty-vehicle road transport, nine types of use can be identified based on the end application. Of these nine uses, two account for more than 60% of emissions, are the most challenging in terms of emissions reduction and are the best fit for green molecules, specifically long-distance transport and line transport.

Chart 23 Global trucking segments and use cases

	Heavy-duty cargo					Medium-duty cargo		Bus	
	Tractor			Rigid		Rigid		Bus	
	Long-haul	**Line transport**	**Special**	**Distribution**	**Special**	**Distribution**	**Special**	**Long-distance buses**	**Urban**
Use cases	• "Classic" long-haul using semi-trailers • Logistics and industry	• Regular transport using semi-trailers • Logistics and industry	• Heavy goods • Hazardous substances • Logistics and industry	• Packages and mail • Industry • Food • Municipal (waste collection, fire brigade, public services...)	• Road construction (tipper truck, cement mixer, etc.) • Special applications	• Packages and mail • Industry • Food • Municipal (waste collection, fire brigade, public services...)	• Road construction (tipper truck, cement mixer, etc.) • Special applications	• Line traffic • On demand	• Urban service bus • Short-distance transport for events
Share of Production Volume	12%	20%	5%	18%	11%	15%	10%	5%	4%
Annual mileage (km)	150,00	100,000	50,000	50,000	30,000	50,000	30,000	100,000	100,000
Annual share of emissions[1,2]	28%	31%	4%	14%	5%	8%	3%	5%	2%

Notes: (1) CO_2 emissions totalling 500 Mt per new truck registered in 2022 (2) Average consumption: ICE = Diesel 0.35 l/km for HD, 0.25 l/km for MD, 0.24 l/km for buses
Sources: Moeve analysis

The decarbonisation of European HDVs is being accelerated by emissions regulations, economic incentives and geopolitical motivations. Together, these factors are nurturing a favourable environment for the adoption of sustainable technologies in battery electric trucks (BET) and fuel cell trucks (FCT), spurring the decarbonisation of road freight transport.

Heavy-duty vehicles (HDVs) span nine use cases, with long-distance and line operations accounting for approximately 60% of emissions.

Chart 24 Motivation for the decarbonisation of trucks in Europe

Emissions regulation

- **EU targets for CO_2 emissions reduction** of new trucks compared to 2019:
  - **15% by 2025,** driven by greater ICE efficiency and hybridisation
  - **45% by 2030,** driven by electrification
  - **65% by 2035,** driven by electrification
  - **90% by 2040,** driven by electrification
- **Penalties for manufacturers** starting January 2025 in case of **excess CO_2 emissions.**

Regulatory motivation for manufacturers to avoid penalties

Financing

- **EU financing:** Since 2023, the road toll system grants ZEVs a 50% discount, with savings of up to €25,000 per truck/year.
- **National financing:**In 2026, several countries maintain direct subsidies for the purchase of ZETs and grants for charging infrastructure or hydrogen. In Germany, billions of euros have been allocated for the expansion of the charging network for commercial vehicles (CV) and passenger cars (PC); 1.6 billion euros for the purchase of CVs.

Economic motivation for fletes to electrify their vehicle fleet

Energy sovereignty

- The progressive electrification of heavy-duty transport would allow replacing part of the consumption of fossil fuels with locally produced electricity.
- Truck mileage in Germany corresponds to an oil consumption of approximately 21 Mt/year.[1]
  - **~22%** less oil consumption per year in case of **100% electrification.**
- Truck mileage in Germany is equivalent to an electricity consuption of approximately 77 TWh/year[2]
  - **~15% additional anual electricity consumption under a 100% electrification scenario**

Geopolitical motivation for countries to reduce oil consumption

Notes: (1) Total CO_2 emissions of 500Mt per new truck registered in 2022 (2) Average consumption: ICE = Diesel 0.35 l/km for (HD), 0.25 l/km for medium-duty (MD), 0.24 l/km for bus
Sources: European Commission and Moeve Analysis

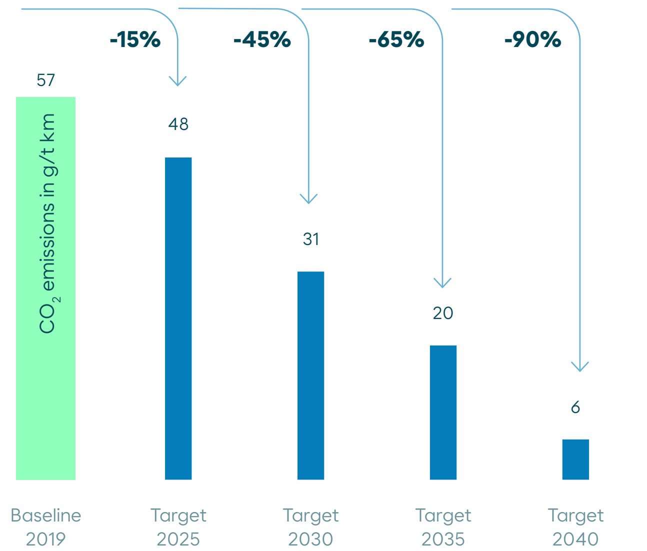
Emissions regulation has a crucial role in the industry's decarbonisation. The European Union has implemented two types of regulatory measures to tackle CO_2 emissions. One set of regulations is broad and applies to all modes of transport, while the other is more specific and tailored to various vehicle types.

The former (RED III) require a 14.5% reduction in emissions below 1990 levels or, alternatively, an increase in the share of renewable energy consumption to 29% by 2030. This directive also includes sub-targets, such as supplying 5.5% of second-generation biofuels and combined Renewable Fuels of Non-Biological Origin (RFNBO), subject to a minimum of 1% RFNBO. Although these goals are not limited exclusively to road transport, they are intended to have a profound impact on it.

The second type of measures target a cut in CO_2 emissions per HDV kilometre compared to 2019 levels by means of various temporary objectives. This reflects a determined commitment to decarbonisation and marks a crucial shift towards cleaner, more sustainable transport. Specifically, the regulations impose emissions reduction targets of 45% by 2030, well above the previous target of 30%. On the back of this momentum, the reduction targeted for 2035 is even more ambitious at 65%, followed by 90% for 2040, underlining the long-term pledge to decarbonise the transport industry. The European Union has also recently revised its CO_2 emissions reduction targets for light vehicles and vans, setting a demanding goal of 100% for new cars and vans sold from 2035 onwards.

Chart 25 EU emissions regulations for trucks

EU targets for new trucks
[CO_2 emissions in g/t km]



Sources: European Commission

Key facts

1. The achievement of emissions reduction **targets will be propelled by efficiency and low-emissions solutions in the short term** (hybridisation, biofuels, LNG/CNG), and by the transition to electrification in the medium-to-long term.
2. Incentives for **zero- and low-emission** vehicles.
3. **Penalties for manufacturers as** from **2025 for excess CO_2 emissions:**
   - Up to **€4,250 per gram of CO_2** per tonne-kilometre of excess emissions from 2025 to 2029.
   - Up to **€6,800 per gram of CO_2** per tonne-kilometre from 2030 onwards.

Technological assessment

On examining the light vehicle technology landscape, internal combustion engine (ICE) vehicles are the most widely used solution, as a familiar, widely accessible method of transport. Nonetheless, in view of growing concerns about environmental sustainability and the urgent need to bring down carbon emissions, there is a critical need to explore alternative fuel options. Electrification, particularly battery electric cars, stands out as the primary decarbonisation solution. This transition is a crucial step towards cutting CO_2 emissions in the automotive industry. Biofuels are an alternative solution for the electrification of light and heavy-duty vehicles, providing an opportunity to mitigate the climate change impact of ICE vehicles while leveraging existing technologies and infrastructure.

For heavy freight transport, the search for sustainable alternatives has spurred the exploration of various technology avenues. They include battery electric trucks (BET), hydrogen fuel cell trucks (FCT), overhead catenary hybrid trucks (CHT) and internal combustion engine trucks powered by synthetic fuels or biofuels (SYT). FCTs, together with BETs and biofuels such as renewable diesel or biomethane, are seen as the most appropriate solutions for long-distance and line-haul trucks, which account for an overall 28% and 31% of annual emissions, respectively, making them the largest contributors to CO_2 emissions in the trucking sector.

Chart 26 Asessment of powertrain options for trucks

BET

Battery electric trucks

Direct use of electricity in the electric engine for propulsion; Battery used for energy storage

+

- **Competitive technology**
- Lower vehicle costs, higher load capacity and range
- High efficiency, low energy costs and high public acceptance

FCT

Hydrogen fuel cell trucks

Conversion of electricity into hydrogen; fuel cell for converting hydrogen into electricity for use in an electric engine for propulsion

+

- **Competitive technology**
- Lower vehicle energy costs
- High flexibility thanks to low refuelling speed (compared to charging) and high public acceptance

BIO

Organic waste conversion

Use of organic waste to make biofuels that can be used in internal combustion engines (ICE), such as renewable diesel or biomethane

+

- **Competitive technology**
- High flexibility thanks to high refuelling speed and high public acceptance
- Lower investment by the end user, retrofitting capability of current technology and reuse of existing infrastructure

SYT

ICE trucks using synthetic fuels or biofuels

Conversion of electricity into carbon-based fuel or synthetic fuel (Power-to-Liquid or Power-to-Gas); internal combustion engine for propulsion

–

Questionable competitiveness

- High investments in renewable primary energy due to low end-to-end efficiency
- High latency of additional renewable energy production to facilitate large-scale synthetic fuel

CAT

Catenary hybrid trucks

Direct use of electricity in engine for propulsion; Small battery used for energy storage, as the main source Power is transferred via the catenary

–

Questionable competitiveness

- Non-scalable initial investments with underutilisation of infrastructure
- Low public acceptance

Sources: Moeve analysis

Increasing the share of biofuels in road transport by just 1-2% can have the same decarbonisation effect as replacing 400,000 conventional vehicles with alternative electric vehicles.

Biofuels are positioned to accelerate decarbonisation when used in road transport, particularly in the case of heavy-duty vehicles for which electrification entails greater challenges compared to light-duty vehicles like cars or vans. As they are suitable for use in current technology, offering the same advantages in terms of available range, power and refuelling speed, renewable diesel and biomethane are the leading solutions for decarbonising road transport in the short-to-medium term. By replacing conventional petrol and diesel, biofuels enable end users to decarbonise CO_2 emissions without a major investment, while reducing the need to deploy new refuelling infrastructure, such as electric charging stations or hydrogen stations, which will require a large investment.

In the medium-to-long term, battery electric trucks (BET) and fuel cell trucks (FCT) are emerging as the most efficient solutions, with a well-to-wheel (WtW) efficiency of 73% and 30%, respectively, clearly outperforming conventional internal combustion engines with a WtW efficiency of around 15-18%. BETs are currently seen to be the most technologically advanced option thanks to an established infrastructure and technological maturity. Meanwhile, FCTs are gaining ground as a potential long-term solution, thanks primarily to considerable flexibility in terms of refuelling speed and range, coupled with a lower weight and significantly shorter refuelling times than BETs by 2030 and 2035. Advances in charging are expected, with the potential for a 15-minute charge at 700 bar and a range of 700 kilometres.

Chart 26 Alternative powertrain options for trucking

		H2 long-haul	H2 line-haul	Charging speed	
		1: ~600 km/d; 2: 300-450 kW	1: ~400 km/d; 2: 300-450 kW		
ICE[1] (diesel fuel)	3	700-1,500 l (diesel)	700 - 1,500 l (diesel)		**Current**
	4	2,000 – 4,000 km	2,000 – 4,000 km		
	5	2,200 kg	2,200 kg		
BET[2] (electric charging)	3	600 – 850 kWh	300 – 600 kWh	MCS: **850km/h** Night-time and DCS: **50km/h**	**Alternative**
	4	500 – 700 km	250 – 500 km		
	5	4,300 – 5,300kg	3,100 – 4,300 kg		
FCT[3] (H2 feed)	3	~80kg (hydrogen) +50 kWh (electricity)	~80kg (hydrogen) +50 kWh (electricity)	Up to 3,400 km/h	
	4	~900 km	~900 km		
	5	2,300 kg	2,300 kg		

1 Mileage (based on 250 business days per year) 2 Performance (power) 3 Range 4 Onboard power 5 Powertrain weight

Notes: (1) Average power consumption:
ICE = diesel 0.35 l/km; (2) Average power consumption: BET = electricity 1.20 kWh/km; (3) Average power consumption: FCT = hydrogen 0.09 kg/km
Sources: Moeve analysis

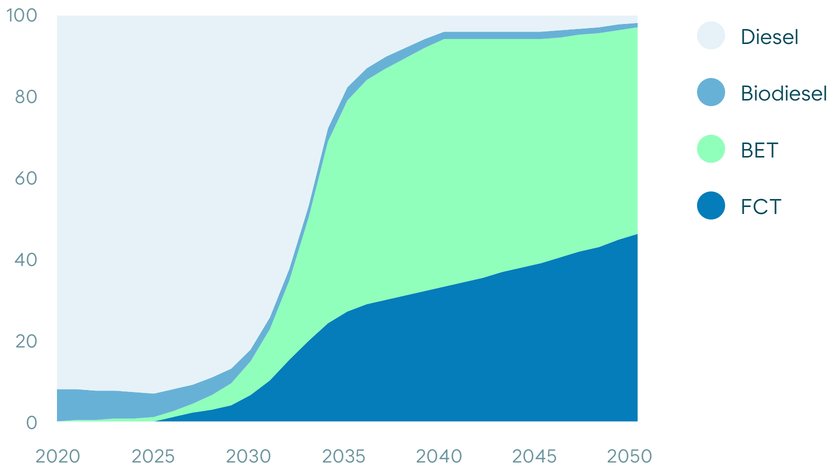
Fuel cell lorries are a promising long-term solution for decarbonising heavy-duty road transport, as they combine fast refuelling with a long range, making them an efficient option for reducing emissions.

Future demand

Demand for light vehicle fuel is forecast to shift mainly towards electricity, in line with the general trend towards decarbonisation and the use of sustainable energy sources. Although the use of biofuels is expected to remain limited, this change opens the door to reallocating resources such as biomass and waste to other, more efficient uses.

In the long-haul heavy-duty truck segment, the fragmented adoption of technologies is expected, specifically involving BET and FCT. Mission Possible Partnership (MPP) projections suggest that, in the most likely scenario for 2050, around 62% of total sales in Europe will be BET and 35% will be FCT, with a smaller share for diesel and renewable diesel.

Chart 28 Share of MPP sales in the European long-haul segment. (%, 2020-2050)



Notes: (1) Fuel-cell electric trucks (FCT); (2) Zero-emission trucks (ZET); (3) Battery electric trucks (BET); (4) Emission costs increase linearly to €230/t by 2050
Sources: MPP – Mission Possible Partnership (Making-Zero-Emissions-Trucking-Possible)

This change highlights a significant transition towards alternative energy sources in heavy-duty goods transport, reflecting efforts to mitigate the environmental effects and achieve sustainability goals. These advances and the planned transition are prompted mainly by European Union regulations and ESG commitments made by enterprises such as the Volvo Group, through the First Movers Coalition, pledging that at least 30% of its heavy-duty truck sales and 100% of its medium truck sales will be zero-emission trucks by 2030.

2.5.

Green industry: hydrogen for green raw materials and hard-to-abate thermal processes

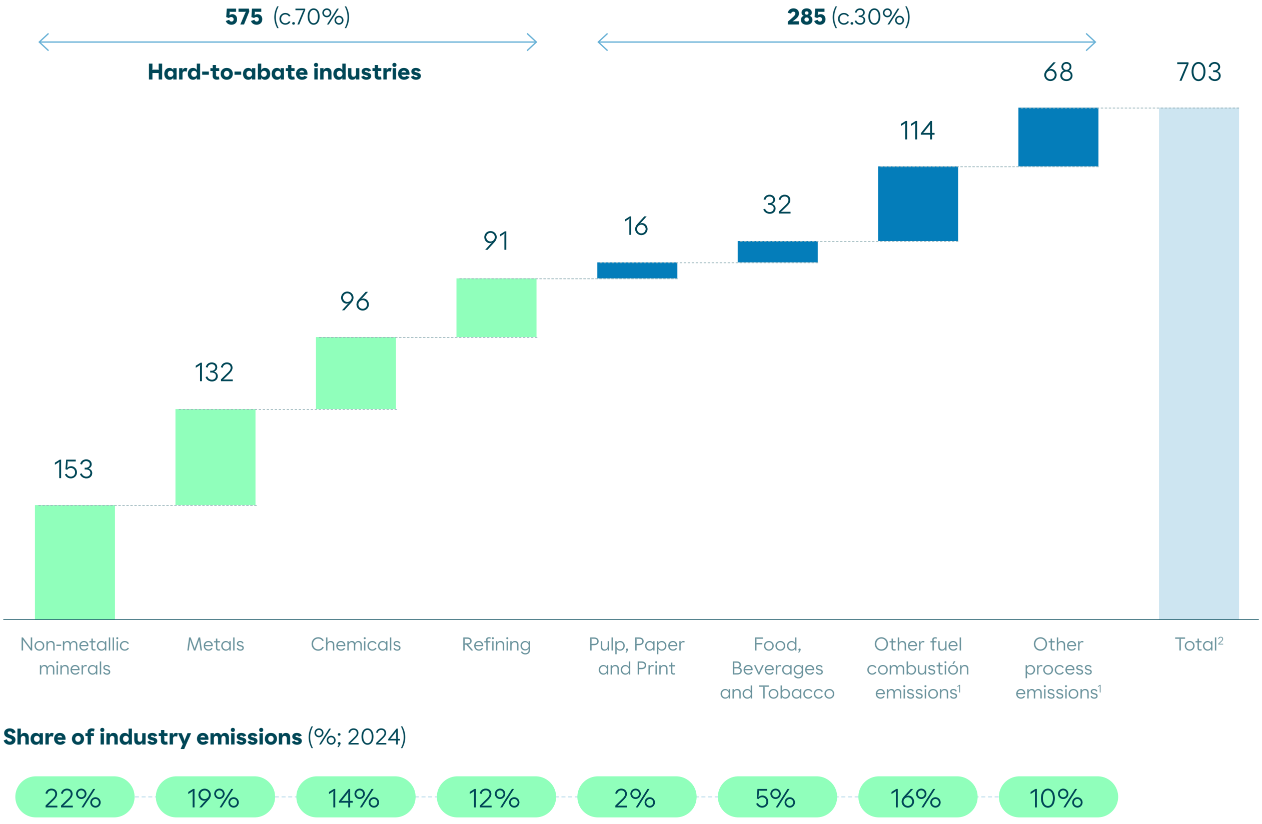
The industrial sector is the backbone of the European economy, sustaining its strength through 35 million direct jobs, according to the European Commission[46]. Renowned for its focus on high-value-added products, including the automotive, chemicals and aeronautical industries, European industry both drives economic growth and generates significant job opportunities. Beyond economic contributions, European industry affects various aspects of daily life thanks to its considerable influence on wealth creation in Europe.

Besides being the fundamental driver of the region's economy and prosperity, European industry is also a major contributor to emissions at approximately one quarter of the total, according to the European Environment Agency. Attaining sustainable economic growth aligned with emissions reduction targets entails implementing measures and policies to foster energy efficiency, the transition to cleaner energy sources and the adoption of more sustainable technologies and practices across various economic sectors. This may include promoting the use of renewable energy, improving resource efficiency and rolling out CCUS, among other strategies. Comprehensive efforts involving governments, businesses and society as a whole are needed to tackle this challenge and move towards a more sustainable, low-carbon economy.

Within industrial sectors, some present more significant challenges in achieving decarbonisation, as electrification may not be a technically viable alternative. These hard-to-abate industries, include steel and iron production, non-ferrous metals such as aluminum, the chemical industry, non-metallic minerals (cement, ceramics, and glass), and refining. Together, these sectors contribute around 70% of industrial emissions, making them crucial focal points for efforts aimed at achieving decarbonisation targets.

[46] "Internal Market, Industry, Entrepreneurship and SMEs", European Commission

Chart 29 Industrial emissions ($MtCO_2e$, 2024)



Notes: (1) Agriculture, waste and other minority sectors (2) Industry emissions excluding refineries would amount to 628 $MtCO_2e$ by 2023
Sources: European Environment Agency, Moeve Analysis

Although final energy demand and CO_2 emissions in the European Union's industrial sector have been steadily declining at an average annual pace of around 1% since 1990, save for a slight rise observed from 2015 to 2019, efforts are insufficient and further greenhouse gas emission cuts are needed to attain 55% decarbonisation by 2030, compared to 1990 levels, and climate neutrality by 2050.

European Union regulators are implementing two types of measures to achieve net-zero carbon emissions by 2050 and decouple emissions from economic growth so as to reduce industrial greenhouse gas emissions. There are objectives entailing the adoption of green molecules to replace current fossil fuels and mechanisms to expedite CO_2 cuts.

By combining both sets of measures, the European Union seeks to build a comprehensive, effective strategy for attaining the climate goals, promoting sustainable economic growth and minimising CO_2 emissions from industrial activities. This approach reflects the urgency and complexity of the task at hand and needs a sweeping strategy to address emissions from various sectors and nurture a more sustainable industry.

In October 2023, the European Union, through RED III, set ambitious targets to boost renewable energy in the industrial sector. An annual increase of 1.6% in the use of these energies was established until 2030. RED III also seeks to ensure that green hydrogen accounts for 42% of hydrogen consumed by 2030, rising to 60% by 2035. This approach entails replacing grey hydrogen in hard-to-abate sectors. These percentages could be higher based on the latest projections from various sources, such as the IEA, the European Commission and the Clean Hydrogen Monitor on demand for renewable hydrogen.

Some European Union countries are also implementing demanding decarbonisation targets. In its 2024 National Integrated Energy and Climate Plan (NECP), Spain has targeted 74% green hydrogen in relation to the total hydrogen consumed by industry by 2030.

Since 2005, the European Union has implemented an Emissions Trading Scheme (ETS) as an essential part of its efforts to curtail emissions. This system forces polluters to pay for their carbon footprint, which not only encourages a reduction but also generates revenue to fund green, sustainable policies in the EU.

The ETS operates under the "cap and trade" principle, setting a cap on permitted emissions for various industries that becomes gradually lower each year. A price is allocated to carbon, requiring the entities in question to purchase greenhouse gas emission "allowances". The total limit for these allowances is set annually by sector and by industrial facility, decreasing over time. This creates financial incentives for undertakings to try to reduce their carbon footprint. The ETS initially applied to large energy-intensive industries. In 2012 it was extended to include the aviation sector and, since 1 January 2024, the maritime shipping sector. From 2027 onwards, residential buildings, road transport and small industries will also be covered by a new Emissions Trading System referred to as ETS2.

The European Union Emissions Trading System (ETS) is one of the largest carbon markets and has contributed to reducing industrial emissions by 51% since 2005[47]. Furthermore, its reduction targets, which were tightened in 2023, raise the goal from 43% to 62% by 2030 compared to 2005 levels. In the coming years, the number of free allowances allocated to companies participating in the ETS will gradually decrease, accompanied by an increase in their cost. This will undermine the competitiveness of fossil fuel alternatives. Consequently, fossil fuels will become more expensive to use. In recent years, the price of CO_2 has fluctuated between €25 and €80 per tonne[48]. But, according to IEA projections, these prices will rise to approximately €80–125 per tonne by 2030 and reach approximately €175–250 per tonne by 2050.

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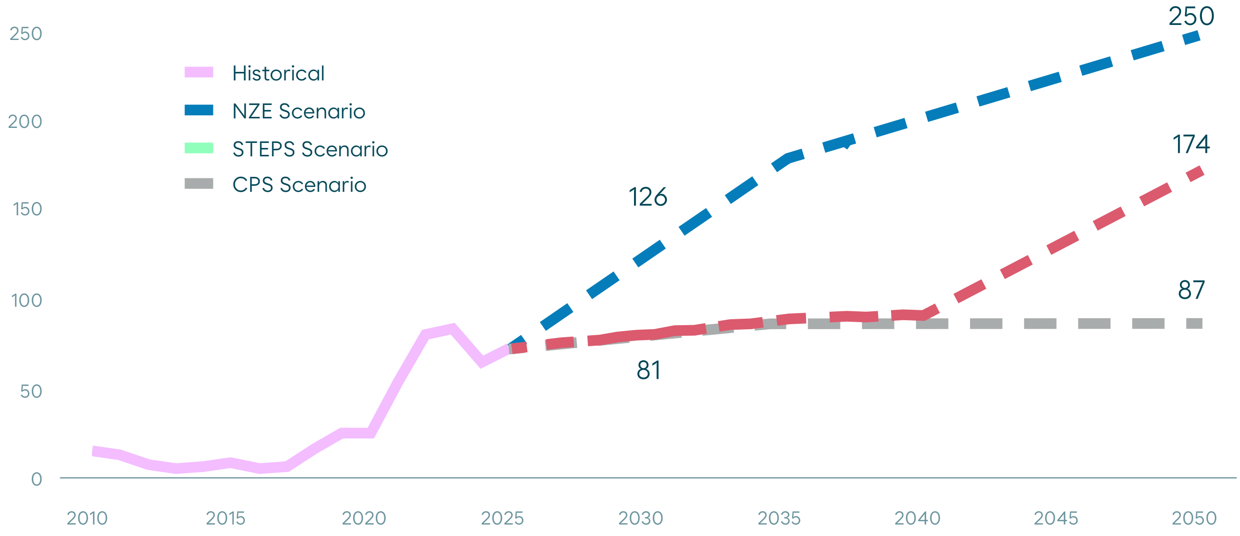
[47] "Trends and projections in the EU-ETS in 2025. The EU Emissions Trading System in numbers", EEA

[48] "Precios CO_2", SENDECO2

Chart 30 CO_2 emission price scenarios in the UE (€/tCO_2)

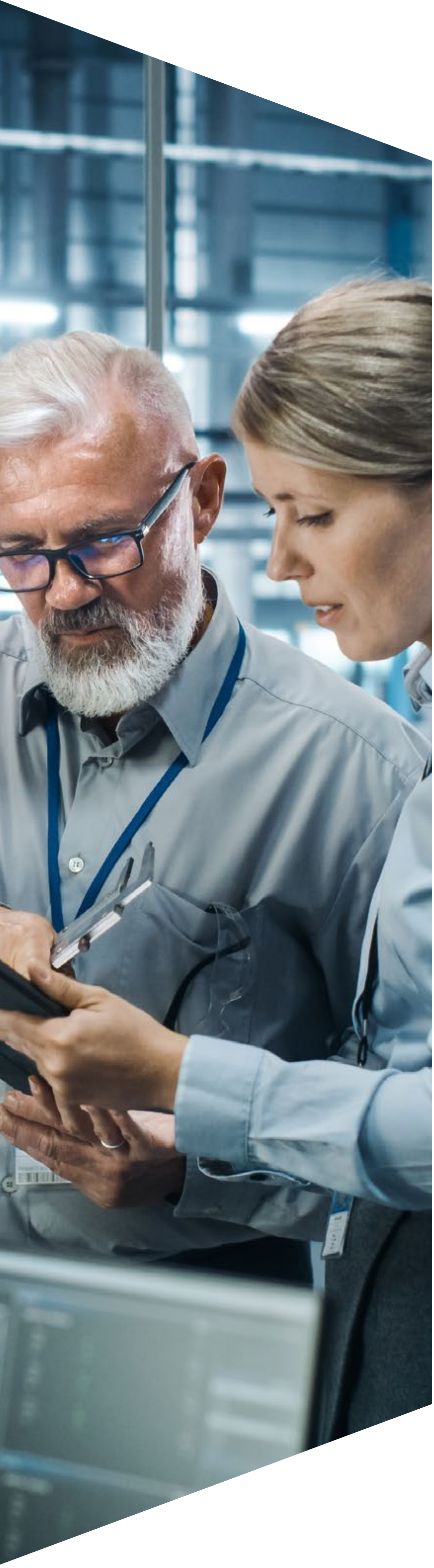


Notes: CPS – Current Policies Scenario ,STEPS – Stated Policies Scenario, NZE – Net Zero Emissions by 2050 Scenario
Sources: IEA (International Energy Agency – World Energy Outlook 2024); Moeve analysis

Another policy developed by European Union regulatory bodies to encourage industrial decarbonisation is the CBAM (Carbon Border Adjustment Mechanism). Its purpose is to promote intra-European products derived from low-carbon fuels and technologies, as a CO_2 tax equivalent to the European Union's carbon price are levied on imported products. The primary objective is to counteract carbon leakage, which occurs when companies with high greenhouse gas emissions move production to territories outside the European Union with less stringent climate policies. This is intended to prevent the transfer of carbon-intensive production to countries with laxer climate policies, where imported products could have a price advantage at the expense of the environment. The CBAM mainly applies to products from hard-to-abate industries, such as iron and steel, cement, fertilisers, aluminium and hydrogen, and is expected to expand to include other products and sectors.

Carbon pricing mechanisms enable investment in solutions that bring down emissions in energy-intensive industries, promoting economic growth while decoupling it from emissions.

The Net-Zero Industry Act and Clean Industrial Deal, aim to bring forward the European Union's climate and energy goals by boosting industrial competitiveness through the development and accelerated production of zero-emission technologies such as renewable hydrogen, second-generation biofuels and e-fuels.



Technological assessment

Technology plays a key role in the decarbonisation of industrial emissions, adapting to European specificities. There are significant differences between sectors, both in their production processes and in the fuels and technologies they employ. Heat requirements across industries also vary substantially, from temperature control and cooling, which are common to all sectors, to processes requiring low, medium, and high-temperature heat. It is important to note that certain industries, such as chemicals, metals, non-metallic minerals and refineries, need fuel both for combustion and as a raw material in the manufacturing process. One example of a commonly used feedstock is grey hydrogen, which is employed in refineries, in the production of chemicals such as methanol or ammonia (essential to make fertilisers) and in steel production, specifically in the iron ore reduction process, so it is a key component for the energy transition going forward. Industries can therefore be classified into three distinct groups on the basis of suitability for decarbonisation using green molecules:

- **Level 1:** industries at this level, such as chemicals, refining and steel, are poised for a swift transition thanks to current reliance on grey hydrogen as a feedstock. This is particularly apparent in the production of ammonia, essential for fertiliser manufacture, and methanol, as well as several industrial processes such as hydrogenation or hydrocracking for refineries. Steelmakers also use this energy vector to reduce iron ore. Green hydrogen is seen as the only feasible alternative for decarbonising this process.

- **Level 2:** this group includes energy-intensive activities with processes operating at medium to very high temperatures exceeding 500 °C and 1000 °C. It includes the manufacture of non-metallic minerals such as ceramics, glass and cement, as well as the chemicals and metallic minerals sectors. These industries rely heavily on fossil fuels for their thermal energy processes. They can embark on the transition to green molecules in the short term, as electrification is often not technically feasible due to the characteristics of high-temperature processes and the equipment required. Biofuels, such as biomethane, could replace natural gas without process modifications, whereas hydrogen would require adjustments to turbines and burners for mixes exceeding 20% natural gas.

- **Level 3:** industries at this level are less willing to switch to green molecules. Examples include the paper and food sectors, which rely on low-temperature processes and mechanical operations. In such cases, direct electrification is often a feasible, preferable decarbonisation option.

Chart 31 Assessment of green molecules: relevant industries and areas of application

Relevance of fossil fuels in production processes

Tier I	<100 °C	100–400 °C	400–1,000 °C	1,000 °C	Molecular
Refineries		Distillation	Cracking and Coking		Hydrogenation
Chemicals	Drying		Gasification		Feedstock
Steelmakers		Tempering	Heat treatment	Casting	Direct reduction
Tier II					
Ceramics			Cocción de bizcocho	Glazing	
Glass			Procesamiento del vidrio	Casting	
Cement				Clinker production	
Tier III					
Food and beverages	Pasteurisation				Hydrogenation
Paper and pulp	Drying				

H2's role in the economy

Leaders (Tier I and Tier II)

- **High applicability of green molecules** in current production processes due to the high temperature requirements of industrial processes.
- **Limited alternatives for decarbonising** industrial processes by means of renewable energy sources

Late adopters (Tier III)

- Other decarbonisation options are preferred
- They will only use green molecules when they can compete with other energy sources

Fuentes: análisis Moeve

But the transition to green molecules will not suffice to attain decarbonisation targets. Other technologies and strategies, such as electrification, CCUS, demand reduction, energy efficiency measures such as heat recovery, and the promotion of a circular economy through product reuse and recycling, will be crucial to decarbonise industry and reach Net-Zero Emissions (NZE).

As mentioned, green molecules play a pivotal role in replacing some fossil-based raw materials and in processes requiring medium-to-high temperatures. In contrast, electrification is considered more suitable for low-temperature and some medium-temperature processes. So green molecules have the potential to decarbonise around 30% of industrial emissions[49], while other technologies such as electrification or CCUS could potentially decarbonise a further ~44%. This highlights the need for a combination of strategies and technologies to effectively achieve decarbonisation targets in the industrial sector.

[49] Moeve analysis based on McKinsey "Net-Zero Europe"

Chart 32 Potential of emissions reduction mechanisms and share by 2050

Decarbonisation lever	Share of mitigation by 2050	Description
CO_2 capture, usage and storage	24%	**Carbon emissions capture** will be key in **sectors without a sustainable alternative**, such as cement, to mitigate the environmental impact. CCUS will also be essential for **developing e-fuels**
Green molecules as fuel or feedstock	29%	**Green molecules used as fuel or feedstock** could potentially become the key lever for decarbonising industry, **primarily in hard-to-abate sectors**
Direct electrification	22%	**Renewable energy generation will drive decarbonisation by means of electrification. Heat pumps** will be used for low temperatures and pre-heating for higher ranges. **Electric furnaces** will also be key to decarbonisation.
Demand reduction, efficiency and recycling	13%	**More efficient technologies, such as heat pumps and energy recovery**, will help bring down industrial demand. **Other measures, such as recycling plastic or glass, will enable circularity** and reduce GHG emissions.
Others	12%	**Other fuel changes** (geothermal heat), **together with a reduction in fluorinated gases** (F-gases) and other innovations.

Sources: Moeve analysis based on McKinsey

Green molecules could abate industrial emissions by nearly 30%, emerging as the main instrument for decarbonising European industry

Non-metallic minerals sector

The non-metallic minerals sector, which includes cement and lime, ceramics and glass, stands out as the industrial segment with the highest carbon emissions intensity in European industry. The sector faces a major challenge when reducing emissions, particularly in view of the anticipated substantial growth in demand for non-metallic minerals driven by infrastructure and construction projects.

The cement and lime subsectors generate a large portion for reasons closely tied to their production processes. To decarbonise these emissions, carbon capture technologies will have to be implemented alongside material efficiency measures such as using recycled cement from demolition sites in new construction projects.

Manufacturing processes in the cement, glass and ceramics segments require fuel combustion at high temperatures of between 1,000 °C and 1,500 °C, using furnaces to generate heat. Electrification is not practical in such cases, although heat pumps can play a core role in pre-heating phases or in heat recovery systems, as is the case of dryers employed in the ceramics industry.

The use of green molecules is seen as a fundamental strategy for these high-temperature processes. Biomethane can completely replace natural gas, while green hydrogen can be blended with natural gas or biomethane at up to 20% without technical complications, or used in a pure form, requiring only minor adjustments to equipment such as gas trains and burners[50].

It is essential to recognise that emissions from the glass manufacturing process can be considerably reduced by means of recycling measures and efficiency improvements. The ambitious recycling targets set by European Union regulations seek to reduce primary glass production, focusing specifically on 90% recycling of glass packaging by 2030. This underlines the significance of sustainable practices to mitigate environmental effects in the non-metallic minerals sector.

[50] "Climate, Navigate uncertainty and build resilient, future-ready strategies", ICF

Metals - Iron and Steel

The iron and steel industry is the main contributor, accounting for over 90% of emissions at this level. This industry is considered hard-to-abate due to the high temperatures and the release of CO_2 as a by-product in the steel manufacturing process.

Steel production primarily employs two methods: the Basic Oxygen Furnace (BOF), which accounts for 60% of European steel manufacturing and is based on iron ore and coke, and the Electric Arc Furnace (EAF). The EAF mainly uses scrap metal as feedstock, or iron ore in an additional Direct Reduced Iron (DRI) process in which oxygen is removed from the ore without smelting, as in the BOF route, but using hydrogen or carbon monoxide (CO), mainly by means of reformed natural gas. Steel manufacturing emissions vary considerably, with conventional blast furnaces emitting, on average, 1.9 tonnes of CO_2 per tonne of steel produced in the EU, while the DRI-EAF process emits 0.4 tonnes of CO_2 per tonne of steel, representing an 80% reduction compared to the conventional method.

This industry faces a significant abatement challenge in transitioning a large part of steel production from BOF to the DRI-EAF alternative. The decarbonisation of process emissions will be achieved primarily by means of DRI using green hydrogen as a reducing agent for iron ore, a technology that has been demonstrated at pilot scale. CCUS and energy efficiency are potential solutions for BOF decarbonisation.

The decarbonisation of fuel-related emissions is viable through the use of hydrogen, which does not require significant changes to equipment and is a method already proven at production scale, as well as through the use of biomass. The electrification of reheating and processing furnaces is also a feasible option and has been demonstrated at scale, reaching temperatures of up to 1,300°C.

Chemicals – Ammonia and Methanol

Ammonia and methanol production in the European chemicals industry are crucial for effective decarbonisation. As this industry works with carbon-containing compounds, it is imperative to bring in sustainable practices. Ammonia, used mainly to make fertilisers, has a pivotal role in these efforts (accounting for 70% globally, according to the IEA[51]) and a core role in global crop development, one of our essential needs.

Currently, ammonia production makes a significant contribution to industrial greenhouse gas emissions, emitting in the European Union an average of 1.8–2.0 tonnes of CO_2 per tonne of ammonia produced. Here, grey ammonia production is based primarily on grey hydrogen generated by means of SMR, which feeds the Haber-Bosch reactor for ammonia synthesis. In this context, hydrogen is critical feedstock when manufacturing ammonia.

While ammonia stands out as a key player in the industry's energy transition process, the conversion of methanol to ethylene presents an alternative approach to ethylene production, shifting away from dependence on natural gas. High-temperature processes in the industry also need attention in the decarbonisation strategy. But replacing feedstocks is the core challenge to be addressed for effective abatement.

The decarbonisation of emissions from raw materials, particularly during ammonia manufacturing, will rely largely on renewable hydrogen, which will replace grey hydrogen produced through steam methane reforming (SMR). Carbon capture technologies could also play an important role in trimming emissions associated with grey hydrogen, particularly in the short-to-medium term, given that CO_2 is needed for urea production.

For fuel emissions abatement, direct electrification and heat pumps are viable solutions, particularly in low-temperature applications and pre-heating phases. High-temperature, may find alternatives in hydrogen or biomass boilers. Optimising energy efficiency through process improvements, heat recovery and insulation is emerging as an accessible, fast route to decarbonisation. These comprehensive strategies underline the industry's commitment to sustainable practices, in line with global efforts to mitigate climate change and reduce environmental impacts.

51 "Ammonia Technology Roadmap", IEA

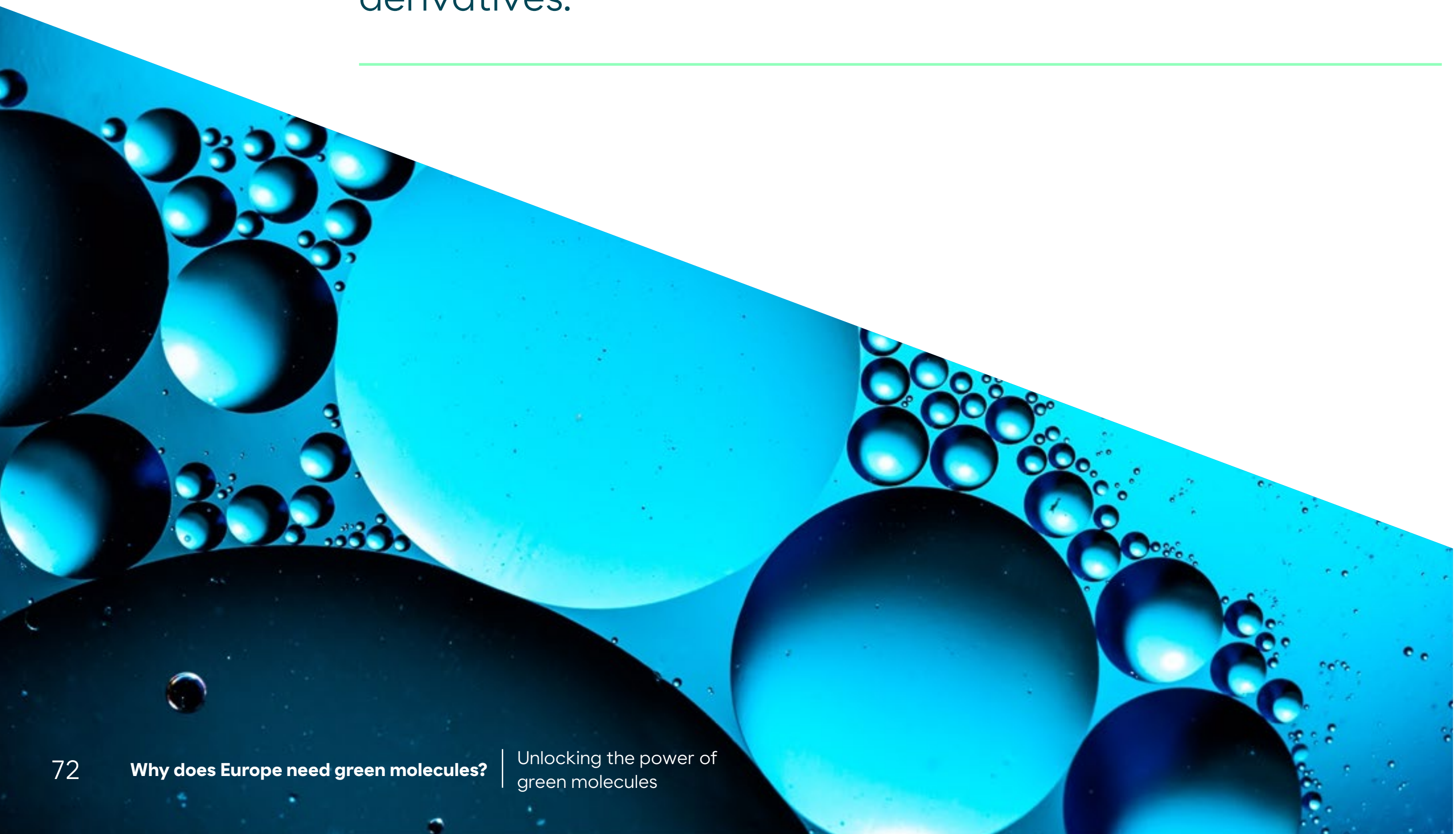
Refineries

In the coming years, as the global economy continues to rely heavily on petroleum products, refineries will remain key components of the energy system. Hydrogen plays a crucial role in refinery processes, particularly in the hydrotreatment and hydrocracking phases undertaken to achieve lower molecular weights. The transition from grey hydrogen to green hydrogen as a feedstock represents a valuable, fundamental opportunity to advance the industry's decarbonisation.

Switching to green hydrogen is not only the primary alternative for decarbonising refinery operations but also complements electrification strategies, as a further way to scale down the carbon footprint. Electrification can be implemented in the pre-heating phases, helping to mitigate the industry's environmental impact. Heat pumps are also essential to meet pressurised water heating needs, making them a key solution for achieving abatement targets.

In short, the dual approach in which hydrogen feedstock is replaced with green alternatives and electrification is integrated into the pre-heating phases provides refineries with an all-encompassing, effective strategy for decarbonisation. These measures not only align with global sustainability goals but also make the industry a proactive contributor to reducing environmental impacts by using green molecules.

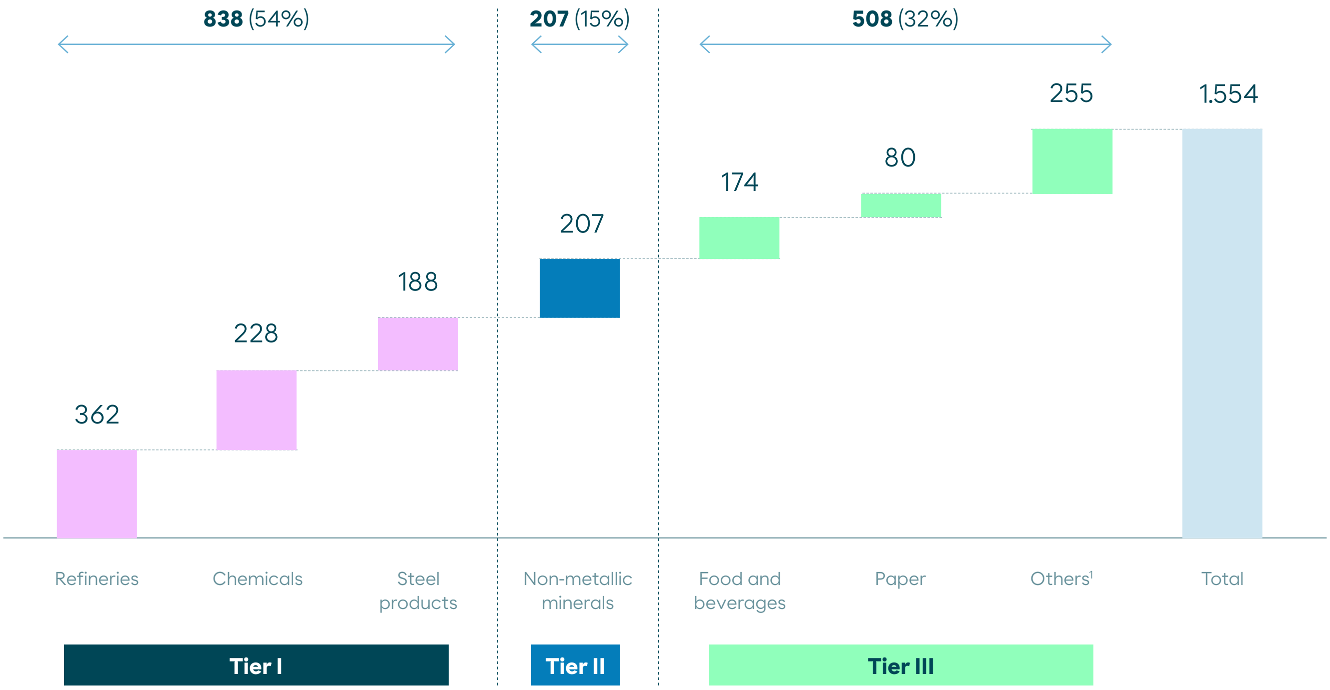
Biomethane and green hydrogen are essential substitutes for natural gas in high-temperature processes. As for the decarbonisation of raw materials, feasible options are still limited to bio-based alternatives and hydrogen derivatives.



Future demand

In 2024, the final energy demand of the industrial sector amounted to 2,500 TWh (terawatt-hours) (reaching approximately 2,900 TWh when refineries are included). This energy was primarily met by fossil fuels, constituting 50% of the total, with 30% attributed to electricity, and the remaining 20% encompassing bioenergy, heat and other sources. The focal point of fossil fuel consumption within industry lies in energy-intensive industries (Tier I and II), where green molecules are the primary solution, offering a promising pathway for the transition towards more sustainable and environmentally friendly fuels.

Chart 33 **Current fossil fuel consumption by industry** (TWh, 2024)



Notes: (1) Agriculture, waste and other minor sectors
Sources: European Environment Agency, Moeve analysis

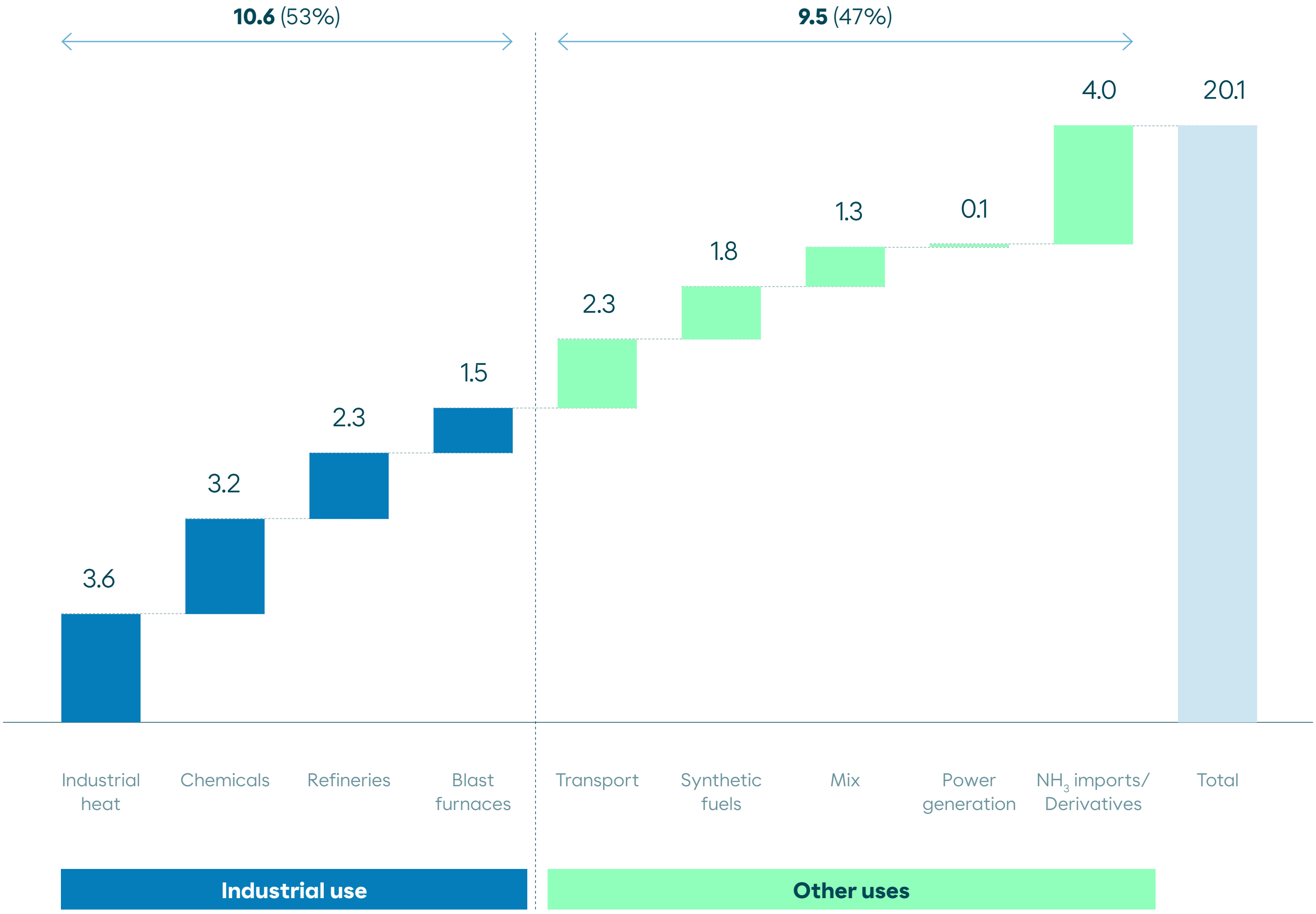
Focusing on hydrogen demand, European industry reached approximately 7.8 million tonnes in 2024[52], produced predominantly through the steam reforming process. Refineries led the demand, constituting 58% of it, followed by ammonia at 25%, and methanol and other chemicals (including hydrogen peroxide, cyclohexane, aniline, etc.) contributing nearly 12%. Other applications made up the remaining 5% of demand.

The future of green molecule demand in the industrial sector, particularly the transition from grey hydrogen to green hydrogen, is shaping up as a key short- to medium-term objective. This transformation is driven by two main factors: evolving energy policies and the growing interest for sustainable solutions.

[52] "Clean Hydrogen Monitor 2025", Hydrogen Europe

In this context, energy policies play a pivotal role in driving the adoption of green hydrogen in the European Union. The REPowerEU initiative has set ambitious targets for hydrogen demand by 2030 at 20.1 million tonnes, of which approximately 10.6 million tonnes is earmarked for industrial applications. This allocation represents more than 50% of the total projected volume, reflecting a strong commitment to integrating green molecules into the industrial energy mix.

Chart 34 **REPowerEU goals** (Mt, 2030)

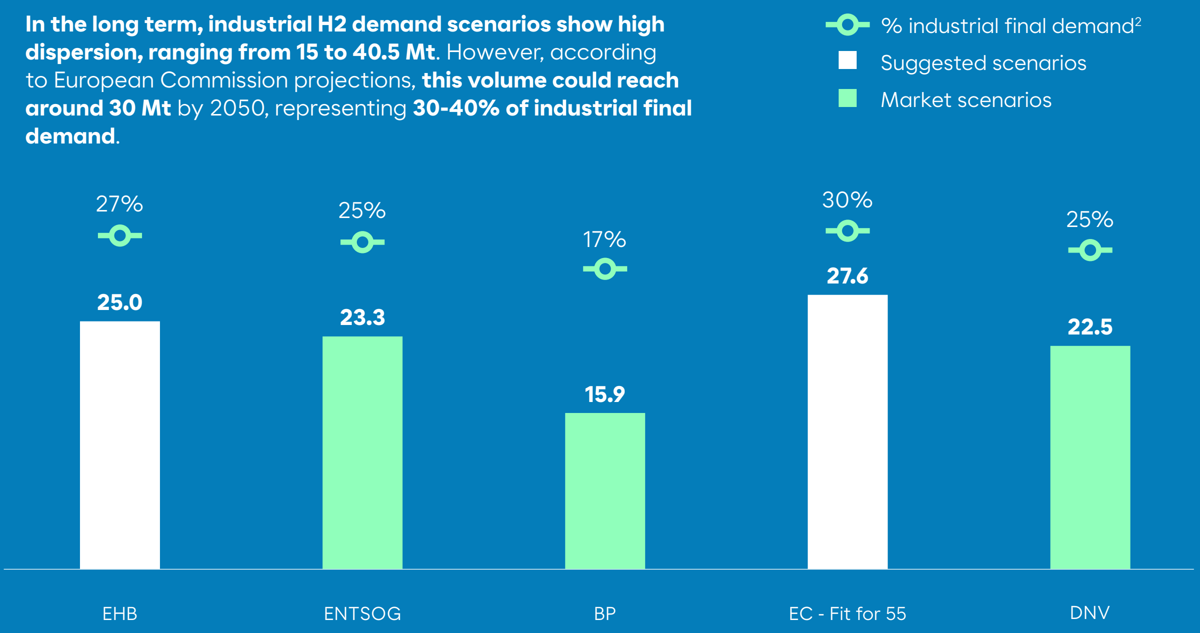


Sources: European Commission; Moeve analysis

Long-term hydrogen demand forecasts from market sources such as DNV and British Petroleum (BP), among others, reveal different projections and roles for green hydrogen in European industry. Forecasts vary considerably, with the projected volume ranging from 15 to 36 million tonnes by 2050. However, according to an EHB analysis, demand should reach 30-35 million tonnes by 2050. Based on the projects announced, this could account for 30-40% of final demand from industry and refineries. This demand is spurred primarily by the transition from grey to green hydrogen in current applications such as refineries, ammonia and methanol, as well as by the emergence of new industrial uses, such as in the steel industry, to decarbonise the BF-BOF (blast furnace - basic oxygen furnace) production route to the EAF-DRI (electric arc furnace - direct reduced iron) route using green hydrogen as a raw material to reduce the ore.

Chart 35 **Hydrogen demand scenarios in EU industry** (Mt[1], 2050)

In the long term, industrial H2 demand scenarios show high dispersion, ranging from 15 to 40.5 Mt. However, according to European Commission projections, **this volume could reach around 30 Mt** by 2050, representing **30-40% of industrial final demand**.



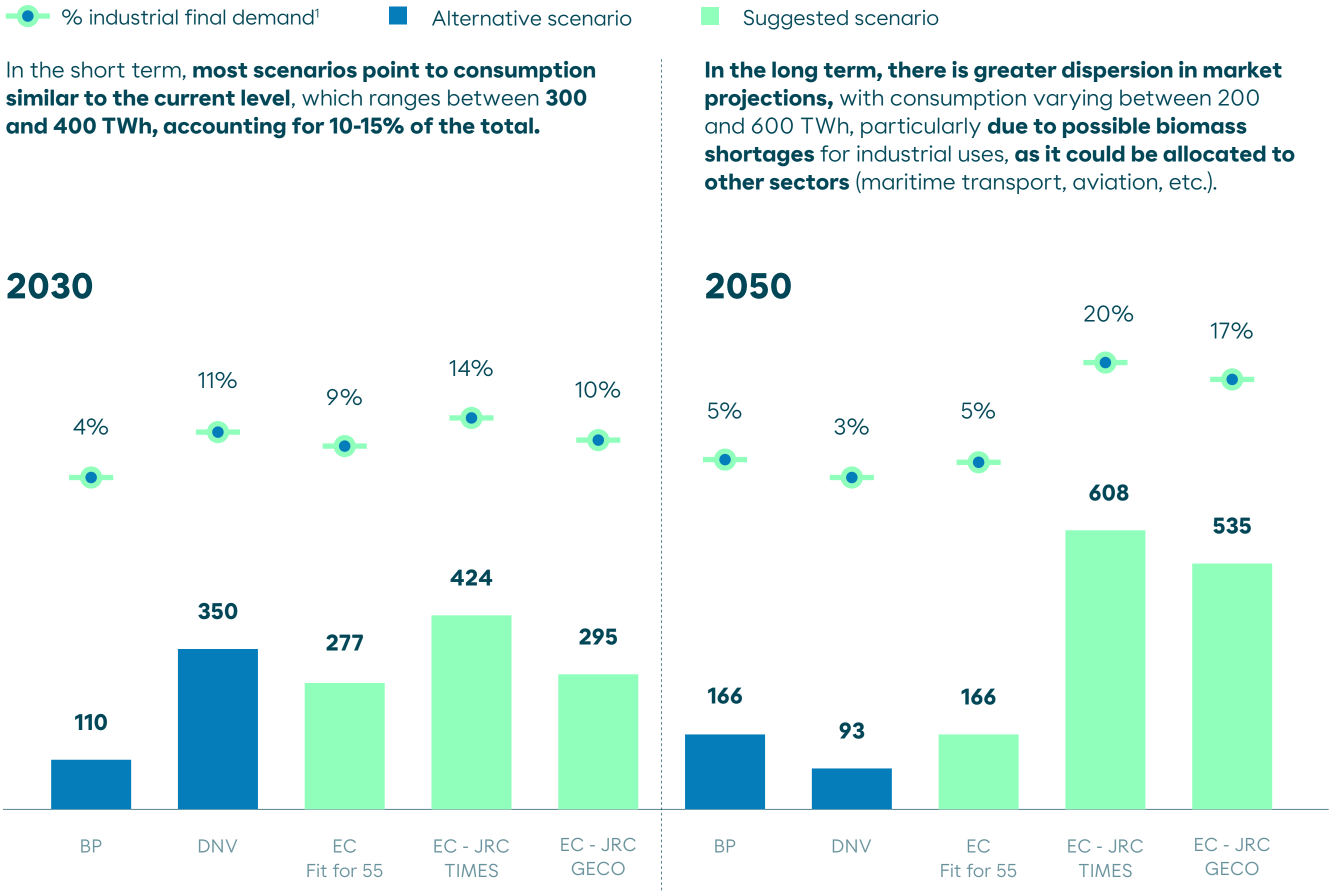
Notes: (1) 1Mt = 33TWh; (2) Industrial final demand is estimated at 3,100 TWh in the IEA WEO scenario
Sources: European Commission; Moeve analysis

Although green hydrogen is positioned as the primary molecule for industrial abatement, green molecules derived from organic compounds, such as biomethane, are set to play a crucial role, replacing natural gas in applications with high heat requirements. At present, bioenergy accounts for around 15% of the industry's total energy consumption, mainly using solid biomass. But future projections for bioenergy adoption are varied and influenced by factors such as limited biomass availability and competition to meet needs in other sectors.

Biomethane will play a critical role in replacing natural gas for high-temperature applications that are hard to electrify, potentially reaching 300 TWh of biogas output by 2030, according to the European Biogas Association's projections.

In the short term, most scenarios expect industrial consumption to remain at similar levels to current ones, at between 300 and 400 TWh, which is equivalent to 10% to 15% of final energy demand. Looking ahead, long-term projections are more diverse and consumption is estimated to range from 200 to 600 TWh. According to the European Biogas Association's January 2025 report, potential output is estimated to climb as high as 1,580 TWh, which is notably higher than the various consumption scenarios. This variability is explained largely by the potential scarcity of biomass for industrial applications, as it may be redirected to meet requirements in other sectors, such as maritime transport and aviation. The dynamics of industrial demand and intersectoral reallocation raise uncertainty as to the role of bioenergy in the industrial future.

Chart 36 **Bioenergy demand scenarios in EU industry** (TWh, 2030-2050)



Notes: (1) Assumes 3,100 TWh as per IEA WEO scenarios
Sources: European Commission; Moeve analysis

03

Capitalising on momentum: accelerating decarbonisation in hard-to-abate sectors

3.1.

Adoption hierarchy for green molecules

The speed at which green molecules are embraced will be influenced by several factors, including the specific type of green molecule, the intended end-use sector, resource availability, decarbonisation efficiency and the alternatives competing to abate different industries. The European Union has the necessary tools to expedite the adoption of these molecules throughout the region.

The region has robust infrastructure in key sectors such as refuelling, aviation and energy. With some of the highest volumes of air and maritime traffic in the world, the European Union is home to globally significant ports and airports and is a core hub for aviation and refuelling. This strong infrastructure position is expected to facilitate the adoption of biofuels 2G and e-fuels (hydrogen-based fuels) for transport, contributing to the region's decarbonisation goals. Although Europe currently depends on biomass imports from Asia, the region holds a privileged position in terms of availability of the resources needed for the production of green molecules, including abundant biomass residues for 2G biofuels and the renewable energy resources necessary to develop competitive green hydrogen across Europe.

This is a considerable advantage in the transition to green molecules compared to other regions and is reflected in the number of hydrogen and 2G biofuel projects under development in the European Union. Specifically, Europe leads the global initiative in the development of hydrogen projects, with a total of 12.7 million tonnes per year (Mtpa) among its announced projects for 2030[23]. However, Hydrogen Europe estimates that the actual capacity by 2030 could be 2.3 Mtpa, taking into account the likelihood that some projects may not materialise. Europe would thus cover approximately 60% of its estimated regulatory demand. While these estimates fall short of the REPowerEU target of achieving an internal production capacity of 10 Mtpa by 2030, they reflect real and essential progress in developing the infrastructure needed to accelerate hydrogen production in the years ahead.

Furthermore, the current international landscape is led by China, which is at the forefront of electrolyser deployment for renewable hydrogen generation and accounts for more than half of the global committed capacity, with the aim of gaining independence from fossil fuels. Europe, for its part, holds second place in committed renewable hydrogen capacity, with around 20% of the global total. This push by China highlights an increasingly clear reality: strengthening energy security and industrial competitiveness through the energy transition is no longer just an option, but a strategic priority for Europe. Meeting and accelerating this progress will be key not only to covering domestic demand with local production, but also to laying the foundations of a market that will define the next decade.

[53] "Merchant Hydrogen Generation Market Size & Share 2025-2034", Global Market Insights

Within Europe, Spain is recognised as a leader in the Power-to-Hydrogen (PtH) project pipeline and has the most ambitious electrolysis target in the European Union for 2030. According to Hydrogen Europe, this leadership is attributed to Spain's favourable conditions related to energy resources and ambitious government initiatives[54]. In Iberia (Spain and Portugal), renewable hydrogen production of 0.39 Mtpa is forecast for 2030, associated with a generation capacity of 3 GW in Spain and 0.9 GW in Portugal. Although this figure falls below the 12 GW initially envisaged in Spain, this target remains in place and continues to underscore the country's commitment to this technology. Furthermore, deployment is expected to accelerate as the regulatory framework is consolidated, for example with the transposition of RED III in the transport sector, as well as with progress in grid access and connection procedures, and the materialisation of public funding that facilitates final investment decisions on large-scale projects. In this context, Spain holds a leading position in Europe, ahead of other benchmark markets such as Germany, where a deployment of 2.2 GW[55] is expected.

This Spanish leadership is due, in part, to the deployment that has already begun to materialise, with multiple players having reached final investment decision on their hydrogen projects. This is the case of Moeve, which has approved the first phase of the Andalusian Green Hydrogen Valley, Onuba, a 300 MW project with an investment exceeding 1 billion euros and the largest green hydrogen project in the EU dedicated to the energy industry. Repsol, for its part, has given the green light to a 100 MW electrolyser at Petronor, aimed at strengthening industrial decarbonisation. Also noteworthy are initiatives in their final construction phase, such as the bp and Iberdrola project in Castellón, with 25 MW.

At the European level, other cases are worth highlighting, particularly in Sweden, where this trend is also gaining momentum through projects such as Stegra, which has recently installed 740 MW of electrolysers, paving the way for the commissioning of the largest hydrogen production plant in Europe, whose output will be used as a feedstock in the manufacture of green steel.

SAF production stands out for biofuel project development. The European Union now has a SAF production capacity of 1.7 Mt, based mainly on HEFA technology, and new facilities are to be built between 2025 and 2030, bringing the total capacity to 4.5 million tonnes. Globally, the United States leads with a planned capacity of 7 million tonnes, however, it is currently prioritizing record production of fossil alternatives such as oil and gas.

It is worth noting that, in terms of the number of planned projects for SAF technology development, Europe stands out by concentrating the highest number of planned facilities. These future facilities account for around 44% of projects worldwide for an estimated capacity of 4.5 million tonnes.

Spain is ranked fourth worldwide among the countries with the greatest potential for SAF production. It currently has one HEFA plant in operation and another under construction. A further 5 projects have been announced for the period 2025–2030: 3 new PtL plants and 2 HEFA plants. It is estimated that SAF output in Spain could reach 1.55 Mt by 2030. But the investments currently announced foresee a production capacity of only 0.78 Mt by 2030, which is sufficient to meet the estimated demand for SAFs (HEFA) in 2030 but insufficient to satisfy the demand projected for 2040, for both SAFs (HEFA) and synthetic fuels (PtL).

Biofuels are therefore poised to play a pivotal role in decarbonisation and are already part of this process through SAFs renewable diesel for road transport and marine diesel and biomethanol for maritime transport. The resources needed to make and adopt these biofuels in the short term are currently available and can count on a high degree of technological maturity. In the medium-to-long term, however, the growing competitiveness of green hydrogen and its derivatives will reduce the exclusive reliance on biofuels for abatement. This will give rise to a scenario of technological coexistence in which biofuels and e-fuels will complement each other to meet regulatory and emissions reduction targets.

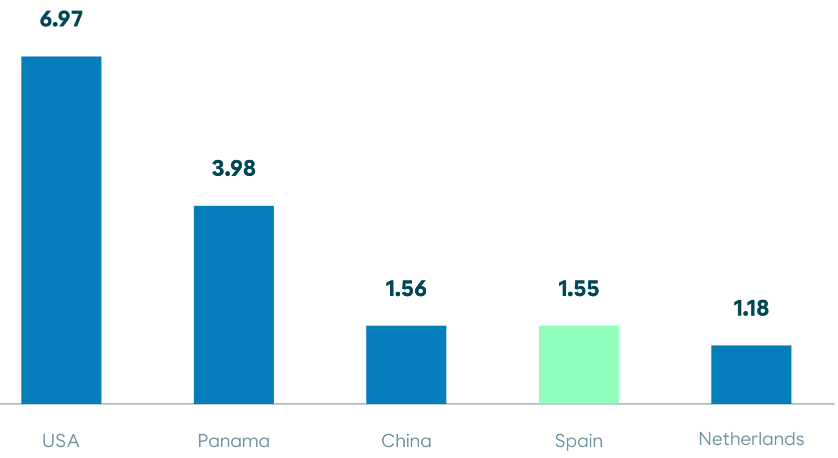
Europe accounts for around 30% of the global hydrogen supply announced for 2030, with Spain leading the way in Power-to-Hydrogen (PtH), aiming for a capacity of 3GW by 2030.

54 "Clean Hydrogen Monitor 2023", Hydrogen Europe

55 "Clean Hydrogen Monitor 2025", Hydrogen Europe

Chart 38 **Top 5 SAF-producing countries** (Mt[1], 2030)

The 5 main SAF-producing countries account for 66% of the projected total potential capacity for **2030.** Panama's high potential is explained by its position as an international fuel trading hub.



Notes: (1) 1 Mt = 33 TWh;
Sources: Argus Media, IEA Bioenergy and Moeve analysis

Green hydrogen and its derivatives will begin to steer decarbonisation in the European Union in the short-to-medium term, initially in industries where it is used as a feedstock and does not require large investments in CAPEX, renovation or modernisation. This will enable emissions to be trimmed in hard-to-abate industries such as refining and fertiliser production. As it becomes more competitive, green hydrogen will expand its reach to other sectors, such as the steel industry, maritime transport, through synthetic ammonia or methanol, heavy-duty road transport using long-range hydrogen trucks and aviation, where synthetic kerosene will be used on medium- and long-haul flights.

Hydrogen valleys, strategically located near industrial centres, petrochemical facilities, steelworks, ports and refineries, will play a pivotal role in the development of green molecules. Proximity to such infrastructures facilitates the integration of sustainable technologies and the scaling-up of e-fuel projects such as e-methanol and e-ammonia. The availability of clean, abundant hydrogen bolsters the viability of large-scale production in response to growing demand for sustainable alternatives in different industries.

The price stability of green hydrogen also makes it a particularly attractive option for sectors with predictable cost requirements, such as ammonia manufacturing for fertilisers. Unlike the traditional feedstock natural gas, green hydrogen offers a more stable cost structure, which is crucial for the agricultural sector. Gas price volatility can significantly affect farmers, particularly during critical periods such as the planting season, when demand for fertilisers peaks. By embracing green hydrogen, the agricultural industry can protect itself from these fluctuations, enhance economic efficiency in fertiliser production and achieve greater stability in crop development.

In this context, the adoption of green molecules and the pace of decarbonisation in hard-to-abate industries will be propelled by various factors. Biofuels are expected to play a core role in the immediate abatement of emissions in maritime transport, aviation and heavy-duty road transport. In parallel, green hydrogen will gain prominence as a raw material in industries such as fertilisers and refineries. In the medium-to-long term, the role of hydrogen-based fuels will become increasingly important in transport, particularly since the scarcity of biomass hinders biofuel scalability.

Chart 38 Hierarchy of green molecule solutions

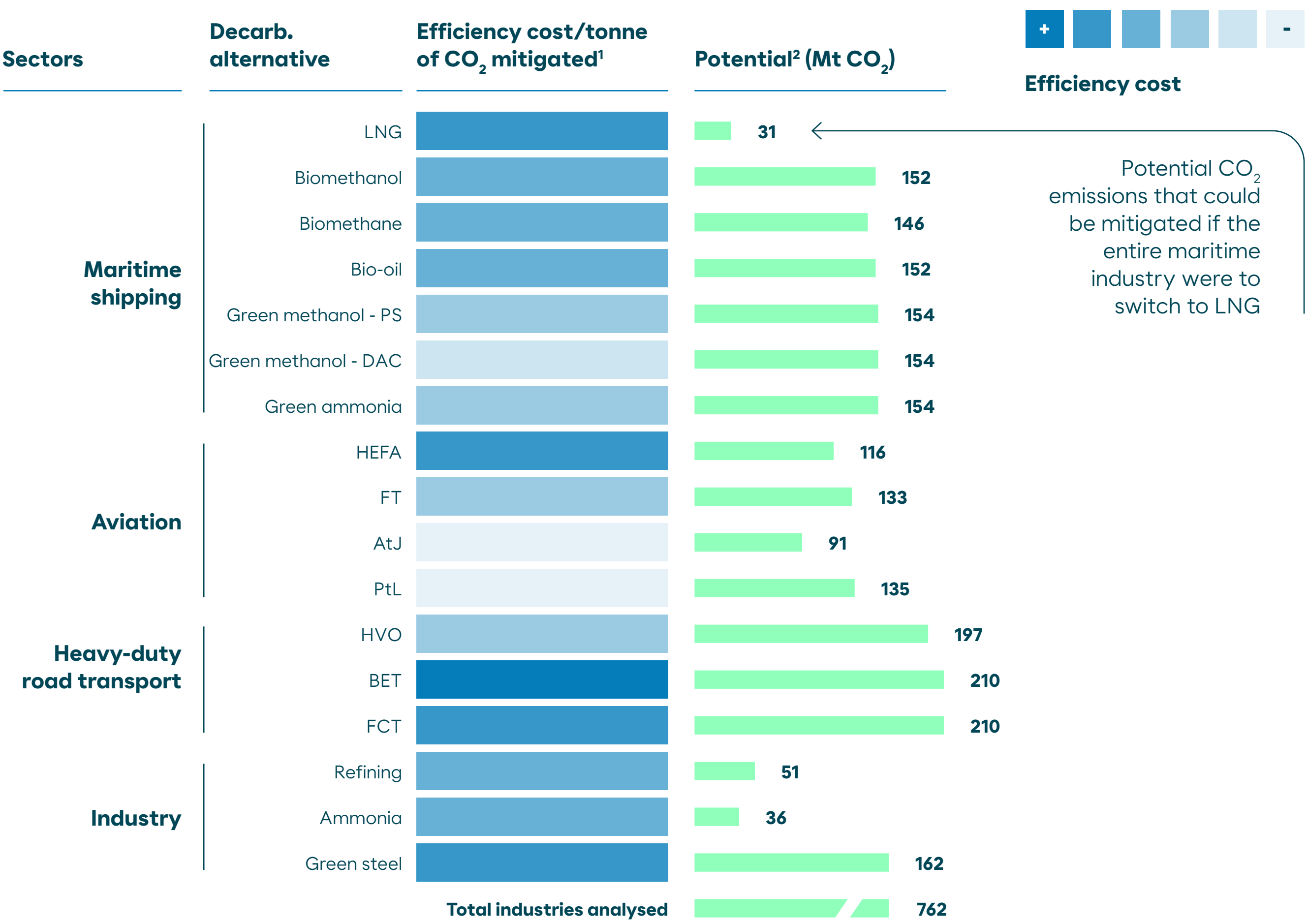
Sources: Moeve analysis based on Ramboll Group

When assessing the speed of adoption of green molecules in various hard-to-abate industries, it is essential to analyse the intensity and efficiency of decarbonisation among the various options available so as to prioritise the most efficient decarbonisation route, given that each application allows a certain volume of emissions to be cut at an associated cost.

After battery electric vehicles (BEVs) and fuel cells trucks (FCTs) for heavy-duty road transport, the most effective abatement strategies include the use of ammonia for fertiliser production, biofuels in the maritime and aviation sectors, and green steel. These solutions not only enable cost-effective emissions abatement but also show potential to significantly reduce emissions.

However, although industries such as steel may find cutting emissions to be cost-effective, the need to modify production processes and purchase new equipment, entailing major CAPEX investments, could slow the pace of decarbonisation and emissions reduction in this sector. Meanwhile, industries that do not need to invest in new CAPEX or production process alterations, such as fertilisers, refineries and, in particular, biofuels for transport, have the potential to accelerate sectoral decarbonisation. These sectors are exposed to less risk in the transition to green molecules, facilitating faster adoption and contributing effectively to global decarbonisation objectives.

Chart 39 Emissions reduction cost matrix



Notes: (1) Compared to alternative fossil fuels. Calculated as (TCOi – TCOfossil) / (t CO_2efossil – t CO_2ei); (2) Potential for CO_2e reduction in Europe, estimated based on current CO_2e emissions and emission factor differences between the decarbonisation alternative and the conventional fossil fuel alternative.

Sources: Moeve analysis based on IEA, IRENA, Hydrogen Europe, EEA, WEF and MMM

3.2.

Cost advantage of green molecules over conventional fuels

Competition between green molecules and conventional fuels will play a crucial role in steering the evolution of green molecules in various sectors of Europe's economy. A sustainable economic transition must be guaranteed to avoid adverse effects on the region's economy and population.

The future competitiveness of fossil fuels versus green fuels will be determined by a number of factors that will vary depending on the type of fuel. In the case of conventional fossil fuels, such as kerosene, diesel, fuel oil or LNG, future prices will be influenced primarily by the cost of CO_2 emissions, as well as by Brent and natural gas prices.

Conversely, for biofuels such as bio-SAFs, biomethanol or renewable diesel, as well as hydrogen-based fuels such as ammonia, methanol or e-SAFs, the price of essential raw materials such as biomass, green hydrogen and captured CO_2 will be the key factors influencing final fuel prices.

Most market forecasts indicate that biofuels are on track to achieve price parity with fossil fuels in all hard-to-abate industries by the 2030s. Hydrogen-derived fuels are also expected to become competitive in the medium-to-long term, from the 2040s onwards. But each hard-to-abate sector has particular features affecting fuel competitiveness and requiring a detailed case-by-case analysis.

As the competitiveness of fuels depends on assumptions concerning feedstock costs, the Levelised Cost of Hydrogen (LCOH) and CCU, a sensitivity analysis has been conducted using different cost assumptions. We have examined the scenarios proposed by the IEA in its World Energy Outlook 2025 report, which projects Brent prices, natural gas prices, CO_2 emissions and LCOH assumptions. The IEA establishes three different scenarios: the Current Policies Scenario (CPS), which considers exclusively the policies and regulations already adopted into legislation, without assuming any new changes even if governments have indicated their intention to make them; the Stated Policies Scenario (STEPS), which broadens the reading of the policy landscape by also including those policies that have been formally presented but not yet adopted, as well as other official strategic documents; and the NZE Scenario, which defines the requirements needed to achieve climate neutrality by 2050 and limit global warming to 1.5°C. As for the assumptions on CCU, these rely on other sources, such as IRENA or the WEF, as the IEA does not provide a forecast on these prices.

Competitiveness of green molecules in the maritime industry

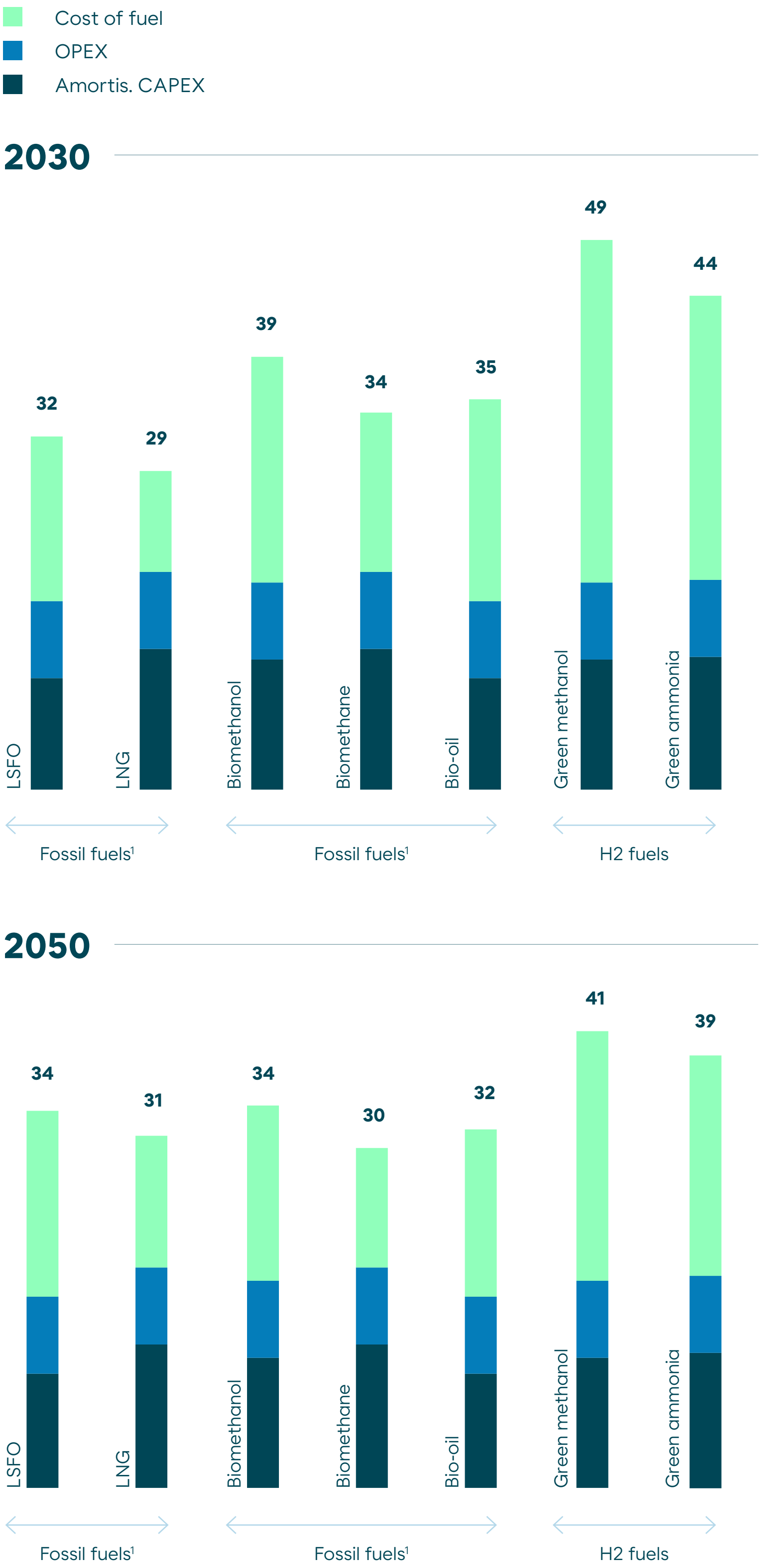
In the maritime sector, the competitiveness analysis focuses on the main alternatives for decarbonising large vessels, which account for 80-90% of emissions. This analysis entails assessing total cost of ownership (TCO), given that future fuel prices and the CAPEX and OPEX of various technologies all impact future competitiveness.

Fossil fuel alternatives analysed include LSFO and LNG. The price of these fuels is projected to rise between 2030 and 2050, triggered by considerable growth in emissions, which will undermine their competitiveness.

As regards biofuels, particular attention has been paid to biomethanol, biomethane and renewable diesel vessels, in view of high expectations of future adoption. Among them, biomethane and bio-oils such as renewable diesel are the most competitive and are expected to reach price parity with fossil fuels in the 2030s, positioning themselves as the best-performing biofuels.

A notable decrease in the prices of hydrogen-based fuels is anticipated, supported by the reduction in the cost of green hydrogen, which is estimated to have a production cost below €2/kg by 2050, following a drastic reduction in electrolyzer costs and reduced renewable electricity prices. The key fuels in this category include methanol produced through Point Source Capture (PS) or Direct Air Capture (DAC) of CO_2, and ammonia. These fuels are expected to achieve price parity with conventional LSFO by the end of the 2050s, although this could occur even earlier in regions with abundant resources.

Chart 40 TCO for container transport technologies (M€ al año)



Notes: (1) CO_2 emissions considered
Sources: IEA; MMM - Mærsk Mc-Kinney Møller Center for Zero-Carbon Shipping; IRENA; Moeve analysis

Biomethane is positioned as the most competitive green molecule for decarbonising the maritime sector in both the short and long term, taking advantage of existing port and maritime transport infrastructure.

SAF competitiveness

The aviation industry makes a significant contribution to emissions, particularly during medium- and long-haul flights, which account for 80-90% of the sector's emissions, and is undergoing a major shift towards decarbonisation. This focus on sustainability has drawn attention to alternatives such as SAFs, which could replace traditional kerosene. The future competitiveness of SAFs has to be assessed to ensure a sustainable energy transition in the industry.

With this in mind, a correlation was established with the future price of Brent crude oil so as to forecast future kerosene prices. The corresponding costs of CO_2 emissions per tonne of kerosene were then added to the equation. This comprehensive approach provides a solid benchmark for assessing the future competitiveness of SAFs.

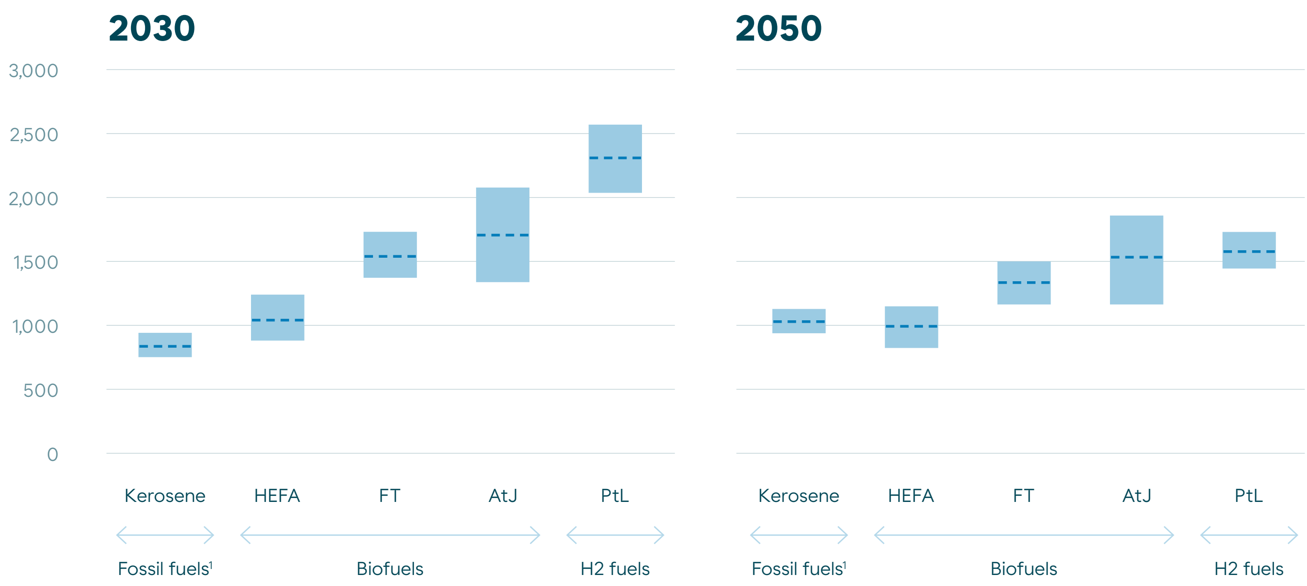
In this context, the costs of aviation fuels based on biofuels and hydrogen are not uniform. HEFA technology appears to be the most economical option, reaching cost parity with conventional kerosene in the 2030s. Its strength lies in its technical and commercial maturity, as well as reliance on affordable raw materials, such as used oil and waste. Projections suggest that HEFA prices will remain stable, with a slight fall attributed to the expected reduction in the price of hydrogen used for fuel production.

FT and AtJ routes are less competitive, mainly because they are less technologically mature and require higher CAPEX. But their competitiveness is expected to improve as the technology matures and CAPEX declines, reaching cost parity with fossil fuels by the end of the 2040s.

Meanwhile, PtL is the most expensive short-term option due to being an emerging technology with high feedstock costs, particularly green hydrogen, which accounts for more than 70% of production costs. Despite these challenges, the price of PtL will potentially be considerably lower in the future, depending on the trend in energy and green hydrogen prices. PtL is forecast to be able to compete with traditional fuels by the end of the 2040s, particularly if the downward trend in the levelised cost of hydrogen (LCOH) continues, as this will substantially improve the production costs of synthetic kerosene.

In short, the competitiveness of green aviation fuels depends on several factors, such as manufacturing processes, technological maturity and CAPEX. Although HEFA is now the market leader, PtL has great potential going forward. The performance of these factors will be decisive for the competitive development of SAFs in relation to traditional kerosene.

Chart 41 Range of SAF cost scenarios (€/t)



Notes: (1) Includes CO_2 emission costs
Sources: IEA; WEF; Moeve analysis

Competitiveness of green molecules in road transport

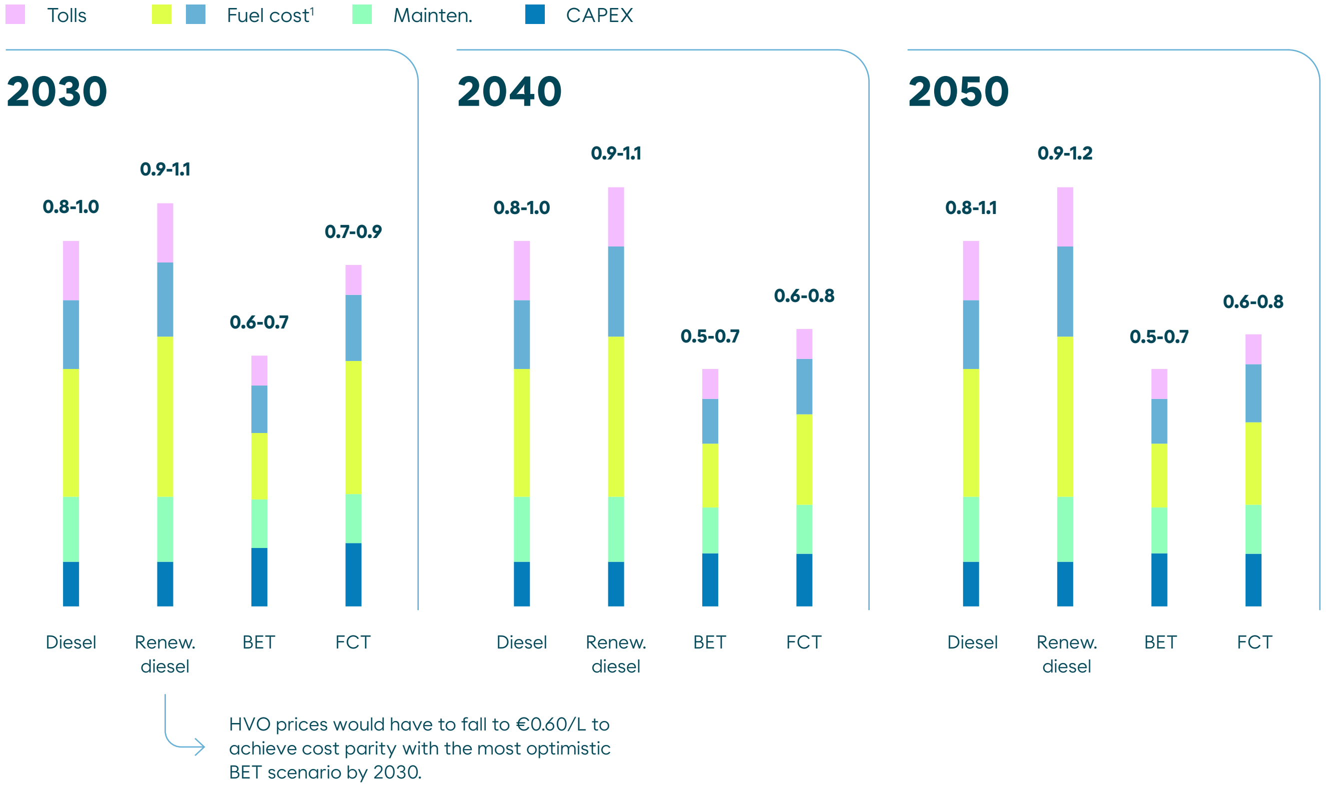
In the heavy-duty road transport sector, the future competitiveness of green molecules is key, above all in the trucking segment. The adoption of these molecules is expected to have a major impact, with the spotlight on renewable diesel and hydrogen-powered fuel cells.

Four main fuels dominate the industry: traditional diesel, renewable diesel, power for charging electric trucks and hydrogen for fuel cells (FCT). The competitiveness evaluation focuses on TCO, taking account of the crucial effect of CAPEX on competition among the various abatement alternatives, along with fuel costs.

Renewable diesel is emerging as a potential competitor to traditional diesel, offering cost advantages by removing the expense associated with CO_2 emissions. But battery electric trucks (BET) are now seen to be the most competitive option. Despite higher initial CAPEX, lower maintenance costs and energy efficiency, cutting operating costs, will make them more competitive than traditional diesel by 2030. Fuel cell vehicles are also projected to be more competitive than traditional diesel by 2030 and even more so by 2050, thanks to falling hydrogen prices and CAPEX.

A key factor enhancing the competitiveness of these options is the reduction in tolls for zero-emission vehicles (BET and FCT) under European regulations. This regulatory aspect is a further incentive to embrace more sustainable heavy-duty road transport solutions, making greener alternatives even more competitive.

Chart 42 TCO for heavy-duty trucking technologies (€/Km)



Notes: (1) The shaded area represents the high range of fuel costs
Sources: Moeve analysis

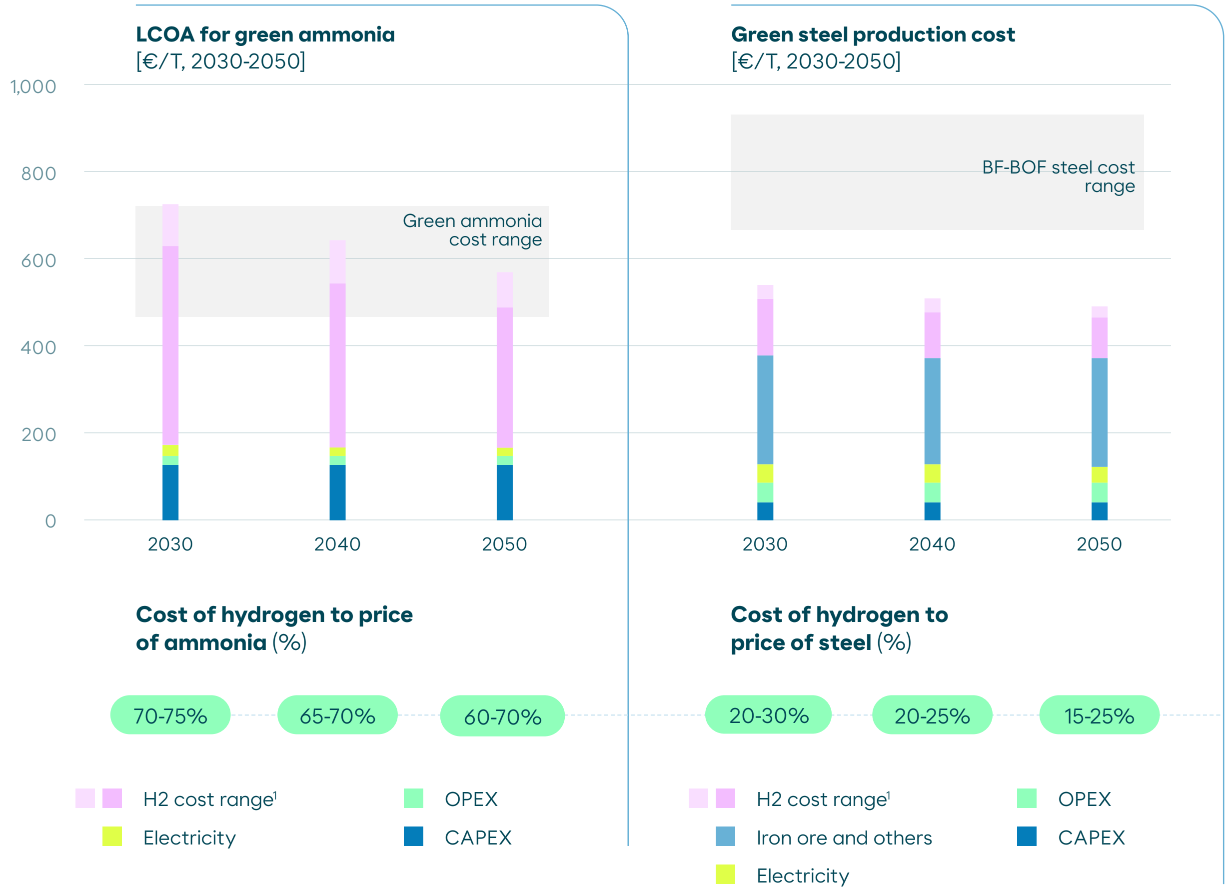
Competitiveness of green molecules in industry

In the industrial sector, decarbonisation is progressing through various technology solutions tailored to specific end uses and the characteristics of each industry. In a comprehensive analysis of green molecule competitiveness in industry abatement, the green ammonia and green steel industries come to the fore. Others, such as non-metallic minerals, are adopting different approaches to decarbonisation, relying on technologies such as carbon capture, energy efficiency improvements and optimisation in the use of materials, each of which plays a core role in the overall abatement process.

Focusing on the green ammonia industry, competitiveness depends on the production method and here steam methane reforming (SMR) stands out. Competitiveness is estimated by reference to the price of natural gas, a key feedstock for grey ammonia, coupled with the emissions associated with the production of one tonne of this fuel, based on CO_2 emission prices. Green ammonia production is focusing on green hydrogen. Projections suggest that this type of ammonia will achieve cost parity with grey ammonia by 2040s.

The steel industry, engaged in green steel production, is another critical sector when assessing the competitiveness of green molecules in industry, driven by green hydrogen. This transformative process has the potential to become competitive from the 2030s onwards.

Chart 43 Levelised Cost of Ammonia (LCOA) for green ammonia and green steel production costs



Notes: (1) The shaded area represents the high range of H2 costs
Sources: Hydrogen Europe; IEA; Moeve analysis

3.3.

Green premium: exploring the impact of the green premium on prices perceived by end users

Amid growing concerns about environmental sustainability, industries are increasingly exploring the integration of green molecules into their production processes. This momentum is propelled both by the desire to stay competitive in the market and by regulatory obligations and voluntary commitments to decarbonise operations, particularly to address Scope 3 emissions[56].

Collaboration among different industries is essential to boost the market for green molecules. Automotive industry and food and beverage sector companies are establishing strategic alliances with steel and green ammonia producers to develop fossil fuel-free products. This transition towards more sustainable solutions is in response to growing market demand and the need to align with global abatement efforts.

Early adopters of these technologies play a pivotal role in accelerating change within their industries. Indeed, many large companies are trying to avoid falling behind in the race to sustainability. According to WEF studies, around 20% of steel producers worldwide have already committed to net-zero emissions targets.

[56] Scope 3 emissions refer to indirect greenhouse gas emissions taking place in an undertaking's value chain but not generated directly by its own operations or by the energy it consumes.

For companies operating in different markets, embracing more sustainable business approaches is both an environmental pledge and a commercial opportunity in emerging low-carbon markets. An example of this is Yara International, a leader in crop nutrition, which has leveraged its abatement strategy to gain a competitive advantage in the production of green ammonia. Besides using it in fertilisers, Yara has begun to market green ammonia as transport fuel, demonstrating the potential for innovation and diversification in the transition towards a more sustainable economy.

When assessing the short-term impact of the green premium on various products, until green molecules reach price parity with conventional fuels expected in the 2040s, it becomes clear that the additional costs will tend to be passed on along the product value chain. But most products will only become 1-5% more expensive.

Chart 44 Assessment of the green premium for key hard-to-abate industries in 2030

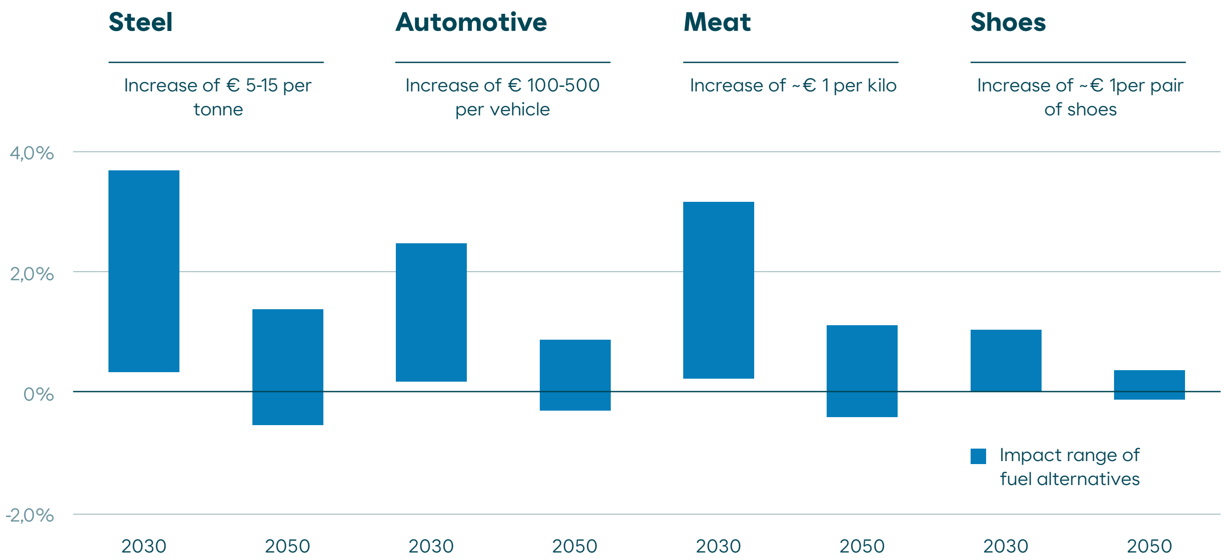
Hard-to-abate industries	Steelmakers **Metallurgical coal**	Fertilisers **Grey H2**	Maritime transport **Marine fuel**	Aviation **Kerosene**
Decarb. alternative	Green H2 for DRI-EAF route	Green H2 / ammonia in urea plant	Biofuels (methanol, LNG or diesel) in e-methanol and ammonia vessels	Bio-based such as HEFA, FT, AtJ and green hydrogen-based such as PtL
Green premium impact	**1-2%** Passenger car	**1-5%** Wheat and maize	**1-4%** Retail price increase	**1-5%** Ticket price increase

Sources: Moeve analysis based on Hydrogen Europe, IEA, Mærsk Mc-Kinney Møller and WEF

For example, opting for green steel in car manufacturing could trigger a price increase of less than 2%. Similarly, bringing green ammonia into farming processes is expected to have a limited effect on fertiliser prices and thus on crops. It is estimated that the average impact on the price of wheat and maize will be 1% to 5%, attributed to the green premium for sustainable practices. These examples show that the transition to green alternatives has a moderate effect on various industries. The feasibility of integrating green molecules at no excessive cost suggests that this shift is acceptable in terms of market dynamics and consumer preferences.

A similar trend can be observed in the maritime shipping industry. Although some eco-friendly vessels currently cost two to three times as much as conventional ones, the impact on the final price of products would be limited. This is because transport costs are only a small fraction of the final price, so the estimated increase in the retail price would be between 1% and 4%. In this context, and until price parity is reached, the additional cost of shipping, for example, a pair of sneakers using green fuels would be around 50 cents per unit. Industries are increasingly turning to sustainable transport options and consumers are becoming more willing to pay a green premium. In this context, the additional costs of green vessels are assessed in connection with sustainability goals, reaffirming the sector's commitment to more responsible practices.

Chart 45 Impact of the transport green premium on retail prices



Assumed retail price

Steel	Automotive	Meat	Shoes
~600 €/ton	~30,000 €	~20 €/kg	~100 €/par

Assumed transport price

Steel	Automotive	Meat	Shoes
25 – 30 €/ton	800 – 1,000 €	~1 €/kg	1 - 2 €

Sources: IEA; MMM - Mærsk Mc-Kinney Møller Center for Zero-Carbon Shipping; Moeve analysis

In the aviation industry, the gradual adoption of SAFs, in line with regulatory objectives, will trigger moderate growth in ticket prices. SAFs are currently between two and three times more expensive than conventional fuels, but their impact on the final price will be gradual, as they will be added to the fuel mix progressively. As their use expands, technological advances are expected to bring down the cost, while the price of traditional kerosene might rise due to the increasing cost of CO_2 emissions. The resulting estimated impact on ticket prices will range from €1 to €5 for intra-European flights and up to €40 for transoceanic routes.

So the green premium paid by consumers varies from industry to industry, but the overall effect tends to be limited. Growing demand for sustainable products, particularly in advanced economies such as Europe, also helps to mitigate this effect. According to a report by the Mærsk Mc-Kinney Møller Center for Zero-Carbon Shipping, 70% of European consumers are willing to pay up to 5% more for sustainable products. This trend suggests a positive market response and momentum for the continued adoption of green molecules and more environmentally friendly practices across various industries.

04

What is needed to unlock green industrialisation in Europe

4.1.

Addressing a major challenge by harnessing existing infrastructure, natural resources and current uses of demand

Europe is ready to play a leading role in global abatement efforts and ensure the widespread adoption of green molecules. The region has several drivers contributing to a green transition. They include the capacity to make hydrogen-based fuels in a cost-competitive way thanks to the region's abundant ability to generate competitive renewable power and therefore green hydrogen. Europe also has policies encouraging the reuse of waste for biofuels, which, together with biomass and forestry practices, provide the necessary feedstocks for their production. European state-of-the-art infrastructure is both technologically advanced and well-integrated. Diverse consumption patterns from country to country and Europe's robust industry give the region some of the world's most important industrial, supply and aviation hubs. The need to ensure energy security and independence, coupled with power grid limitations, highlights the need to integrate green molecules into the European abatement strategy. By capitalising on the strengths of both energy carriers, Europe can bolster a resilient, sustainable energy transition towards a low-carbon economy. All these factors give Europe a number of competitive advantages over other regions when embracing green molecules.

One key medium-to-long-term driver for developing green molecules in Europe is the availability of abundant, efficient, competitive renewable energy to profitably produce hydrogen. The power needed for green hydrogen production accounts for around 70% of the cost, so cost efficiency must necessarily be optimised.

Southern Europe, particularly the Iberian Peninsula, is emerging as a region with considerable potential for achieving a highly competitive Levelised Cost of Hydrogen (LCOH).

This potential is explained by a very competitive Levelised Cost of Electricity (LCOE), thanks to abundant solar photovoltaic and onshore wind resources. As indicated in Goldman Sachs' analysis entitled "Carbonomics: The Clean Hydrogen Revolution", projections suggest that, by 2030, Spain and Portugal could produce green hydrogen at approximately half the cost compared to Central Europe and the Nordic countries, becoming a potential large-scale supplier of green molecules in the region. The synergy between the huge wind resources in northern Europe and the solar radiation in southern Europe reflects optimal conditions for the development of efficient wind farms and solar facilities. These renewable sources play a core role in guaranteeing the lowest Levelised Cost of Electricity (LCOE) and facilitate the roll-out and scaling of hydrogen-based green molecules across the region.

Southern Europe, particularly the Iberian Peninsula, has enormous potential for producing green hydrogen at a highly competitive LCOH, almost half that of northern Europe.

The entire southern region of Europe benefits from high solar radiation, so electricity costs are very competitive. Combined with abundant wind currents in northern Europe and backed by land and sea technologies, these conditions are an optimal environment for developing efficient wind farms and solar facilities throughout the region.

The development of green molecules using green hydrogen is expected to be a collaborative effort across the region, harnessing Europe's competitive renewable energy. This collective approach, spanning several countries, aims to produce hydrogen and synthetic fuels competitively, capitalising on the region's extensive investment and technological development in renewable energy, coupled with abundant natural resources for sustained growth.

According to the "Clean Hydrogen Monitor 2025" report by Hydrogen Europe[57], and in line with studies by the Hydrogen Council and the European Hydrogen Backbone, announced projects in the European Union total 12.7 Mtpa of green hydrogen production by 2030, although currently only 5% of these projects are in the development phase. The study identifies southern Europe, highlighting regions such as Iberia, as well as northern Europe, including the Nordic countries and the United Kingdom, as the main future producers. These regions are anticipated to contribute more than 70% of hydrogen supply by 2040, leveraging their abundant natural resources, with solar energy predominating in the south and wind in the north. This underscores the strategic role of the various European regions in meeting hydrogen demand and advancing the transition to green energy.

[57] "Clean Hydrogen Monitor 2025", Hydrogen Europe

In terms of biomass resource availability and the use of organic waste for the development of 2G biofuels, Europe holds a prominent position. The continent benefits from diverse ecosystems and climates, which contribute to an abundant and varied supply of biomass. This pool of resources includes a range of organic materials such as agricultural and livestock waste, forestry by-products and organic waste streams from various sectors. Sustainable forestry practices play a crucial role in maintaining biomass availability for energy production, while simultaneously ensuring the preservation of biodiversity and ecosystem health. The rich and varied biomass resources in Europe provide a foundation for the sustainable development of renewable biofuels.

This abundance of biomass resources represents an excellent opportunity to produce 2G biofuels, contribute to sustainable energy solutions and decarbonise hard-to-abate sectors. However, it is essential to recognise that demand for biomass is expected to grow considerably going forward, propelled by rising heating needs and the use of biomass for second-generation biofuels. According to several publicly available studies, such as those conducted by Concawe and Imperial College London, together with scenarios prepared by the European Commission, the availability of second-generation biofuels could range between 1,800 TWh and 3,000 TWh by 2050, depending on the scenarios considered.

In view of this high biomass capacity, Europe also has significant potential to make biogas. At the European level, as mentioned previously, resources are available to promote both circularity and the reuse of organic resources, as well as to increase waste recovery for use in the production of renewable gas such as biomethane.

The main advantage of biomethane lies in its molecular composition, which is identical to that of natural gas, giving it the same properties. This similarity puts biomethane in a key position, as it can be used as a direct substitute. So it is an immediate, short-term abatement solution for a broad range of applications.

The adoption of biomethane as a replacement for fossil fuels is essential to accelerate the transition to a low-carbon economy in many sectors. The direct replacement of natural gas makes it a practical solution for decarbonising energy systems without the need for major changes to existing infrastructure. Biomethane can be used in the same equipment and networks, reducing reliance on fossil fuels while leveraging existing gas infrastructure to support sustainable energy flows.

Biomethane is therefore the key renewable alternative for decarbonising gas networks for residential, commercial and industrial uses, without affecting end users, who can continue to use the same equipment while decarbonising thermal applications.

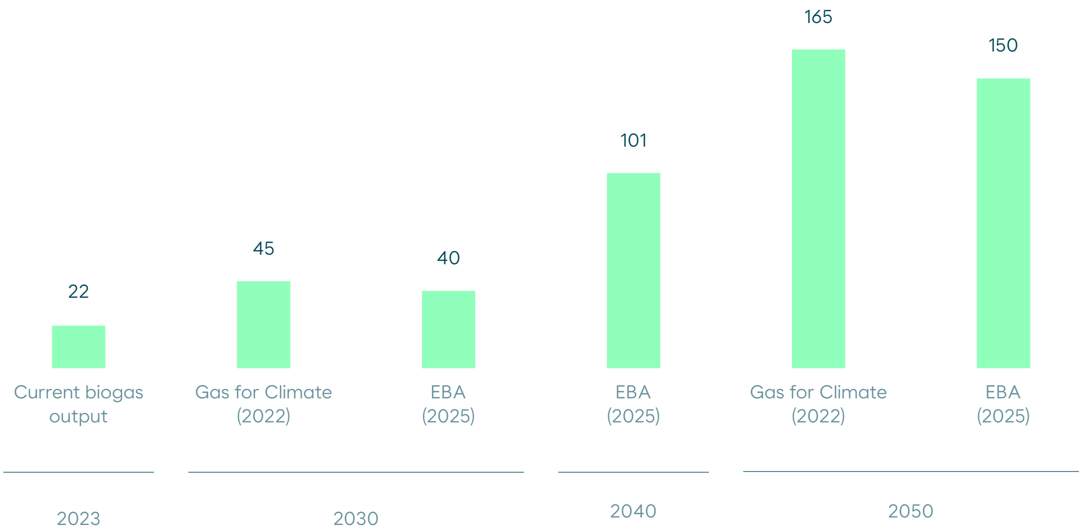
In high-emission industries that rely on medium- and high-temperature processes, biomethane enables decarbonisation without disrupting operations, which is one of the most challenging areas for carbon abatement.

Biomethane also has significant potential for transport, in both maritime and land-based applications. The maritime shipping industry, which currently depends on petroleum derivatives such as fuel oil and diesel, could trim its environmental impact by embracing biomethane as a sustainable alternative to conventional fuels. Road transport, particularly heavy-duty goods vehicles, could also benefit from biomethane's cleaner emissions profile.

In addition, biomethane plays a vital role in green hydrogen production. Compatibility with SMR processes used to produce grey hydrogen enables an immediate transition to green hydrogen production, promoting the use of renewable resources and helping industries meet sustainability goals and abatement targets.

This combination of environmental conditions and resources allows Europe's potential biomethane capacity to become a key lever for decarbonisation. The European Biogas Association (EBA) has published a report highlighting both the current state of biogas production in Europe and its future potential. According to the report, biogas production in Europe reached 22 bcm/year in 2024. Furthermore, the report emphasises the continent's significant potential, estimating that between 2030 and 2050, biogas capacity could increase from 40 bcm/year to 150 bcm/year[58]. This potential biogas capacity by 2050 could cover around 45% of the European Union's current gas demand[59].

Chart 46 **Biomethane potential in Europe** (bcm/year)



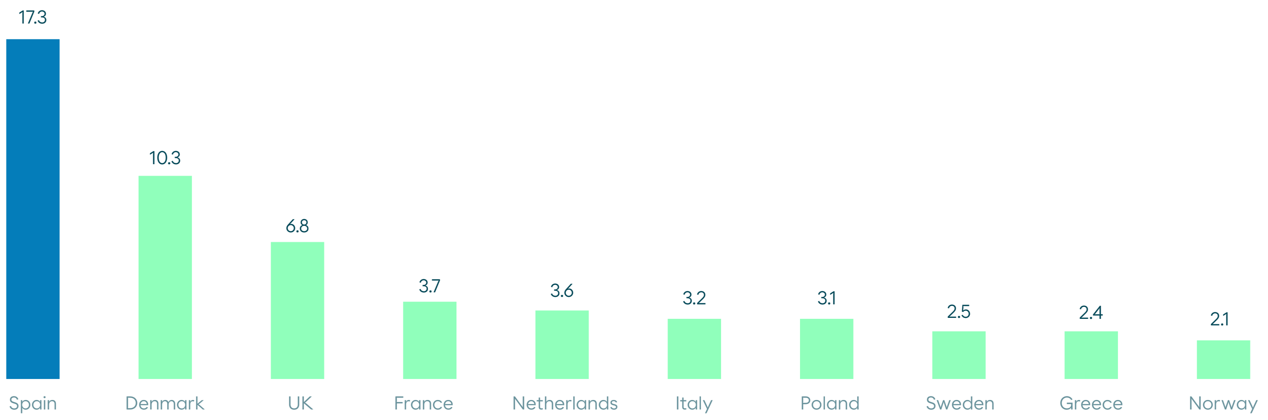
Sources: EBA (2025); Gas for Climate; Moeve analysis

[58] "EBA Statistical Report 2025", European Biogas Association

[59] "Estudio de la capacidad de producción de biometano en España", Sedigas

Within this production potential, Spain is well positioned to become a key player, particularly in biomethane production, where it ranks first[60] in terms of investment volumes and planned capacity in the short term.

Chart 47 **Top 10 countries with biomethane potential in Europe** (TWh/year)



Sources: EBA; Moeve analysis

Furthermore, various studies[61,62] offer different estimates for Spain's potential capacity in the long term, depending on the production sources considered, although all estimates remain high. According to studies by EBA and Gas for Climate, Spain's potential capacity is estimated to reach approximately 19.5 bcm/year by 2050.

Europe's commitment to the energy transition and abatement targets has steered investment and innovation in the renewable energy industry. Policy frameworks at the European Union level provide regulatory backing and incentives for the development and implementation of green molecule solutions. R&D (research and development) efforts are focused on competitiveness, efficiency and sustainability in the use of green molecules, as well as on collaboration between industry players and policymakers to drive innovation in biomass-based and hydrogen fuels, so as to maximise the environmental and economic benefits of using natural resources while minimising their environmental footprint. Overall, Europe's abundant, diverse natural resources, combined with continuous advances in green molecule technology and supportive policy frameworks, position the continent as a global leader in both output and demand.

When shaping the adoption of green molecules, Europe will be guided by consumption patterns, which are particularly influenced by existing supply hubs for maritime transport and airports. These well-established hubs are ready to play a pivotal role in facilitating the adoption of green molecules across the continent.

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60 "Biomethane investment outlook, 3rd edition", (2025), EBA

61 "Biogases towards 2040 and beyond", (2024), European Biogas Association

62 "Geographical analysis of biomethane potential and costs in Europe in 2050", Engie

As the global focus on decarbonising maritime shipping intensifies, major ports along the European coastline, such as Rotterdam, Antwerp, Algeciras and Huelva, will play a crucial role in meeting demand for biofuels and hydrogen-based fuels, as key supply hubs for the maritime shipping industry. Europe's extensive airport network, led by major airports such as Frankfurt, Charles de Gaulle (Paris) and Barajas (Madrid), also brings significant opportunities to embrace SAFs. Airlines are expected to drive demand for SAFs in order to reduce their carbon footprint and comply with stringent emissions regulations, further highlighting the relevance of its production hubs.

It will be essential for Europe to build infrastructure that promotes interconnection within the continent, as this will enable a single, integrated market to develop. Moeve participates in various projects that promote abatement and bolster the continent's energy security by building the infrastructure needed for the market of the future. Notable examples in Europe include the first green hydrogen maritime corridor linking Algeciras and Rotterdam, and the H2med corridor with the Bar-Mar connection, which is destined to be the backbone of the hydrogen value chain in Europe by 2030.

Thanks to these developments, Europe has the potential to become a hub for the production, distribution and consumption of green molecules. This transformation would significantly boost the continent's transition towards sustainable energy sources.

Similarly, green molecules will play a pivotal role in securing future energy supplies and facilitating efficient infrastructure development, especially given the risk of bottlenecks and the current grid saturation caused by extensive electrification efforts. Renewable energy sources such as wind and solar, crucial to abatement efforts, have intermittent, seasonal features. Relying solely on power grids to manage these fluctuations in energy output and demand may not be sufficient to attain the necessary stability and resilience in the energy system.

Green molecules are an alternative to traditional fuels, enabling extensive energy storage and diversification of energy sources. This ensures a reliable energy supply during periods of limited renewable energy generation, fostering energy independence and security of supply for Europe by reducing reliance on a single energy source. Transporting green molecules via pipelines or ships also offers significant advantages over transporting electricity via the grid.

4.2.

Barriers and challenges to accelerating the adoption of green molecules

Despite Europe's advantageous position with abundant natural resources and infrastructure, there are multifaceted challenges along the path to the widespread adoption of green molecules and the attainment of abatement targets. These challenges span various time frames and include technological, economic, regulatory and social dimensions. Effectively addressing these challenges will be crucial to unlock the full potential of green molecules in a sustainable, low-carbon future.

However, a number of support measures and enablers are being actively developed to prevent these challenges from becoming hindrances, such as ambitious regulatory targets and technology R&D alongside government subsidies and incentives, among others. Key stakeholder partnerships are helping in a determined effort to overcome obstacles and foster the adoption of green molecules across the board.

Chart 48 Key challenges and enablers for accelerating the adoption of green molecules

Sources: Moeve analysis

One of the main challenges lies in meeting the substantial investment requirements associated with the development of green molecules. High upfront costs of infrastructure and technology, combined with lengthy payback periods and market uncertainties, require careful planning and stakeholder cooperation to mitigate financial risks and assure long-term feasibility.

Ensuring an adequate sustainable supply of raw materials poses a significant challenge, particularly for second generation biofuels. Although biomass, municipal waste and used oils are essential feedstocks for these biofuels, their finite availability and scalability limitations highlight the need for innovative solutions to tackle potential supply shortages and price fluctuations. Similarly, obtaining CO_2 feedstock for e-fuel production poses logistical challenges that require strategic planning and investment in carbon capture technologies. There is also a risk that these raw materials may not be genuinely sustainable, a concern recently highlighted by the European Commission.

Infrastructure development is another critical area that needs attention, particularly as regards expanding the production and distribution of hydrogen, ammonia and methanol. The challenges to be overcome while implementing electrolysis technologies highlight the significance of strategic investments and collaborative efforts to expand infrastructure capacity and meet growing demand.

The current cost differences between green molecule technologies and conventional alternatives also represent a significant barrier to widespread adoption. But continuous technological advances, along with increased CO_2 emissions from fossil fuel alternatives and falling costs of renewable energy sources, offer prospects for gradual cost reductions that will ultimately improve the competitiveness of green molecules in the energy market.

Finally, end users' willingness to embrace abatement measures varies across industries and regions, depending on factors such as cost competitiveness, consumer preferences, economic considerations and awareness of decarbonisation and sustainable products. Addressing these challenges requires concerted efforts to raise awareness, encourage sustainable practices and build consensus among users to propel the transition towards a more sustainable, decarbonised energy future.

Various support measures and enablers have been implemented in different sectors to address uncertainties and overcome challenges so as to ensure a successful transition towards the adoption of green molecules.

Regulation emerges as the enabler of green molecules and is essential not only for setting ambitious targets but also for putting in place frameworks that stimulate production and adoption. Regulators are actively engaged in raising these targets and rolling out mechanisms to boost both output and demand. Crucial tasks still lie ahead, however, such as developing certification systems to guarantee the sustainability of manufacturing processes. Exploring options such as investment subsidies or tax benefits for early adopters of green molecules could also further incentivise the shift to green molecules. In infrastructure development, regulations play a core role in simplifying and streamlining project permitting processes.

The role of technological development in accelerating green molecules cannot be underestimated. Drawing parallels with the rapid growth observed in renewable solar and wind power generation, continuous technological advances are poised to deliver considerable cost reductions, particularly in hydrogen production. These advances are expected to bolster the competitiveness of green molecules, making them more viable alternatives to conventional solutions. As regards the use of green molecules as fuel, several challenges will be overcome as technological innovations progress. Although hydrogen has a high energy density per mass, its density per volume is low. This means that large storage facilities are needed or hydrogen has to be compressed or liquefied (increasing energy demand) to reduce its volume. Government subsidies, supplemented by price stabilisation mechanisms, are powerful tools to encourage investment in green molecule projects. Measures such as penalties for non-compliance with mandates or contracts for difference can assure stability and predictability for investors. Carbon pricing mechanisms and emissions caps can provide additional momentum and stimulate the adoption of sustainable energy solutions, further driving the transition towards green molecule technologies. Similarly, prioritising projects is crucial to concentrate aid rather than spreading it across multiple initiatives, thereby ensuring the feasibility of strategic projects. Furthermore, policies such as reducing grid access tolls can benefit the competitiveness of green hydrogen and e-fuel projects, enhancing and facilitating project development.

Besides regulatory support and financial incentives, partnerships between key public and private stakeholders also play a pivotal role in scaling up production and aligning it with market demand, mitigating risks for early investors. Through collaborative efforts, stakeholders can more effectively navigate logistical challenges by establishing long-term contracts and forging strategic alliances. By harnessing each other's experience and resources, stakeholders can steer innovation and facilitate the widespread adoption of green molecules, contributing significantly to the transition towards a sustainable energy future.

In short, although there remain significant challenges while pursuing abatement goals and advancing green molecules, coordinated efforts are under way to bring down these barriers and pave the way towards decarbonisation. Regulatory improvements, technological advances, financial incentives and strategic partnerships are driving this progress towards a sustainable energy future.

4.3.

Driving growth: promoting job creation and economic progress with sustainable green molecules

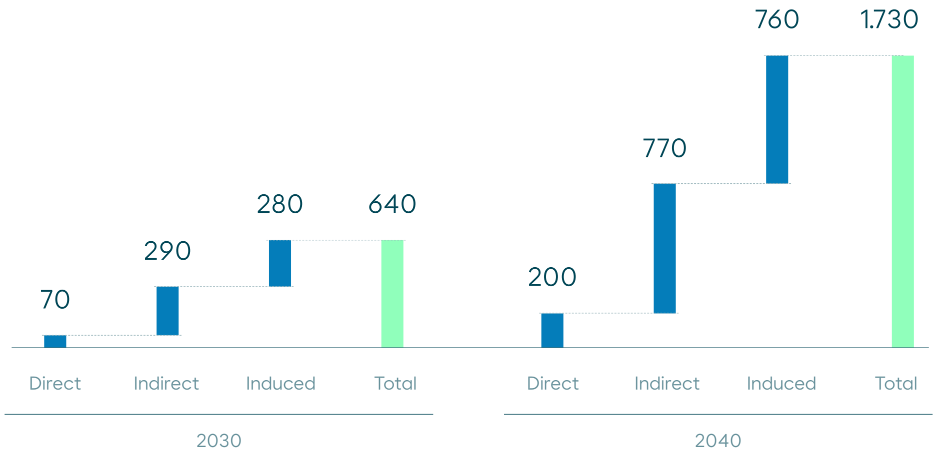
The energy transition facilitated by advances in green molecules is set to drive considerable growth in the European Union, with significant implications for regional employment opportunities and economic progress.

Beyond this widespread impact, certain EU regions blessed with abundant renewable resources with which to develop green molecules are ready to see even more striking benefits. These areas are destined to become hotspots for job creation, attracting talent and investment in green molecule technologies.

In a collaborative effort between ManpowerGroup and Moeve, a report entitled[63] "Green Molecules: The Imminent Revolution in Europe's Employment Market" delves into the economic and labour implications of green molecules in the European Union, spanning biofuels and green hydrogen derivatives. It also analyses the potential impact on some individual Member States, such as Spain, Germany, United Kingdom, France and Portugal, among others.

This report points out that the development of and investment in green molecules could generate between 1.7 million and 2 million new jobs (direct, indirect and induced employment) in the European Union and the United Kingdom, averaging around 100,000 jobs annually. More than 10% of this increase would take place directly within the energy industry, while around 40% would be indirect and the remaining 40% would affect the value chain in general. Notably, more than half of these new jobs would be linked to green hydrogen development and biofuels would account for approximately 40% of total job creation.

Chart 49 Impact of green molecules on employment growth in Europe (thousands of jobs)

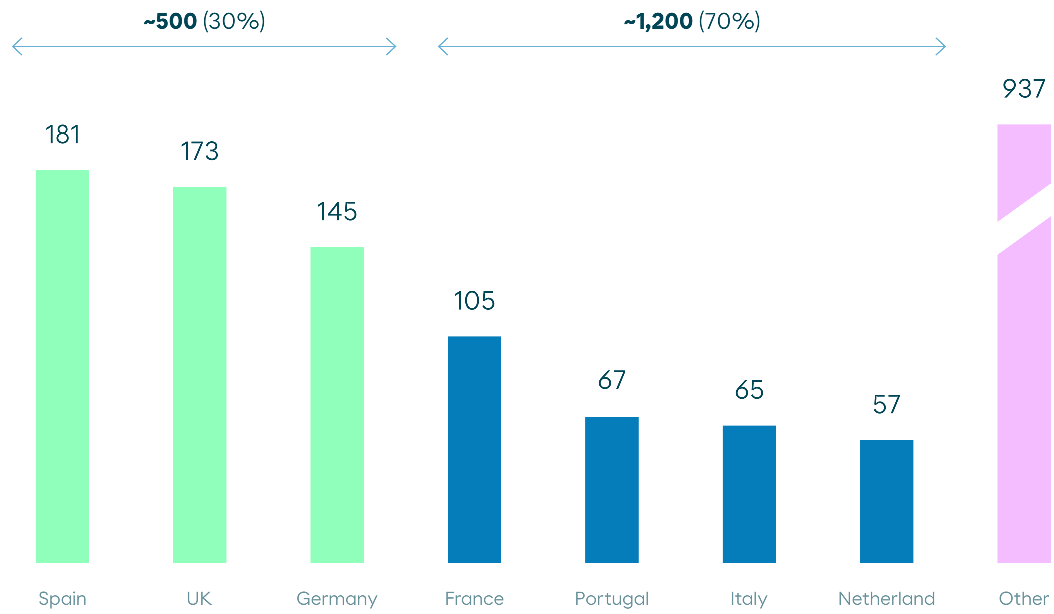


Sources: Manpower Group and Moeve analysis

[63] "Green Molecules: The Imminent Labor Market Revolution in Europe", Moeve & ManpowerGroup

When assessing the impact on job creation by European country, Spain emerges as the country with the greatest potential for generating jobs within the European Union, both in the short and long term, accounting for 10% of total employment, followed by the United Kingdom, Germany and France. This is attributed to conditions in southern Europe, particularly in the Iberian Peninsula, favouring the development of green molecules, as explained at the beginning of this section.

Chart 50 **Job creation by 2040** (thousands of jobs)



Sources: Manpower Group and Moeve analysis

Employment growth will also bring substantial economic benefits and has the potential to boost the region's GDP (Gross Domestic Product) by up to €145 billion by 2040, equivalent to an annual increase of €8.5 billion. In Spain, the advancement of green molecules could add approximately €15.6 billion to GDP by 2040, a potential 1% above the 2022 figure.

To estimate the effect of green hydrogen development on employment and economic growth in the European Union, European Hydrogen Backbone (EHB) projections for green hydrogen production are used throughout the report issued by Manpower and Moeve. These projections indicate an expected output of approximately 1.200–1.400 TWh of green hydrogen in the EU by 2040. It is important to note that these projections include UK output and exclude potential imports from North Africa or other non-European countries.

[64] https://ehb.eu/files/downloads/EHB-Supply-corridor-presentation-Full-version.pdf

So, the European Union's transition to a green economy is a compelling opportunity for economic growth and job creation. However, realising this vision also requires major investments to attain net-zero emissions targets and effectively decarbonise the economy. As underlined in the reports "New Energy Outlook: Europe" by BloombergNEF[65], "Net-Zero Europe: Decarbonization pathways and socioeconomic implications" by McKinsey[66] and "Road to Net Zero" by the Rosseau Institute[67], Europe's transition to a net-zero economy by 2050 will require investments in energy and related technologies totalling over €28-30 trillion from 2022 to 2050, of which approximately 20%, or around €5 trillion, will be incremental investments compared to a scenario devoid of climate action, as the remaining €23 trillion will come from redirecting investments that would have funded fossil fuel technologies. This investment is essential to deploy renewable energy sources, upgrade infrastructure and advance technologies that are crucial for reducing carbon emissions. BloombergNEF also estimates that the required hydrogen supply side investments will increase steadily over the years, expecting around €300-400 billion in the period 2022-2050.

Europe's transformation to a net-zero economy will require additional investments of €5 trillion between 2020 and 2050, less than the cost of inaction.

[65] "Energy sector investment requirements in Europe under BNEF Net Zero Scenario", BloombergNEF

[66] "Net-Zero Europe, Decarbonization pathways and socioeconomic implications", McKinsey

[67] "Road to Net-Zero, Bridging the Green Investment Gap", Institut Rousseau

4.4.

Counting the costs: the consequences of failing to decarbonise

The urgency and necessity of carbon abatement cannot be underestimated, as it is crucial to mitigating the increase in GHG emissions that would otherwise trigger temperature rises. The failure to address this issue would have severe, irreversible consequences for our future.

According to the IEA[68], if current infrastructure, including power plants now under construction, continues to operate as in the past, there will be a long-term temperature increase of approximately 1.65 °C. CO_2 emissions from 2020 to 2050 are projected to exceed by around 30% the total emissions permitted to effectively limit global warming to 1.5 °C[69].

But even with the goal of limiting global warming to 1.5 °C, the Earth is already experiencing temperature increases causing significant changes that can be mitigated but not eliminated. They include rising sea levels, melting ice caps, heat waves and flooding, among others. The findings of an IPCC report[70] on the effects of climate change point out that exceeding the 1.5 °C threshold would result in extreme events such as severe storms, intense heat waves, prolonged droughts and heavy rainfall. The consequences of such changes, including water scarcity and the displacement or extinction of flora and fauna, would be irreversible.

In a study undertaken by the European Commission[71], the economic implications of climate change were assessed, focusing specifically on the impact of global warming on the European Union and the United Kingdom under three warming scenarios: 1.5 °C, 2.0 °C and 3.0 °C. The study revealed that, as temperatures rise, the additional loss of well-being increases sharply, damaging capital stock, undermining economic output and impacting households. If the current economy is exposed to 3 °C global warming, the annual loss of well-being will amount to at least €54 billion (equivalent to 0.43% of GDP). Under a 2 °C scenario, the additional loss of well-being will amount to €18 billion per year (0.14% of GDP), while limiting warming to 1.5 °C will bring it down to €6 billion per year (0.05% of GDP). These findings underscore the significant economic implications of various warming scenarios and the importance of limiting global warming to mitigate the loss of well-being.

The study emphasises that well-being losses in southern regions are considerably higher than in northern regions. This underlines Spain's crucial role in the abatement process and its support of the European Union's climate change targets, because the failure to meet these goals would have a substantial adverse impact on the region.

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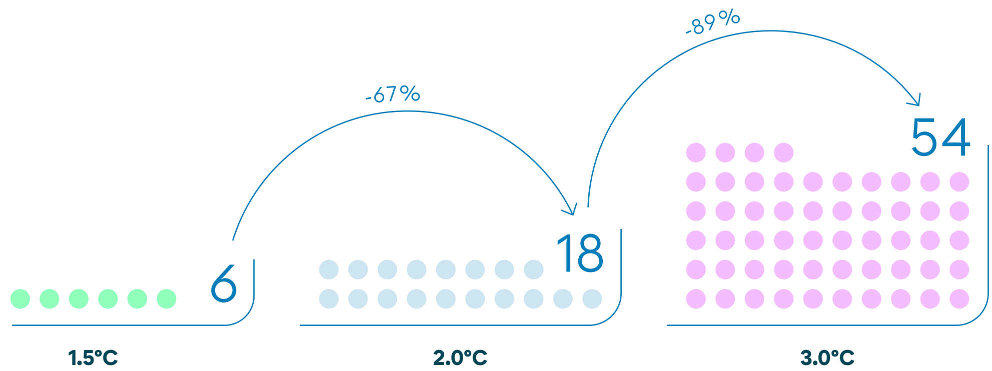
68 "Security of Clean Energy Transitions", International Energy Agency

69 "Net Zero by 2050 A Roadmap for the Global Energy Sector", IEA

70 Climate Change 2022: Impacts, Adaptation and Vulnerability (IPCC)

71 "Climate change impacts and adaptation in Europe", European Commission JRC

Chart 51 Annual loss of well-being due to the impacts of climate change (€bn)



Impact of loss of well-being on GDP

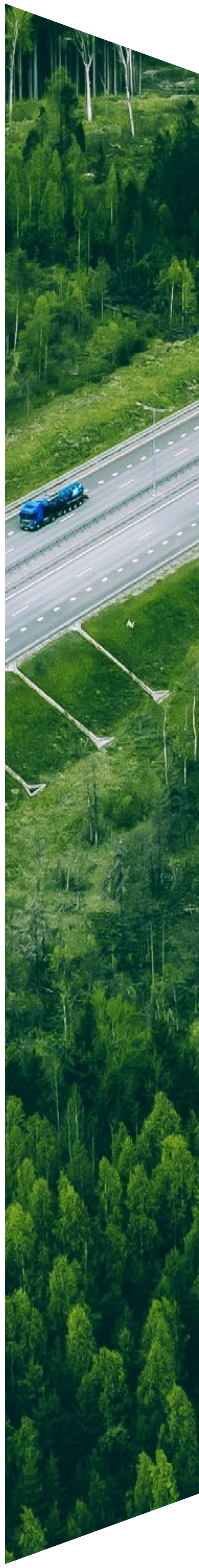
1.5°C	2.0°C	3.0°C
0.05%	0.14%	0.43%

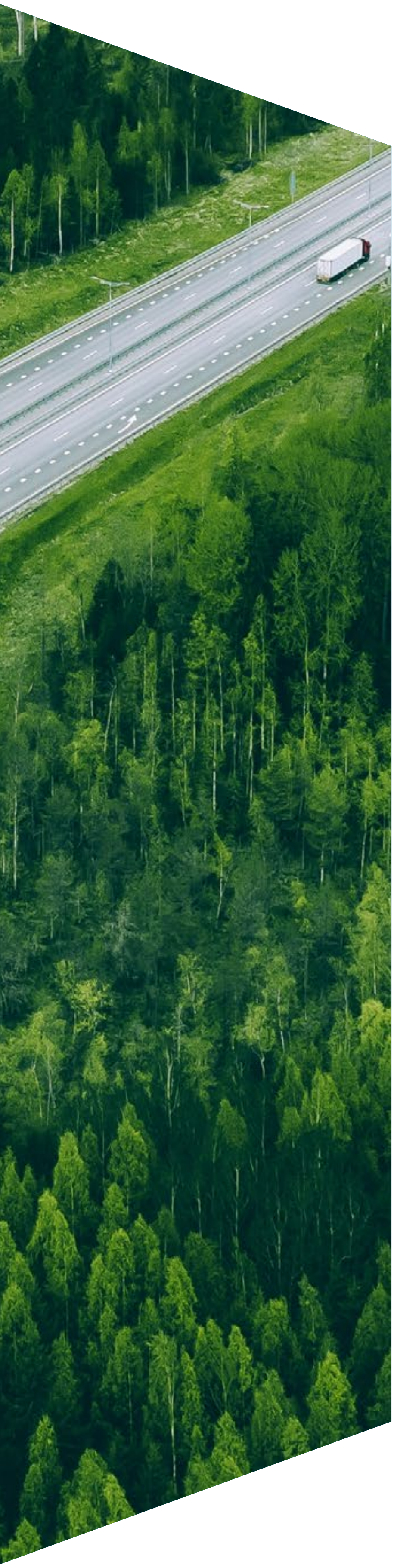
Sources: European Commission and PESETA IV

Climate change is also expected to act as a multiplier of poverty, intensifying current levels. Climate change alone is projected to push an additional 100 million people into poverty by 2030[72]. This is attributed primarily to adverse effects on agriculture followed by increases in food prices, conflicts over limited resources, displacement of entire populations and a decline in the availability of clean water, among other factors. These consequences highlight the urgent need to address climate change and its implications for poverty eradication efforts.

Ignoring climate change in Europe could entail losses of more than €6 trillion over the next 50 years, while achieving climate goals could trigger economic benefits of up to €730 billion.

[72] "Climate Change and Development Series Managing the Impacts of Climate Change on Poverty", World Bank





Finally, based on a report by Deloitte[73] in "The Turning Point", the failure to tackle climate change is forecast to lead to substantial destruction of GDP, reaching a staggering $178 trillion globally over the next 50 years in a 3 °C global temperature increase scenario. In Europe alone, the projected loss exceeds €6 trillion[74] during this period, with a potential risk of 110 million fewer jobs. Conversely, achieving global climate goals could potentially bring considerable economic benefits estimated at $43 trillion and €730 billion in economic gains globally and in Europe, respectively.

Failing to decarbonise the European economy would therefore have negative consequences not only for the environment and public health, but also from an economic perspective. Compared to the estimated additional investment of €5 trillion[75] needed to achieve climate neutrality by 2050, as described in section 4.3 based on the McKinsey analysis[76], the economic impact of failing to decarbonise would exceed the required investment by 10–20%, amounting to over €6 trillion in the next 50 years.

As mentioned above, decarbonisation could serve as a new economic driver, contributing over €730 billion to the European economies. This shows that investment in carbon abatement will generate a positive return for the economies of European countries. These findings underline the relevance of pursuing decarbonisation efforts for both environmental sustainability and economic prosperity.

Without decisive climate action, the EU risks facing losses of €6 trillion, well above the €5 trillion needed to attain carbon neutrality by 2050.

[73] "The turning point: A global summary", Deloitte

[74] Net present value, GDP

[75] The additional investment required to achieve Net Zero refers to the incremental investment needed in comparison to a scenario where no climate action is taken

[76] "Net-Zero Europe, Decarbonization pathways and socioeconomic implications", McKinsey

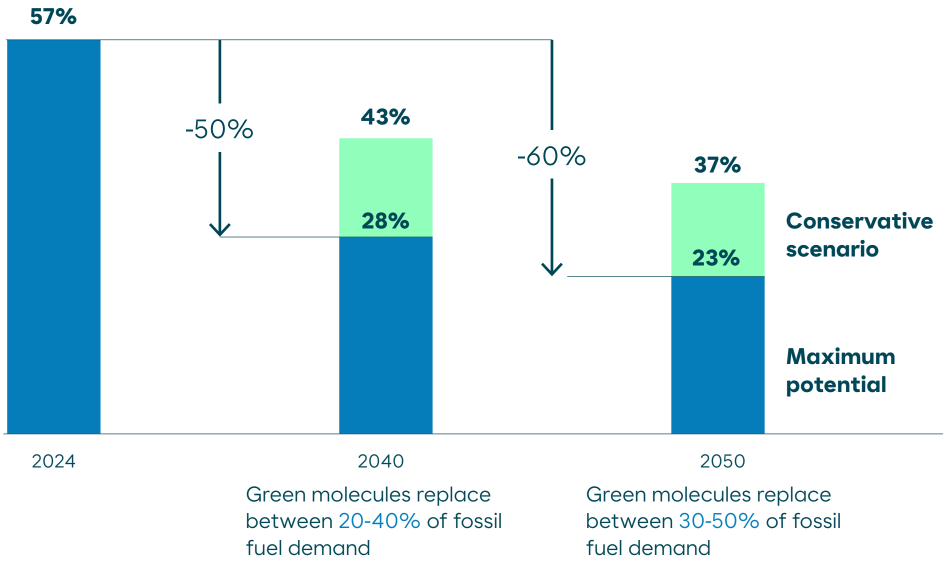
05

Green molecules, the driving force behind Europe's strategy

Green molecules represent the vital solution that will enable Europe to meet its current and future security of supply needs while also fulfilling its energy transition, energy sovereignty, reindustrialisation and industrial competitiveness objectives. These demands are even more pressing in light of recent international tensions, prompting Europe to consolidate its position as an autonomous continent and reduce its reliance on major powers in an increasingly fragmented world.

Moeve's vision is that, by 2040, green molecules could replace approximately 20% to 40% of the current demand for fossil fuels (half through biofuels and half through hydrogen), which would allow **the use of green molecules produced in Europe alone to bring down the European Union's external energy dependence by 50%[77], down to 28%.** By 2050, this shift could replace up to 50% of fossil fuel demand, reducing external energy dependence by 60%, **thus bolstering the continent's energy stability.**

Chart 52 **EU energy dependence after the rollout of green molecules** (% total demand, 2024)



Note: This analysis does not consider the impact of electrification and assumes a rollout of green molecules in line with decarbonisation targets.
Sources: Eurostat and Moeve analysis

Transforming external dependence and achieving technological sovereignty will require platforms that enable the full development of the green molecule value chain, particularly in view of China's growing dominance in the renewable energy market, in which Europe relies on raw materials from abroad.

[77] Eurostat and Moeve Analysis

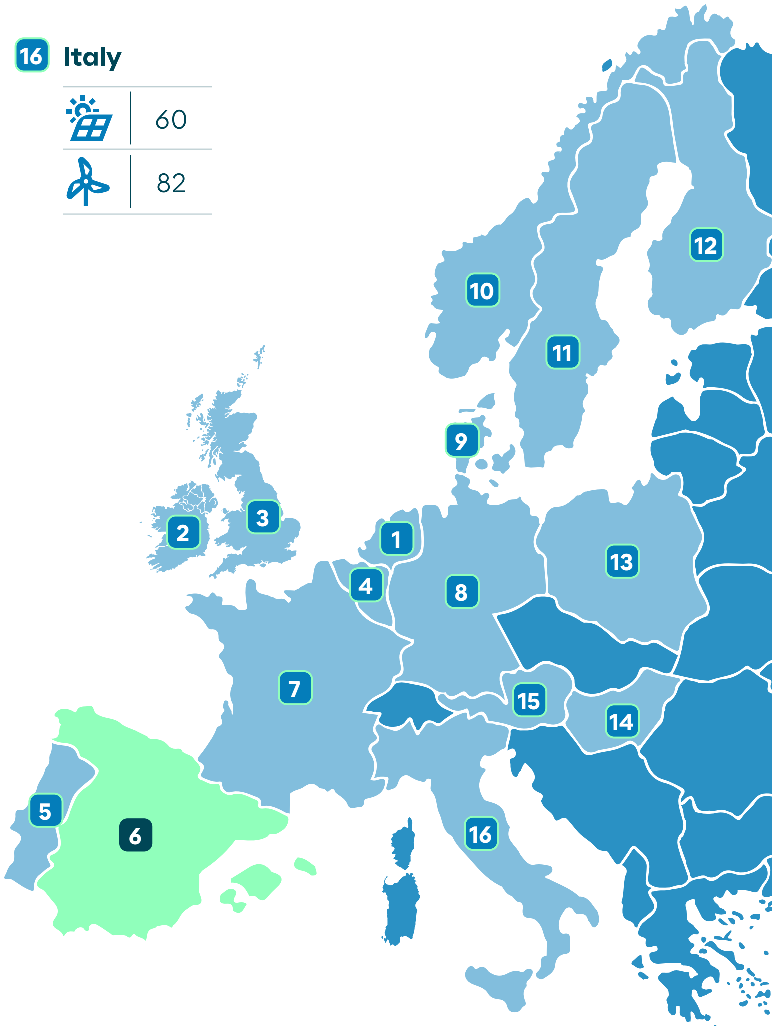
> As the impacts of climate change become more apparent and energy security is put at risk, demand for green solutions will grow, and in a world of decarbonised value chains, Europe can be a world leader.

Maarten Wetselaar, CEO de Moeve

The green molecule push will be championed by southern Europe, taking advantage of high solar availability to make green molecules such as hydrogen, ammonia and synthetic fuels. The Iberian Peninsula, and Spain in particular, stands out among the European countries with the highest renewable energy capacity installed and has a highly interconnected strategic position that will enable it to lead in this field within Europe.

Chart 53 **Comparison of wind and solar PPA prices in Europe** (€/MWh, 2024)

	Country	Solar	Wind
1	Netherlands	85	74
2	Ireland	99	75
3	UK	87	79
4	Belgium	83	81
5	Portugal	45	70
6	Spain	38	66
7	France	65	85
8	Germany	56	81
9	Denmark	99	76
10	Norway	111	64
11	Sweden	115	68
12	Finland	115	77
13	Poland	71	70
14	Hungary	56	83
15	Austria	62	91
16	Italy	60	82



Sources: S&P Global Commodity insights

Europe will have to commit to innovation and the domestic manufacturing of the technology needed for green molecules, as it has the raw materials and expertise to meet energy needs autonomously, competitively and sustainably. In turn, hydrogen will contribute to enabling greater penetration of renewables into the electricity system, providing demand and flexibility to the system.

These circumstances will be a catalyst, attracting industries such as chemicals and steel, which are capable of embracing hydrogen and biofuels as clean energy sources. Europe will not be able to grow or adapt to this constantly changing environment without a competitive industry. Decarbonisation and energy security must become drivers of European industrial growth, as envisaged in the Clean Industry Deal, which will be particularly relevant for energy-intensive sectors and will position Europe as a leader in the green economy of the future.

The first industries to pioneer the use of green molecules will have a knock-on effect which, according to projections by Moeve and ManpowerGroup[78], could generate up to 1.7 million new jobs across Europe, with Spain taking the lead to create 181,000 jobs by 2040. Employment growth will come hand-in-hand with substantial economic benefits, increasing GDP in the area (European Union and the United Kingdom) by up to €145 billion by 2040, of which €15.6 billion is attributed to Spain.

The lead roles in this growth, where green molecules will be key, are hard-to-abate sectors such as industry and transport, which are currently responsible for 55% of greenhouse gas emissions in Europe. So, the adoption of these alternative fuels will undoubtably help to decarbonise the continent, bringing us closer to the goal of carbon neutrality by 2050.

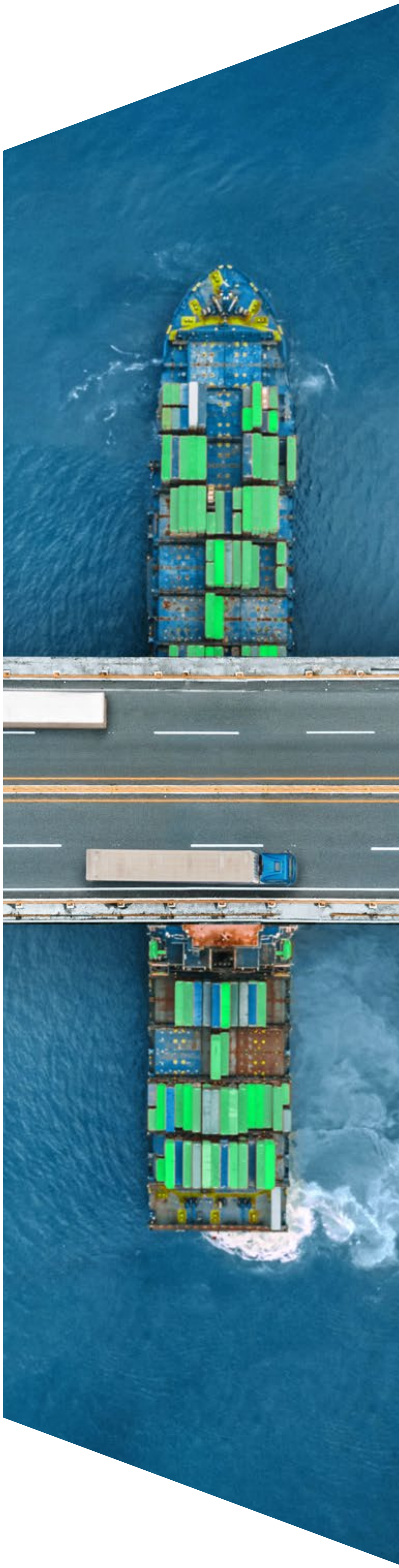
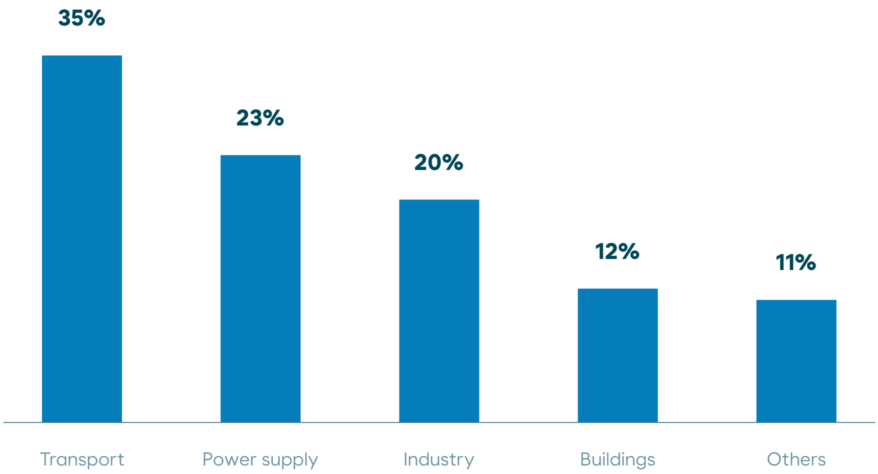


Chart 54 Industries that emit the most greenhouse gases in Europe ($\%CO_2eq$, 2024)



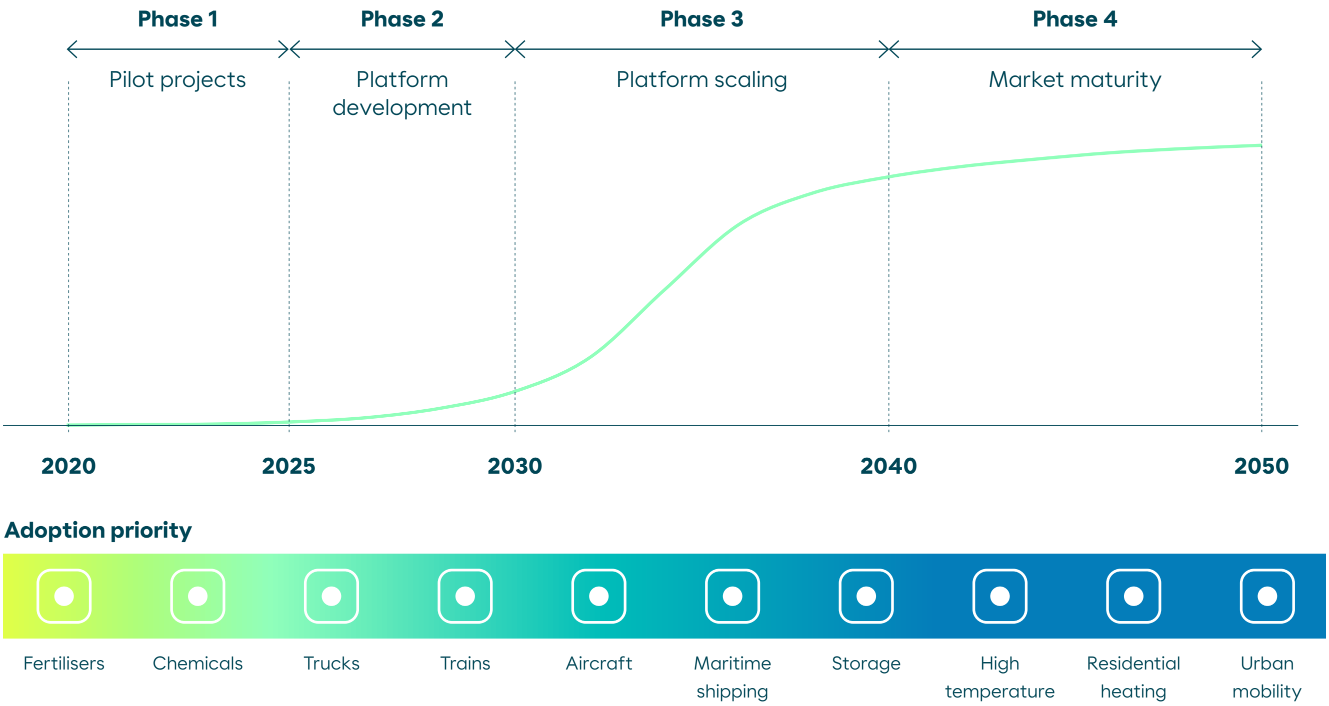
Sources: European Environment Agency

Maritime and air transport are the sectors best positioned to bring on board these solutions with minimal impact on the final price for consumers. For example, air transport could opt to use SAFs, as they require no engine modifications and cut CO_2 emissions by 90% compared to traditional fuels, while ticket prices would only rise by €1 to €50 per flight.

This additional cost, or green premium, requires consumers and businesses to be willing to bear it, which entails creating platforms and defining standards so that consumers can distinguish these green alternatives. It is essential to raise awareness that the added cost of adapting to green molecules is lower than doing nothing, as the costs of climate change on the economy and society will be even greater.

[78] "Green Molecules: The Imminent Labor Market Revolution in Europe". The impact was assessed using the EHB's green hydrogen projections. These projections anticipate approximate output ranging between 1,200 TWh and 1,400 TWh of green hydrogen by 2040, spanning the European Union and the United Kingdom.

Chart 55 Evolution of the hydrogen platform and industries leading the way



Sources: Moeve analysis

The path to building these platforms is already marked and the foundations are being laid to harness the potential of green fuels. In recent years, pilot projects have been undertaken, providing deeper insight into the challenges, opportunities and potential of the hydrogen market. We are currently in the platform development phase, during which the installation of the infrastructure needed to manufacture, store and distribute this technology is beginning, laying the groundwork for future scaling.

By building a European H2 platform, Europe opens up the opportunity to design a competitive, inclusive market for the continent from the outset, promoting innovative initiatives such as the Andalusian Green Hydrogen Valley, which will produce up to 300,000 tonnes of green hydrogen per annum and will be connected to the rest of Europe via H2Med and the Bar-Mar connection, the first major hydrogen corridor in Europe. Alliances such as H2Med between consumers, technologists and energy companies will be key to ensuring that the infrastructure actually gets off the ground.

In the coming years, it will be necessary to establish trade agreements and define price signals in the market to consolidate the framework required to attract investment and ensure a stable supply. Advances in engineering and more efficient system designs will also play a pivotal role in this phase, marking a turning point for the expansion of hydrogen.

For this development, the role of first movers like Moeve is decisive. This has led us to invest in what will be the largest green hydrogen project in southern Europe. Those who position themselves in the early stages of development will have a significant strategic advantage, acting as true "market makers" capable of shaping the market and paving the way for other players to join.

> The groundwork must be laid during this decade for a solid platform that will enable the accelerated deployment of hydrogen in the next. Acting now is essential to develop the infrastructure necessary to achieve the scale we will need going forward.

Maarten Wetselaar, Moeve's CEO

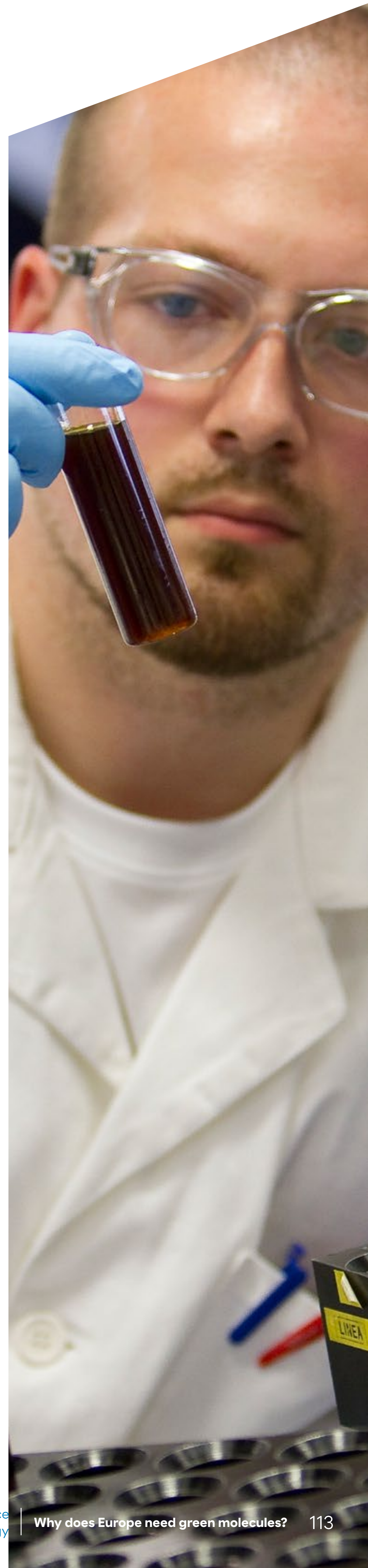
To achieve this vision of a green, competitive Europe thanks to a developed green molecule market, **regulation must serve as a catalyst, providing a clear, stable framework that facilitates investment and ensures a fair, competitive transition.**

At a time when these green alternatives are not yet fully competitive, it is essential to take action in the short term in the form of temporary public aid to promote strategic projects that have the potential to trigger knock-on effects throughout the economy, including:

- **Harmonised electricity tariffs:** priority grid access for electrolysers and critical corridors such as H2med connecting southern production hubs to continental demand in a truly integrated European hydrogen market.
- **Strategic state aid:** bold public-private collaboration to unlock private capital and speed up deployment of large-scale transformative projects, such as the Andalusian Green Hydrogen Valley project.
- **Policies that incentivise,** rather than hinder, clean innovation and a clear direction backed by a strong, stable legal framework with well-defined carbon abatement targets.

In the medium-to-long term, regulation will be needed to progressively foster the use of these technologies by means of specific emissions reduction targets and instruments to help mitigate the impact of the green premium.

As a first mover, Moeve embodies the opportunity Europe needs to boost decarbonisation, industry and security of supply by building a green molecule platform that will enable the continent to realise its vision of a more integrated, modern, independent, competitive Europe.



06

Appendices

6.1.

Cost assumptions

The competitiveness of fossil fuels versus green fuels depends on a number of factors, the main drivers being the future cost of CO_2 emissions, Brent and natural gas prices, LCOE, electrolyser CAPEX and CCU.

The scenarios described in the IEA's World Energy Outlook 2025 have been analysed as the main point of reference when assessing the sensitivity of fuel competitiveness under various cost assumptions. To ensure the soundness and accuracy of the analysis, reputable sources such as IRENA and the WEF have been reviewed in order to corroborate and adjust the scenarios proposed by the IEA, as necessary.

IEA scenarios	**Stated policies**		**Announced commitments**		**Net-zero emissions by 2050**	
	2035	**2050**	**2035**	**2050**	**2035**	**2050**
Oil (USD/barrel)	89	106	80	76	33	25
EU Gas Natural (USD/MBtu)	9.1	10.6	6.2	8.4	4.2	4.0
Cost of CO_2 in advanced economies (USD/tCO_2)	87	87	89	174	180	250
Solar PV – LCOE (USD/MWh)	35	30	35	30	35	30
Onshore wind – LCOE (USD/MWh)	55	55	55	55	55	50
Offshore wind – LCOE (USD/MWh)	50	40	50	40	45	35
Hydrogen electrolysers (USD/kW)	440 – 1680	390 - 1460	420 - 1650	390 - 1450	330 - 1310	310 - 1180

CCUS assumptions are based on other market sources such as IRENA, WEF or the Mærsk Mc-Kinney Møller Center, as the IEA does not provide a forecast for these prices.

CCUS (USD/tCO_2)	**2030**	**2050**
Point source	119	71
Direct air capture	188	94

6.2.

Glossary

APS (Announced Pledges Scenarios)

ATAG (Air Transport Action Group)

AtJ (Alcohol-to-Jet)

BET (Battery Electric Trucks)

BF-BOF (Blast Furnace-Basic Oxygen Furnace)

BOF (Conventional Blast Furnace)

BP (British Petroleum)

CAPEX (Capital Expenditure)

CAT (Catenary Hybrid Truck)

CBAM (Carbon Border Adjustment Mechanism)

CCU (Carbon Capture Usage)

CCUS (Carbon Capture, Usage and Storage)

COP30 (United Nations Climate Change 30th Conference)

CSR (Corporate Social Responsibility)

DAC (Direct Air Capture)

DNV (Det Norske Veritas)

DRI (Direct Reduced Iron Process)

EAF (Electric Arc Furnace)

ECA (Emission Control Areas)

e-fuels (electric fuels)

EHB (European Hydrogen Backbone)

ETS (Emissions Trading System)

EVs (Electric Vehicles)

FCT (Fuel Cell Trucks)

FT (Fischer-Tropsch)

GDP (Gross Domestic Product)

GHG (Greenhouse Gas)

GW (Gigawatt)

GWel (Gigawatt of electrolysis)

HDV (Heavy-Duty Vehicles)

HEFA (Hydroprocessed Esters and Fatty Acids)

ICAO (International Civil Aviation Organization)

ICE (Internal Combustion Engine)

IEA (International Energy Agency)

IMO (International Maritime Organisation)

IRENA (International Renewable Energy Agency)

LCOE (Levelized Cost of Electricity)

LCOH (Levelized Cost of Hydrogen)

LNG (Liquefied natural gas)

LPG (Liquefied petroleum gas)

LSFO (Low Sulphur Fuel Oil)

MGO (Marine Gasoil)

MPP (Mission Possible Partnership)

NECP(Integrated National Energy and Climate Plan)

NZE (Net-Zero Emissions)

O&M (Operation and Maintenance)

PS (Point Source)

PtH (Power-to-Hydrogen)

PtL (Power-to-Liquid)

PV (Photovoltaic)

R&D (Research and Development)

RED III (Renewable Energy Directive)

RFNBO (Renewable Fuels of Non-Biological Origin)

SAFs (Sustainable Aviation Fuels)

SMR (Steam Methane Reforming)

STEPS (Stated Policies Scenario)

SYT (Synthetic fuel-powered Truck)

TCO (Total Cost of Ownership)

TWh (Terawatt-hour)

WEF (World Economic Forum)

WtW (Well-to-Wheel)

Throughout this document, the terms e-fuels, RFNBO (renewable fuels of non-biological origin), hydrogen derivatives and synthetic fuels are used interchangeably.

6.3.

Data sources

BloombergNEF (BNEF)

First Movers Coalition

International Air Transport Association (IATA)

International Council on Clean Transportation (ICCT)

Air Transport Action Group (ATAG)

International Energy Agency (IEA)

Mission Possible Partnership

Det Norske Veritas (DNV)

International Civil Aviation Organisation (ICAO)

International Maritime Organisation (IMO)

International Renewable Energy Association (IRENA)

Mærsk McKinney Møller Center for Zero-Carbon Shipping (MMM)

World Economic Forum (WEF)

EuroControl

Lloyd's Register Maritime Decarbonisation Hub

European Commission

Transport & Environment

Hydrogen Europe

ICF Climate Center

Fertilisers Europe

Imperial College London – Concawe

ManpowerGroup

European Environment Agency (EEA)

Goldman Sachs

Our World in Data

Hydrogen Council

European Hydrogen Backbone (EHB)

United Nations Climate Change

International Airlines Group (IAG)

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