Benelux Business Roundtable

May 2021

How Benelux's industry and power sector could become carbon neutral by 2050

A pathway and action plan

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Preface

Since its founding in 2015, the BBR has put Europe's energy transition, along with infrastructure, digitalization and mobility, at the top of its agenda. Each of these areas presents challenges that individual countries can't meet alone—a reality reflected by the fact that all 27 EU member states have subscribed to the European agenda on these issues.

The EU Green Deal is undoubtedly one of the greatest projects of our time—an undertaking we must wholeheartedly embrace to preserve the interest of Europe's citizens and economies. However, collaborating at the EU level will take time because of the diverging interests and unique challenges of its countries.

Because of its large industry sector and high concentration of CO_2e emissions, the Benelux can play a pivotal role in Europe's transition to green energy. At €16 million per square kilometer, the region's GDP intensity is five times the EU average. The carbon density of its industry and power sectors is 2.5 times the EU average. This density offers several competitive advantages that would allow Benelux to scale its energy transition more quickly than any other region in Europe. However, recent data show its starting line is behind those of many other EU countries and reaching the 2030 and 2050 targets will take greater effort.

Without extraordinary effort in the coming decade, it will be nearly impossible for the Benelux to meet the ultimate goal of reaching net-zero emissions by 2050. The master plan presented in this report shows why the converging interests of the Benelux countries and their economies require the region's policymakers and industry players to take quick, decisive action on several measures to reduce $C0_2$e emissions and facilitate the production and import of green energy. It's the only way the region can come even close to reaching the 2030 and 2050 targets and reap the economic and societal benefits that come with them.

The industry and power sectors have decreased their $C0_2$e emissions by 29% since 1990, far more than the non-ETS sectors, but still account for more than 50% of the Benelux's emissions. Ramping up emissions reduction efforts in the non-ETS (transport, agriculture, and building) sectors will be required for achieving the EU targets. However, it's unlikely that the measures taken in those sectors can reduce the region's emissions enough to meet the 2030 target, which is why the immediate focus needs to be on reducing greenhouse gases in the industry and power sectors.

Fortunately, the Benelux industry and power sector have numerous emissions abatement advantages, including:

- Proximity to the North Sea and several major ports, which will make storing, exporting, and transporting captured CO_2 and importing renewable fuels much easier.
- A high concentration of petrol, steel, cement, lime and chemical clusters that create economies of scale for capturing and storing emissions.
- Interconnected natural gas transmission infrastructure that can be gradually retrofitted and repurposed for transporting CO_2 and sustainable molecules such as hydrogen.
- Close connections with industrial clusters in the North of France and Ruhr region.
- A history of close collaboration among member states with treaties in place for pursuing shared interests.
- World-class knowledge centers, along with the maritime and logistical experience that will help accelerate green technology innovation.

Unlocking the full potential of these assets will require close collaboration among the three Benelux countries, and by extension, the North of France and the Ruhr region, to leverage synergies of scale and scope, connect industrial clusters, align cross-border projects, put the necessary regulatory framework in place, and attract the public and private funding needed to develop realistic business cases.

For a start, Benelux policymakers need to resolve energy and tax-related challenges and create regulations that level the playing field for all industry players their highest priority. This kind of effort is what the renewed Benelux treaty of 2008 foreshadowed when the parties added the objective to create a more integrated common market and economic union.

Only by working together can the Benelux countries reach the 2030 and 2050 targets while reaping the vast business and social benefits a transition to a carbon-neutral economy presents.

Like all formidable yet worthy goals, this will require ambitious leadership and good governance.

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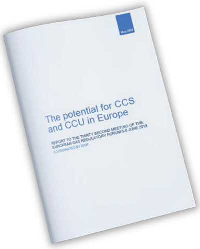
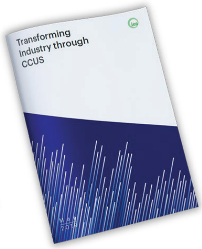
In addition to the ones listed here, some other reports are used as reference, such as IEA "The Future of Hydrogen" (June 2019)



IOGP

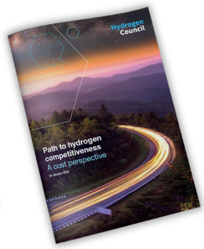
RWE



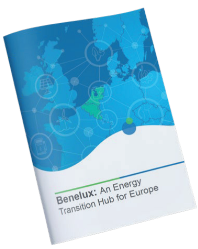
IEA

Hydrogen Import Coalition

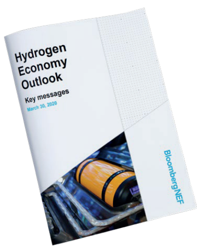
Fraunhofer



Hydrogen council

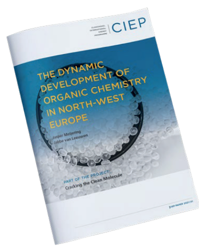


BBR



BNEF

IRNEA



CIEP

Xodus GROUP

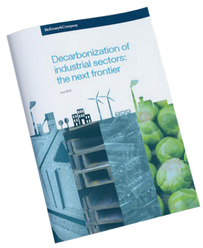
Net zero 2050

The Northern Netherlands hydrogen investment plan 2020

Florence School of Regulation

McKinsey

Net zero Europe

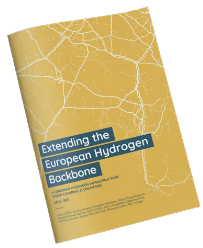


McKinsey

Decarbonization of industrial sector

McKinsey

Energy transition mission (im)possible for industry?



Gasunie, Fluxys, Creos

Extending the Hydrogen backbone

Contents

Executive summary

The Benelux faces a once-in-a-century opportunity to reorient its economy towards carbon neutrality. As one of Europe's top five industrial hubs by GDP, it has a high density of carbon emissions concentrated in large industrial clusters that are located near major ports. This makes the region crucial to achieving the EU's reduction targets, and its success in evolving to carbon neutrality could set the pace for the entire EU.

Becoming carbon-neutral could generate broad economic benefits for the region, particularly because the industry sector plays such a significant role in its economy. In 2019, industrial segments such as power, chemicals, iron and steel generated €242 billion, comprising 20% of Benelux's GDP.[1] Its industry sector directly employs more than 2 million people, accounting for approximately 17% of the region's full-time jobs and an even higher percentage of indirect jobs. Investments in green energy initiatives are required to keep these businesses in the region. They would also provide opportunities to grow the region's economy, create an additional 1 million direct and indirect jobs by 2050, and establish new trade relationships.[2]

Because of the Benelux countries' different starting points from a renewable energy and energy policy perspective, their exact pathway will differ. However, to put the region on the path to net-zero emissions by 2050, industrial players will need to pull all available emissions reduction levers. These include energy efficiency, demand circularity, electrification, sustainable molecules, carbon capture use and storage (CCU/S), biomethane, biomass, and rolling out renewable electrons and molecules.

Sustainable molecules and carbon capture storage (CCS) will play a crucial role in the transition. Although CCS technology is already available and the development of sustainable molecules is rapidly advancing, reaching the 2030 target will require ramping up CCS at scale and developing a new market for producing and importing sustainable molecules like hydrogen, ammonia, e-methane, e-methanol etc. Achieving these objectives will require a new regulatory framework, public and private funding, knowledge sharing, and pooling innovative competencies to overcome significant financial, regulatory, public, and coordination challenges.

Although Benelux's numerous advantages that can help it overcome these hurdles, cross-border collaboration within Benelux and by extension the North of France and Ruhr region will help to achieve these objectives:

- Develop a holistic action plan based on progressive insights and growing cross-border experience from policy, industry, and scientific experts.
- Rapidly create the required scale and scope to accelerate and reduce the cost of CCS and hydrogen projects, including producing and importing sustainable molecules from places where renewable electricity is abundant and inexpensive.
- Develop the regulatory framework needed to allow cross-border transport and storage of CO_2 and hydrogen.
- Align the timelines of cross-border projects along the same value chains.

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1 Industry segments including mining and quarrying, manufacturing, electricity, gas, steam, and air conditioning supply, water supply, construction.
2 Net jobs growth for industry activity as well as energy services related (including power generation).

- Improve access to public and private funding for (cross-border) projects with significant CO_2 reduction and green energy development potential.

The collaboration for achieving these goals needs to happen at three levels: regional (e.g., local businesses and governments); cross border (e.g., within Benelux and across the North of France and Ruhr region), and internationally (e.g., between sustainable molecules exporting countries). This multi-level collaboration will protect the whole region's economic interests by maximally leveraging synergies of scale and scope, protecting the exiting industry and employment, and creating future growth opportunities.

The BBR and broader industry stakeholders' action plan presented in this report is built on four main pillars and three critical enablers. The four main pillars include:

1. **Maximize the deployment of mature levers**, such as energy efficiency, demand circularity, electrification, and sustainable molecule projects within the member states and accelerate the build-up and scaling of renewable energy projects, including cross-border interconnectivity

2. **Develop clear business cases for using all available levers**, including technology development for CCU, circularity, electrolyzers, and process innovation. This also involves creating a step-by-step plan to build a CO_2 and hydrogen backbone that includes import and export terminals, storage, and pipeline infrastructure. The backbone should start in industrial clusters and ultimately expand countrywide to create scale and accelerate adoption throughout the region (e.g., Benelux, North France, Ruhr like Rotterdam/Antwerp, Gent/Terneuzen, Chemelot/Antwerp).

3. **Harmonize or establish the required regulatory frameworks,** starting with leveling the playing field for access to public funding throughout Benelux and developing a regulatory framework that encourages the development of all green technology and emissions reduction levers. One example is SDE++ in NL for which there is no equivalent in Belux. Another example is the regulatory framework required for cross-border transport and storage of sustainable molecules and CO_2 (e.g., Carbon Connect Delta between Gent and Terneuzen, and between Ports of Antwerp Bruges and Rotterdam). Tailoring regulation to the maturity level of sustainable molecules production in a specific region while imposing minimum standards such as unbundling/neutral operator, transparency, and non-discriminatory Third Party Access (TPA) will ensure that hydrogen and other sustainable molecules investments are future proof. This will contribute to increasing the liquidity of the hydrogen and sustainable molecules market. Incorporating the rules into the existing gas legislation would be the most efficient way to ensure regulatory alignment between these two energy vectors.

4. **Address public and government concerns** being transparent about the best available technology solutions for achieving carbon neutrality. This includes educating the public and government officials about the importance of sustainable molecules and CCU/S in reaching emission reduction targets and maintaining industrial jobs in the Benelux. It also requires involving the public in early discussions about achieving carbon neutrality, explaining the measures being taken to make it safe, and investing in open-access infrastructure for hydrogen and CCU/S.

The three critical enablers include:

1. **Increased collaboration within the Benelux and with the North of France and Ruhr industrial area**, starting with setting up joint public-private task forces to develop and accelerate roadmaps for key projects, such as the hydrogen backbone, CO_2 backbone, regulatory framework, and level playing field for public funding.
2. **Innovation that accelerates technological advancements and process breakthroughs**, starting with setting up pilot programs across industry, academia, and governments to spark innovation in areas such as hydrogen technology, CO_2 purification technologies, CCU technology, high-efficient electric furnaces, and mineralization solutions.
3. **Efficient access to financing and funding**, starting with jointly submitting cross-border projects with significant CO_2 reduction potential to the EU and exploring how to attract long-term private funding to complement public funding.

1.

Benelux's once-in-a-century opportunity in the transition to carbon neutrality

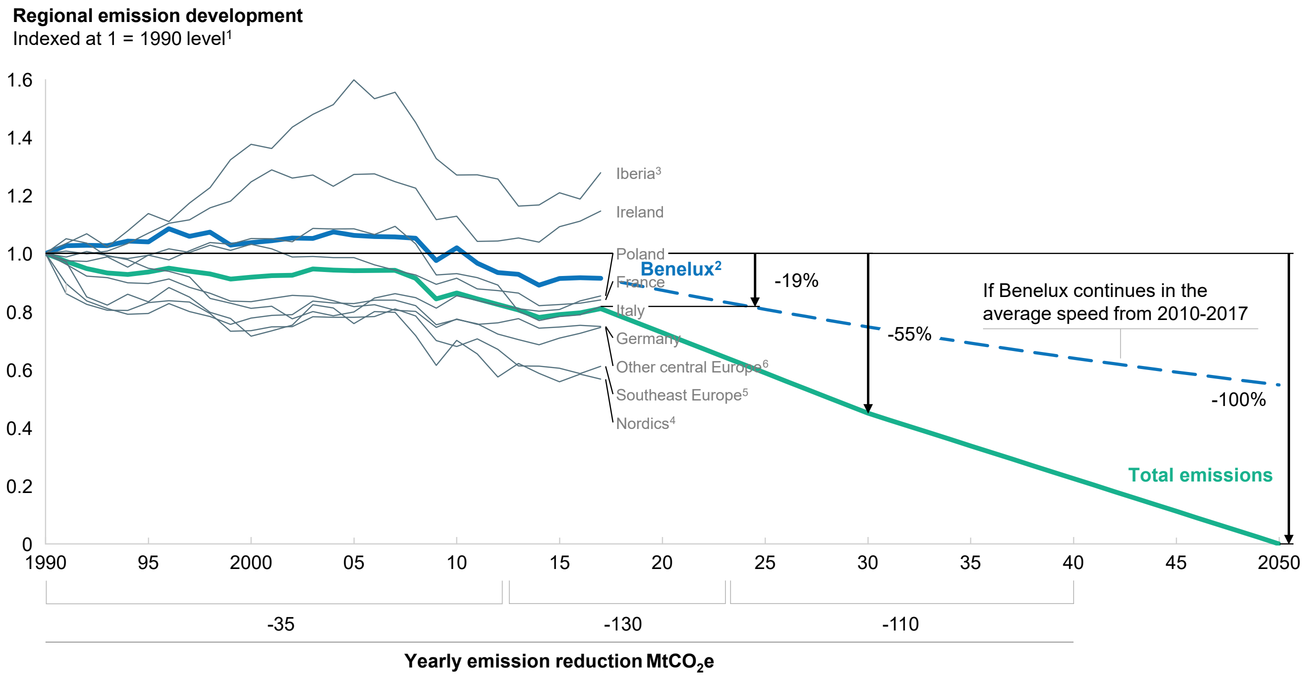
Benelux's involvement is pivotal to the EU achieving its carbon neutrality goal

From 1990 to 2017, the EU reduced its emissions by 19%, an average rate of 35 $MtCO_2e$ per year. To meet its 2030 reduction target, the EU would need to reduce CO_2e emissions by 130 $MtCO_2e$ a year—three times faster than the current rate. Reaching carbon neutrality by 2050 would require every EU member state to cut greenhouse gas emissions in all sectors, including transport, buildings, power, and industry (Exhibit 1).

Since the European Commission approved these targets, the race towards carbon neutrality is on, and some EU member states have already responded. Germany and France have taken key steps toward creating a hydrogen economy, allocating €9 billion and €7 billion respectively to the transition. 2021 will be a crucial year for getting these initiatives in motion. Businesses will need to come together to present plans for achieving the EU targets, particularly the most pressing goal for 2030. Throughout the EU, government and business leaders will be drafting bids for green technology and infrastructure funding. And as the world emerges from the COVID-19 crisis, addressing

Exhibit 1

Example of EU net zero pathway



1. Emission development of LULUCF, waste, and other sectors are included in total emissions but not shown separately in the graph; these sectors also show a decrease in emissions (and increase of uptake of carbon for LULUCF) between 1990 and 2017
2. Belgium, Luxembourg, Netherlands
3. Spain & Portugal
4. Denmark, Estonia, Finland, Latvia, Lithuania, Sweden
5. Bulgaria, Greece, Romania
6. Austria, Croatia Czech Republic, Hungary, Slovakia, Slovenia

Source: Eurostat, EEA

climate change will become an even bigger priority and opportunity.

Without immediate action, the Benelux risks being left behind and missing out on significant business opportunities. The deadline for EU countries to create their energy reform and investment agendas is fast approaching.

The Benelux has the opportunity to play a pivotal role in helping the EU meet its reduction targets. The region is among the top five industrial hubs in Europe, generating €242 billion in 2019, or 8% of the EU's industry GDP (Exhibit 2). At 2,280 tCO_2e per square kilometer, the carbon density of Benelux's industry and power sectors is 2.5 times the EU average. These emissions are concentrated in industrial clusters near large ports in Rotterdam, Antwerp Bruges, North Sea Port, and Amsterdam, making it easier to transport and store CO_2 in offshore locations.

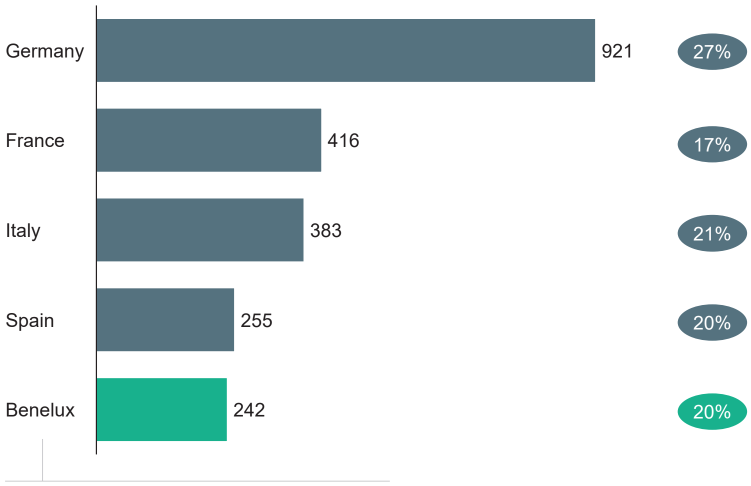
Exhibit 2

Benelux as a key industrial region in Europe

Large industrial base

Top 5 ranking of industry[1] sector GDP for EU 27
EUR billion

Industry share in total GDP
Percent



About 20% of Benelux GDP is concentrated in Antwerp, Rotterdam and Amsterdam areas

Employment

>17%
of direct employment created by industry[1] in 2019 (~2 Million jobs)

>25%
of total private sector employment, excluding indirect jobs induced by industry

Leadership in selected segments

Benelux ports represent > 22% of total weight handled by EU ports

The 2 busiest ports of Europe are in Benelux (Rotterdam and Antwerp)

2nd largest petrochemical cluster globally

Large metals industry with significant exports beyond local markets

1. Based on data from Eurostat where GDP is split into three big categories, namely industry, agriculture and services. Industry here covers mining and quarrying, manufacturing, electricity, gas, steam, and air conditioning supply, water supply, construction

Against this backdrop, the Benelux has a once-in-a-century opportunity to transform its economy and create economic growth

2021 will be a crucial year for getting decarbonization initiatives in motion. A significant part of the Benelux economy is built on industry,[3] which generates 20% of the region's GDP.[4] The sector directly employs 2 million people, accounting for 17% of the region's full-time jobs in 2019. Investments in green energy initiatives could create new ways to grow the region's economy, retain existing jobs, and create new ones.

Local businesses would get the chance to collaborate on decarbonization projects and make the best use of existing infrastructure to reduce costs and other impacts on society. Once it can import sustainable molecules, the Benelux could diversify its energy and feedstock market. Also sustainable molecules (incl. hydrogen) could be used as an option to store/buffer energy and help Europe reduce its reliance on fossil fuels. Benelux businesses could also build new trade relationships with sustainable molecule producers in growing markets. And it could export carbon-neutral industrial products, green technology, and knowledge to other parts of the world. There is also growing momentum to import sustainable molecules in Benelux, as demonstrated by recent announcements of MOU's with Saudi-Arabia, Chili, Oman and Egypt.

From a global perspective, becoming a leader in carbon-neutral technologies would give the region and its industrial businesses international prominence. Benelux is home to the world's second-largest petrochemical cluster and has a large metals industry that exports products across the globe. Initiatives to reach carbon neutrality in these sectors would expedite the EU's transition to carbon neutrality. It could also help expand the Benelux's research facilities and industrial R&D capabilities in green technologies such as CCU/S, electrolysis, and green chemistry. And by becoming the first to transition to a carbon-neutral economy, the Benelux would be well-positioned to influence the international climate change agenda.

But to reap these benefits, the Benelux has a steep road ahead

From 1990 to 2017, the region reduced its CO_2e emissions by only 9%, well below the EU's goal to reduce emissions by 55% by 2030. During this timeframe, the industry sector has decreased emissions the most, with a total reduction of 32%, whereas emissions in the power sector have risen 5% (Exhibit 3). The industry sector has achieved this reduction primarily by improving industrial energy efficiency with process optimization and waste heat reduction while increasing the share of low-carbon energy use such as nuclear, gas, and wind power. If the Benelux continues to decarbonize at its current speed, the region could only reduce emissions 25% by 2030—far below the 55% EU target (Exhibit 1).To meet the target, the Benelux would need to reduce CO_2e emissions by 9 $MtCO_2$e per year, about four times faster than its current rate.

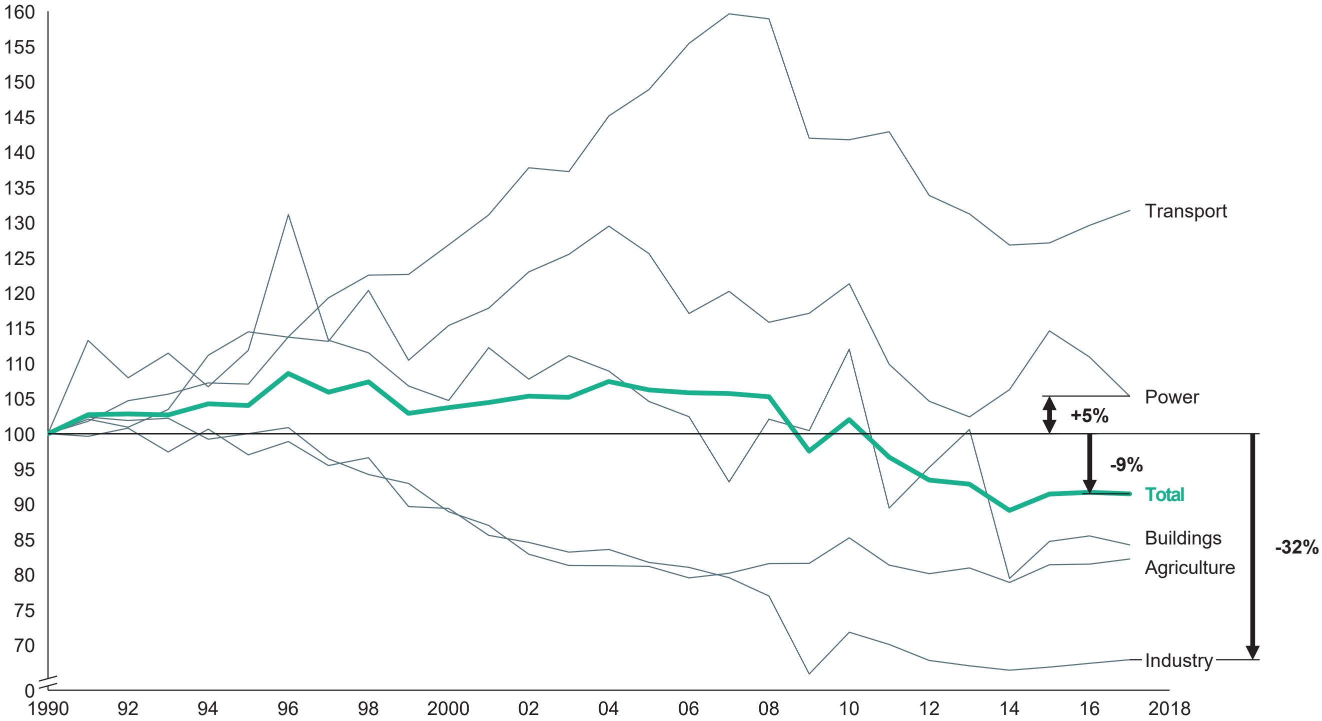
[3] Including mining and quarrying, manufacturing, electricity, gas, steam, and air conditioning supply, water supply, construction.

[4] Eurostat.

Exhibit 3

Benelux emission evolution since 1990

Emission evolution by sector[1], indexed vs 1990
%



1. Excluding LULUCF, waste sector and other emissions

Source: Eurostat

If the Benelux continues to decarbonize at the current speed from 2010-17, it could only achieve about 25% of reduction by 2030, which is far below the 55% target from the EU level (Exihibit 1).To meet the 2030 reduction target, the Benelux would need to reduce CO_2e emissions by 9 $MtCO_2e$ per year, about four times faster than its current rate. This would require significant collabaration cross borders to enable infrastructure development for the deployment of levers to reach carbon neutrality such as cross border CCS and H_2 applications, also scaling and innovation incurred by the collbaration would help to develop more positive business cases for these levers to reach carbon neutrality.

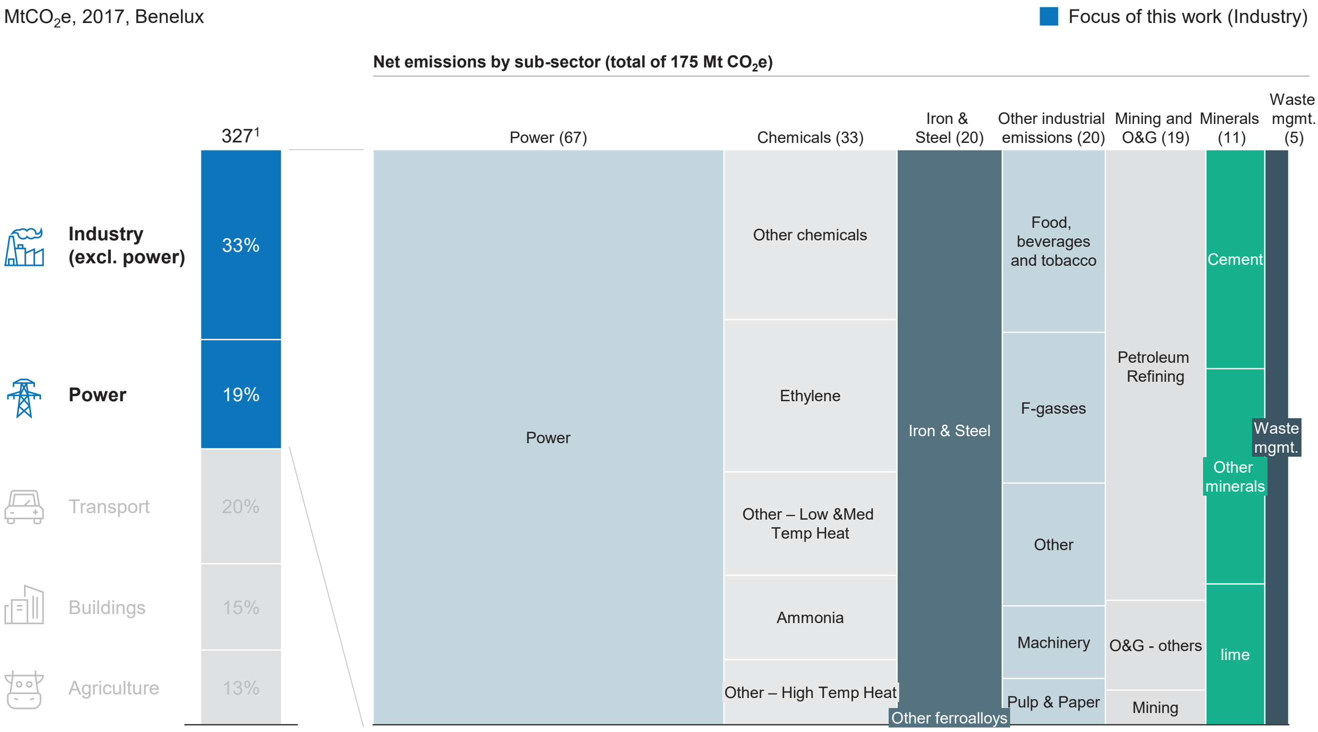
Achieving the industry and power sector targets is crucial for Benelux to meet its 2030 emissions reduction target

As the largest source of greenhouse gases, the industry sector accounts for 33% of the Benelux's annual emissions, followed by power with 19%. Within the industry sector, chemicals is the largest CO_2e emitter, contributing 33% of the region's industrial emissions, followed by iron and steel (Exhibit 4).

The type of emissions varies by industrial segment. Most come from heat generation, production processes, electricity, and on-site transport. For example, 40% of the Netherlands' industry emissions come from heat generation for manufacturing processes such as iron and steel production, which require very high temperatures. Other types of manufacturing, such as chemicals and cement production, generate a significant amount of process emissions.

Exhibit 4

Net emissions by industry sub-sector in 2017



1. Total Benelux's net emissions, excluding international aviation and marine

Source: IEA, National Inventory reports

Because the industry and power sector face significant technical, financial, and structural challenges to decarbonize, it's crucial to act now

One of the first technical challenges that industry players must address is how to reduce process emissions. In many cases, industrial process emissions can only be decreased by changing the feedstock or manufacturing process. In some cases, it's relatively easy to switch to clean feedstock or fuel, such as using green or blue hydrogen instead of gray hydrogen to produce ammonia. But in others, such as lime and cement production, there is no proven alternative feedstock available at scale, and the only way to reduce emissions is to implement CCU/S.

Another technical challenge for the industry sector is reducing emissions from the fuels used to generate high-temperature heat for specific manufacturing processes. This would require switching from gas-fired furnaces to industrial-scale electric or clean fuel-based furnaces, which aren't yet economically viable. The only alternative is to change the manufacturing processes, which is expensive and impractical without further innovation.

Transitioning to carbon neutrality also presents financial challenges. Industrial sites are often sprawling compounds with average equipment lifetimes of 50-plus years. Deploying new clean energy technologies on these sites would require capital-intensive rebuilds. And because of the interconnectivity of industrial processes, any change to one part of the production process would require adjustments elsewhere. The investment decisions that industry players make now will affect the economic gains for decades to come.

In addition, the Benelux faces structural challenges, such as limited renewable energy resources and a heavy reliance on imported fuels. High energy costs are another obstacle. For example, in Belgium, energy taxes and grid costs for electricity are higher than in neighboring countries like France, undermining its industrial competitiveness.

The Benelux countries also need to align their policies on things like CO_2 levies, cross-border CO_2 and hydrogen transport and storage, and access to funding for green energy initiatives. This could pose a challenge given their complex institutional structures, such as Belgium's federal and three regional governments.

Despite these challenges, the Benelux has the advantages of North Sea access and connections to crucial inland hubs

The Benelux countries are some of the most connected in the world, with direct access to large seaports that serve as import/export hubs and gateways to continental Europe, including the Port of Rotterdam, Seaport Groningen, Port of Amsterdam, Port of Antwerp Bruges, and the North Sea Port (Exhibit 5). Its proximity to the North Sea allows access to offshore resources that could help fuel the power supply and provide storage for renewable electricity through power-to-gas solutions. Its nearly depleted oil fields could serve as CO_2 sinks. In addition, the Benelux is well connected to surrounding industrial centers, such as those in the North of France and Ruhr region.

Benelux is also home to world-leading oil and gas and dredging companies, with a high concentration of global petrochemical, steel, and integrated chemical clusters located near major ports. This proximity makes it easier to achieve economies of scale in capturing concentrated CO_2e emissions. And some industry players are already funding initiatives to evolve towards carbon neutrality.

The region also has an open investment environment and many special policies and business treaties in place to protect the shared interests of its member states. Throughout the Benelux, there is close collaboration within the industry sector and other types of business. It has a long history of serving as a fuel import hub as well as a center for technology innovation, with vibrant institutions such as EnergyVille (incl. VITO) and TNO.

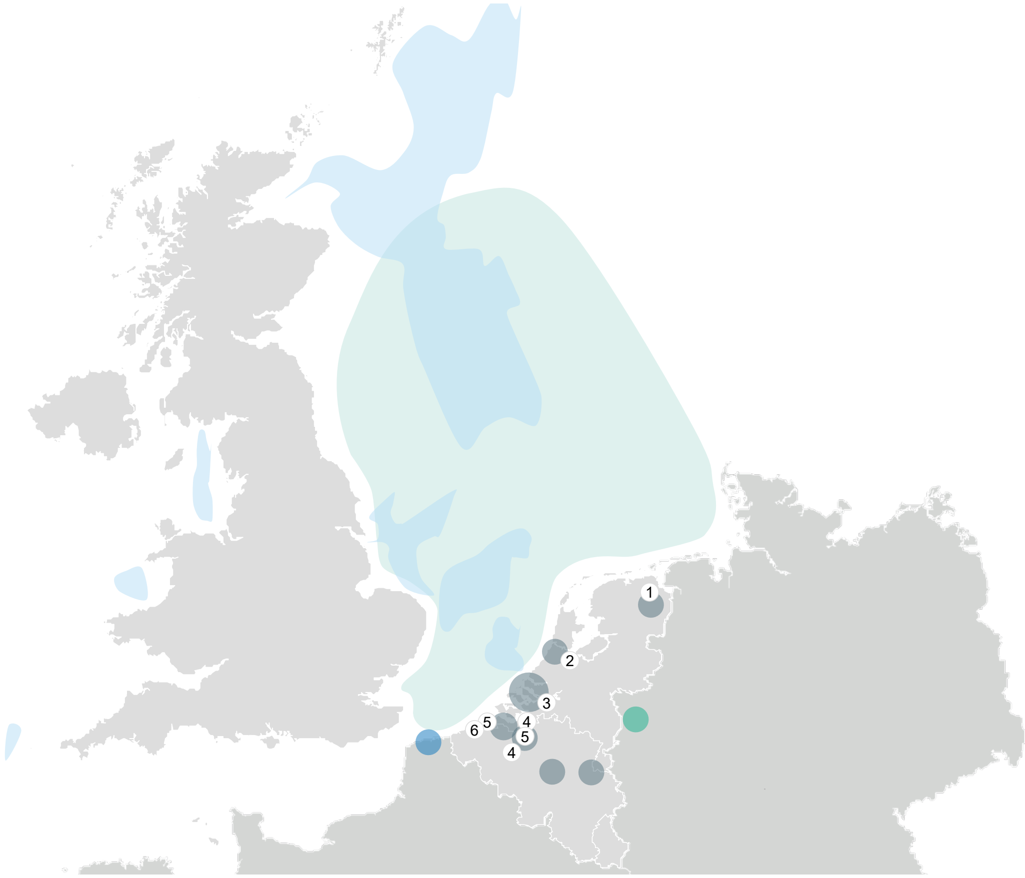
But leveraging these advantages will require intensive collaboration among policymakers and industry players across the Benelux, the North of France and Ruhr region

That collaboration includes:

- Developing a holistic action plan driven by progressive policy, industry and scientific insights, and growing cross-border experience.
- Creating the scale and scope required to accelerate CCS and hydrogen projects, including producing and importing sustainable molecules from regions where renewable electricity is abundant and cheap.

Exhibit 5

Benelux' North Sea access and connections to important inland hub



- Put the required regulatory framework in place to allow for cross-border transport and storage of CO_2 and sustainable molecules.
- Align the timelines for cross-border projects along the same value chains.
- Improve access to public and private funding for cross-border projects with significant CO_2 reduction and green energy development potential.

Achieving these goals will require collaboration at three levels: regionally among local businesses and governments; cross-border among Benelux, North of France, and the Ruhr region; and internationally, such as with countries that export sustainable molecules. Only by working together can the Benelux protect existing businesses and jobs, creating future growth, and reap the benefits of transitioning to a carbon-neutral economy.

2.

A pathway to a climate-neutral industry and power sector

Options for decarbonizing the Benelux industry and power sectors

Reaching the EU reduction targets will require a variety of carbon neutrality measures. The applicability and technological maturity of those measures differ by industry segment (Exhibit 6). The full spectrum of levers include:

- **Energy efficiency:** Adapting production equipment and processes to lower the energy consumption per produced volume. This includes measures to improve waste heat recovery, enhance maintenance to keep equipment in optimal condition and enhance process control. Building on the energy efficiency efforts already undertaken by the industry sector will require additional innovation.
- **Demand-side measures:** Reducing demand for a product by replacing it or increasing circularity. This includes recycling plastics, glass, and metals to reduce emissions from producing virgin materials.

Exhibit 6

Key solutions for industry and power sector carbon neutrality by segment

Chemicals | ● Applied at industrial scale sites | ◐ (Applied) research phase | ○ Technology (to be applied) in pilot site

	Energy intensity and demand measures	Renewables/ Electrification of process and heat	Hydrogen as fuel or feedstock[9]	CCU/S[7]	Biomass as fuel or feed-stock[2]	Example innovations[3]
Power	●	●	◐	○	●	• New power technologies, such as small module reactors, new crystal structures of PV solar module
Ethylene[8]	●	○	◐	○	●	• Electrochemical processes for monomer production, chemical looping, chemical recycling of plastics, mechanical recycling of plastics, electrified methane reforming
Ammonia	●	○	●	●	◐	• Methane pyrolysis for hydrogen production, N-capturing bacteria, molten metal bath for H_2+C from CH_4, electrified methane reforming
Methanol	●	○	●	●	○	• Methane pyrolysis for hydrogen production
Iron and steel	●		○	○	●	• Hydrogen reduction, Biomass injection in BF, Technologies to maximize scrap input/melting in BOF, CCU (e.g. CO_2 to ethanol)
Other industries heat deamnd[1]	●	●	○	○	●	• Medium temperature heat pumps, high temperature electric furnace
Mining and O&G (e.g., refining[6])	●	○	◐ ●	○	●	• High efficiency electric furnace under R&D • Hybrid system for electric & gas furnace next to each other
Minerals (e.g., cement and lime)	●	◐	◐	○	●	• Alternative feedstocks[4], increased clinker substitution[5], CO_2 cured cement (Solidia, Carbon cure)

1. Includes heat demand in other sectors, such as manufacturing, construction, food and tobacco etc.
2. Type of biomass depends on the sector and process: cement (mostly solid or gaseous biomass), iron and steel (charcoal or biogas), ammonia (biogas), ethylene (biodiesel, sugar, bioethanol)
3. Not exhaustive
4. Technological maturity depends on the type of alternative feedstock
5. Activated pozzolans – EMC cement, calcined clays – CL3
6. H_2 use in refining furnace is still at research phase, while H_2 use in production has been piloted
7. CCU here refers to the usage of carbon dioxide
8. H_2 used as fuel mixed with other gases as part of cracking gas (no pure H_2 combusted)
9. Only grey H_2 applied as feedstock at industrial scale now

- **Renewables/electrification of process and heat:** Replacing fossil fuel heating systems with electric furnaces, boilers, and heat pumps. For example, replacing steam turbines with electric motors and using electric heat pumps for low-temperature heat for washing, rinsing, and food preparation. Ensuring these electrification efforts achieve their full emissions reduction potential would require using zero-carbon electricity.
- **Hydrogen as feedstock or fuel:** Substituting green hydrogen for natural gas as the feedstock for producing chemicals like ammonia or in industrial and power production processes that require high-temperature heat.
- **Carbon capture use and storage:** Capturing CO_2 from exhaust gases of industrial processes and using it as a feedstock in other industrial processes (CCU) or storing it underground (CCS).
- **Bio-based and renewable or recycled fuels and feedstock:** Replacing fossil feedstocks and fuels with solid biomass, biogas, and biomethane or recycled and renewable feedstock.
- **Other technology and process innovations:** Using new technologies for achieving objectives like purifying CO_2-containing streams, carbon usage and mineralization, and switching to molten oxide electrolysis to make steel.

A pathway for the power sector

The power emissions reduction pathway can be divided into two phases. In the first phase from now through 2030, demand for electricity will grow as electrification of the industry, transport, and other sectors rises.[5] Meanwhile, the planned phase-out of nuclear and coal plants will reduce the region's existing power supply. The Benelux will need to add renewable power capacity from wind and solar power to fill this gap. The Netherlands and Belgium have already set offshore wind energy targets of 11 GW and 4 GW, respectively.[6]

However, the power supply shortage cannot be met entirely by renewables in the next decade because of constraints in how fast renewables can be built out. Additional capacity, such as 10 GW natural gas-fired power generation, would be required to fill the supply gap. The Benelux would also need to strengthen its power transmission grid with neighboring countries such as Germany and France to enhance the security of its power supply.

In the second phase from 2030 and beyond, renewable energy build-outs would need to accelerate to reduce emissions from the existing power demand and cover the increased demand from the other sectors. By 2050, renewable power would need to account for 90% of the total power supply.

At-scale battery storage, hydrogen, and sustainable molecules could help the power sector compensate for the intermittency of renewable energy generation for hours, weeks, and even months. The security and flexibility of the power supply could be expanded by establishing structural connections with neighboring countries, such

5 Net electricity consumption excluding grid losses and own consumption etc.
6 National Energy and Climate Plans.

as cross-border power flows. Other technological innovations, such as small modular nuclear reactors, could improve the economics of the power sector's most expensive CO_2 abatement levers.

A pathway for the industry sector

In Benelux's industry sector, meeting the emissions reduction targets would require applying all reduction levers—all of which would increase production costs except for energy efficiency and demand reduction. The reasons for the increased costs are threefold. First, because the Benelux has such a large existing industrial asset-base, it would require greater investment to rebuild or retrofit these sites. Second, zero-carbon fuel and feedstock such as electricity, biomass, and hydrogen are more expensive per energy unit than fossil-based alternatives like coal and natural gas. Third, industry players that switch from fossil fuel-based production to zero-carbon production won't increase their energy efficiency, which would otherwise offset their higher fuel and feedstock costs. New production technologies could change that and change our prescribed pathway. But those technologies would only be implemented after 2030.[7]

Until 2030, deploying technologically mature levers such as energy efficiency, demand-side measures, and electrification will help to further reduce emissions. Electrification would be the largest contributor, accounting for 30% of total reduction by 2030. In the near-term, electrification would be applied to low-temperature heat applications (less than 100 degrees Celsius). Installing electric heat pumps could generate cost savings because of their significant energy efficiency gains. Electrifying high-temperature heat processes is being researched.[8]

Using zero-carbon hydrogen, including hydrogen-based fuels, along with CCU/S could further reduce emissions by 2030. In the short term, zero-carbon hydrogen would be a combination of blue (natural gas-based with CCS) and green (electricity-based) until the equipment to produce green hydrogen and the infrastructure to import it reaches scale.

Until 2030, abatement costs will vary widely depending on the type of process and industrial plant. Although energy efficiency measures could be cost-neutral, industrial heat electrification would cost between €40 to €100/tCO_2e. Depending on its application, the cost of CCU/S application can range from €40 to €120/tCO_2e. CCS applications involving high CO_2 concentration streams, such as ammonia production, have the lowest cost, whereas those for lower CO_2 concentrations, such as in ethylene naphtha crackers, have the highest.

The production costs for zero-carbon hydrogen would range from €50 to €120/tCO_2e. However, the capacity required at green hydrogen production sites would be limited and only needed in the short term. Because Benelux has limited renewables capacity and hydrogen production will compete with less expensive electrification measures, importing hydrogen and its derivatives should be cheaper than producing them locally once the infrastructure is in place.

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7 Detailed description of industrial decarbonization options and pathways can be found in 'Decarbonization of industrial sectors: the next frontier' (McKinsey 2018) and 'Decarbonization: Mission (im)possible for industry?' (McKinsey 2017).

8 https://blog.topsoe.com/article-in-science-extremely-compact-reactor-has-potential-to-reduce-global-co2-emissions-significantly.

By 2050, electrification would play the biggest role in decarbonizing the industry sector, accounting for 35% of total emissions reduction, followed by green hydrogen and CCU/S, which would each reduce emissions an additional 20% to 25%. Energy efficiency and other levers such as biomass would be used to maintain carbon neutrality after 2050, although on a smaller scale than electrification, CCU/S, and hydrogen.

Different pathways for different countries

The pathway we present in this report is for all of Benelux. However, because the three member countries have different starting points in terms of their energy landscapes, regulatory environments, and business initiatives, each country's pathway will be slightly different.

As for the electricity landscape, the Netherlands has more abundant renewable resources than its neighbors, particularly offshore power resources with a potential capacity of more than 40 GW, compared with 4 GW that's generated today. The Dutch government has set a target of generating 84 TWh from renewables, including 49 TWh from offshore wind and 35 TWh from onshore wind and solar energy by 2030. Overall, Benelux has limited renewable resources and relies heavily on imports.

In the next few years, the Benelux will face even greater pressure to secure its power supply. In Belgium, the phase-out of nuclear power is expected to create a supply gap of 45 TWh. To fill that gap, the government has committed to building 14 TWh of offshore energy by 2030 and investing in gas power plants. In the Netherlands, the government plans to halt production at Groningen, Europe's largest onshore natural gas field, by 2022.[9]

From a regulatory perspective, the three countries also differ. The Netherlands has a hydrogen strategy that focuses not only on green hydrogen development but also on developing blue hydrogen as a short-term transition fuel. As part of this strategy, the government has committed to ambitious targets of developing 0.5 GW of electrolysis by 2025 and 3 to 4 GW by 2030, and offered public funding to promote supply and demand. The Netherlands is providing more than €80 million in government subsidies through the Demonstration Energy Innovation grant and other scaling instruments. Hydrogen and CCS technologies are also eligible for funding from the SDE+ operating grant, which has a budget of €5 billion this year to allocate to covered solutions to reach carbon neutrality.

Additionally, the Netherlands has developed a CO_2 levy for the industry sector, aiming to set a minimum floor compared with the EU ETS price. The CO_2 levy per ton of CO_2 is calculated based on the difference between the rate established by the Environmental Taxes Act, which will increase between 2021 and 2030, and the EU ETS price.

Besides financial support, the Dutch government is committed to collaborating with network operators like Gasunie and Tennet to develop electricity and hydrogen networks and establish regulations to help secure supply and demand for green hydrogen, such as blending 2% hydrogen into the existing gas network.

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9 The production is expected to fall to zero assuming normal winter days. However, the field would be kept operational by 2026 at the latest, only standing by to meet high gas demand on exceptionally cold winter days.

By contrast, the Belgian and Luxembourg governments haven't developed hydrogen, CCU or CCS strategies yet, although Belgian government declarations reference developing CO_2 and hydrogen backbones. The Flemish government is focused on becoming a leader in hydrogen and has allocated funding as part of Vlaamse Veerkracht, its recovery plan. Local governments in Belgium have committed to promoting hydrogen use in transport. For example, they are switching to alternative fuels like hydrogen and electricity for public transport and trucks. The Flemish government has also committed to supporting CCS and CCU initiatives, while the Luxembourg government doesn't consider them legitimate options for reaching carbon neutrality. There's a growing consensus in both countries that they'll need to scale hydrogen and sustainable molecule imports to compensate for their lack of renewable resources. Belgium's prime minister has said the next step is to develop a long-term strategy for importing hydrogen.

The business initiatives of leading industrial players will also impact the Benelux countries' individual carbon neutrality pathways. In the Netherlands, several integrated green hydrogen projects are already underway, such as Energy Valley in Northern Netherlands. There are also a few projects under financial investment decision (FID), such as electrolysis in Delftzijl (20 to 60 MW) and Rotterdam (250 MW). The Dutch gas network is mature and robust, and Gasunie has been leading the development of a countrywide hydrogen network.

In Belgium, the Hydrogen Import Coalition—a collaboration between DEME, ENGIE, Exmar, Fluxys, Port of Antwerp Bruges, and WaterstofNet—aims to prepare seaports for developing a hydrogen import chain by 2030. The first green hydrogen projects that use offshore wind power, Port of Ostend (50 MW) and Port of Antwerp Bruges (25 MW), are expected to come online by 2022. Antwerp@C is also planning a joint CCS project in the Port of Antwerp Bruges and Carbon Connect Delta in North Sea Port. Lime and cement players in Wallonia are working on CCU/S, low carbon and biomass based initiatives to reduce their carbon footprint. The Belgian gas network is mature, interconnected and robust, and Fluxys Belgium has been leading the development of a countrywide open access hydrogen network.

Because of these differences in energy landscape, regulation, and business initiatives, the Benelux countries will use a slightly different mix of levers to reach carbon neutrality. However, there's a growing consensus about the importance of taking a collective approach to decarbonizing the region. All member states will face similar barriers when deploying these levers, which increases the need for collaboration.

3.

Technology deep-dives: CCU, CCS and hydrogen

CCU and CCS

The vision for CCU and CCS

CCU and CCS will play a crucial role in decarbonizing the Benelux's industrial sector. For many industrial applications, capturing CO_2 is the most cost-effective way to reduce CO_2e emissions, especially in sectors with highly concentrated CO_2 streams. In other sectors, such as cement, lime and waste-to-energy, CCU/S is the only abatement option to avoid carbon leakage.

Based on estimations of projects in the pipeline, CCS has the potential to store 10 to 15 Mtpa of CO_2 by 2030, whereas today's CCU pilots capture and reuse about 1 Mtpa of CO_2. Initially, CCU and CCS will be applied to manufacturing processes with highly concentrated CO_2 streams, such as ammonia and chemical production. This could grow to 20 to 35 Mtpa by 2050 when CCU/S is applied to hard-to-abate plants where the exhaust streams are less pure.

The Benelux is well-positioned to become a CCU and CCS hub for many reasons. **First**, the region has numerous industrial clusters that produce large volumes of chemicals, steel, lime, cement, and refined oil products, all of which produce significant amounts of CO_2 in concentrated streams, often close to the coast. **Second**, the Benelux can leverage its proximity to depleted gas fields in the North Sea and its upstream gas transport and storage expertise to safely transport and store the captured CO_2 (Exhibit 7). **Third**, its location as the gateway to Western Europe from the North Sea makes the Benelux an attractive CCS hub for CO_2 transported from industrial clusters in neighboring countries such as the North of France and Ruhr region that lack good storage options.

Although the Netherlands and Belgium have begun to pursue CO_2 capture initiatives, Luxembourg has declined to allow these projects within its borders. In their recommendations for decarbonizing energy-intensive industries, both the Intergovernmental Panel on Climate Change and the EU stressed the necessity of using carbon removal technologies such as CCU and CCS to reach carbon neutrality by 2050. An energy policy that rejects these technologies could hurt Benelux's ability to take a leadership position in the transition to carbon neutrality.

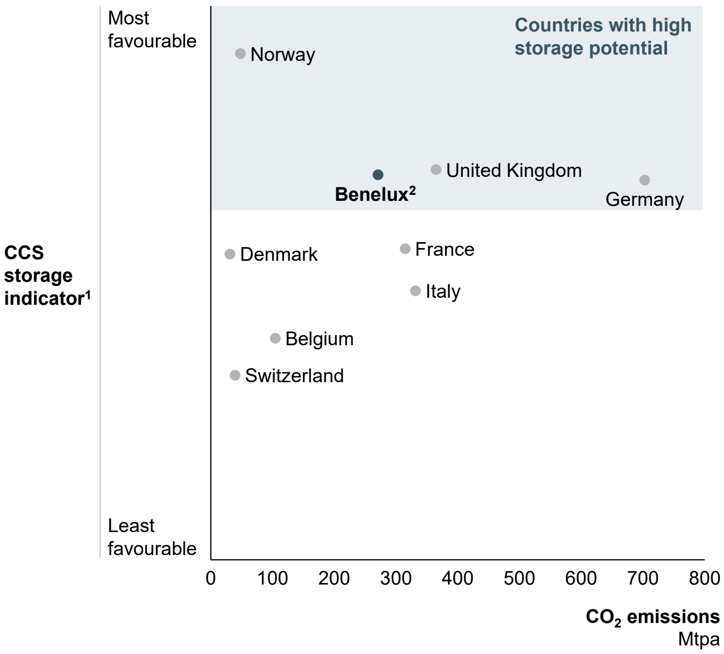
Although both CCU and CCS projects are expected to be deployed in the Benelux, CCU projects would only account for 5% to 15% of the region's total CO_2 capture capacity. Despite its potential, CCU is constrained by its technological immaturity and the fact that the EU only recognizes CCU applied during building materials production as a genuine decarbonization option. As the technology matures and availability to high-quality CO_2 streams initially captured for storage increases, CCU projects near industrial clusters might become more prevalent.

In the future, most CCU projects will likely focus on capturing CO_2 from industrial processes and combining it with green hydrogen to produce sustainable molecules such as e-methane, e-ammonia, and e-methanol. These sustainable molecules can be injected into the gas grid or used as an alternative fuel for manufacturing and transport. In Belgium, several industrial-scale pilots to produce e-methane and e-methanol are already in the pipeline. Those include the Columbus Project in Wallonia (green lime

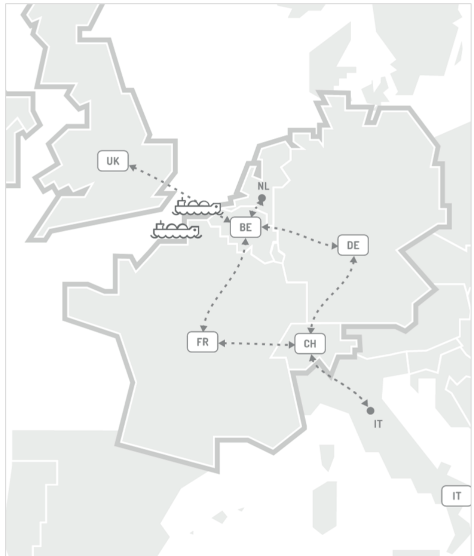
Exhibit 7

Benelux's unique position in CCS

The Benelux benefit from considerable storage potential and direct access to large supply of CO_2



In the long-run the Benelux could become a CCS hub for Eastern Germany and Northern France



1. The CCS storage indicator is a composite index based on a country (i) geological storage potential, (ii) maturity and confidence of storage resource assessments and (iii) experience in CO_2 storage projects and large facilities
2. Storage indicator for the Netherlands combined with emissions from the Netherlands, Belgium and Luxembourg

Source: Global CCS Institute

and e-methanol), Renewable Jet Fuel in Liege, North-C-Methanol in Gent, and Power-to-Methanol projects in Antwerp.

The interest in innovative CO_2 capture project development in the Benelux is evident by the range of industrial pilots currently being planned (Exhibit 8 and 9). At least six large-scale projects are in the pipeline with a combined capacity of reducing more than 35 Mtpa of CO_2e by 2035, although it's unlikely that all of them will be developed. At the moment, these projects must compete for limited public funding rather than collaborate on building networks and ecosystems. For example, the primary source of public funding for low-carbon technologies in the Netherlands (SDE++) would support CCS initiatives up to 7.2 Mtpa capacity by 2030 but stop funding new CCS projects from 2035 onwards.

What it will take

To implement CO_2 capture in the Benelux, policymakers and business leaders would need to take steps to collaborate on developing the required infrastructure, establish a clear regulatory framework, generate funding, and educate the public.

Infrastructure

From an infrastructure perspective, unemployed gas pipelines and depleted fields that are suitable for CO_2 storage would need to be made available for CCS projects.

Exhibit 8

Overview of large scale CCS projects in the Benelux

Carbon capture | Transport (pipeline) | Transport (ship) | Use | Offshore storage

Project	Scope	Capture capacity	# CO_2 suppliers	Source of supply
1 Porthos	Carbon capture, Transport (pipeline), Offshore storage	2.5 Mtpa (2023) 10 Mtpa (optional phase 2)	4	Air Liquide, Air Products, Shell and ExxonMobil
2 Athos[1,2]	Carbon capture, Transport (pipeline), Offshore storage, Use	4-5 Mtpa (2030)	1	Tata Steel
3 Aramis	Offshore storage	N.A.	N.A.	N.A.
4 H-Vision	Carbon capture, Transport (pipeline), Offshore storage, Use	2.2 Mtpa (2026) 4.3 Mtpa (2031)	5	Shell, ExxonMobil, BP, Equinor, Air Liquide
5 Carbon Connect Delta	Carbon capture, Transport (pipeline), Transport (ship)	1 Mtpa (2023) 6.5 Mtpa (2030)	5	Arcelor Mittal, Dow, Yara, Zeeland Refinery and PZEM
6 Antwerp@C	Carbon capture, Transport (pipeline), Transport (ship)	~9 Mtpa (2030)	6	Air Liquide, BASF, Borealis, ExxonMobil, Ineos and Total)

1. Includes the Everest project from Tata Steel which is the carbon capture segment of the Athos project
2. Assuming all projects will come online

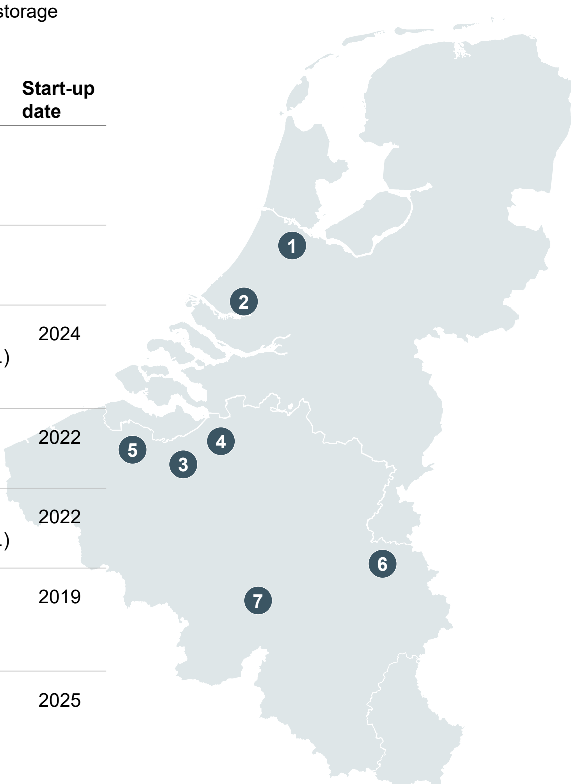
Source: Company websites, Press search

Exhibit 9

Overview of CCU pilots and industrial scale projects in the Benelux

Carbon capture | Transport (pipeline) | Transport (ship) | Use | Offshore storage

Project	Scope	Key companies	CO_2 source	CO_2-based product	Start-up date
1 Basic Oxygen Furnace 2 Urea	Carbon capture, Transport (pipeline), Use	Arcelor Mittal, TNO	Steel (0.1 mtpa)	Urea	
2 Renewable Jet Fuel from air	Carbon capture, Transport (pipeline), Use	EDL	Direct air capture	E-kerosene (~300t p.a.)	
3 North -C-Methanol	Carbon capture, Transport (pipeline), Use	Arcelor Mittal, Engie, Fluxys	Steel (0.07 mtpa)	E-methanol (~45,000t p.a.)	2024
4 Power-to-Methanol	Carbon capture, Transport (pipeline), Use	Engie, Fluxys, INOVYN		E-methanol (~8,000t p.a.)	2022
5 Steelanol	Carbon capture, Transport (pipeline), Use	Arcelor, Primetals, Lanzatech	Steel (0.2 mtpa)	Bio-ethanol (~65,000t p.a.)	2022
6 Leilac project[1]	Carbon capture	Heidelberg Cement	Lime (0.02 mtpa)		2019
7 Columbus	Carbon capture, Transport (pipeline), Use	Engie, John Cockerill, Carmeuse	Lime (0.02 mtpa)	E-methane	2025



1. The Leilac project focuses on improving capture technology for CO_2 produced during the lime & cement production process. Captured CO_2 is released into the atmosphere

Source: Company websites, Press search

Captured CO_2 would be shipped or transmitted by pipeline to international storage or usage locations. With cross-border collaboration, these pipelines could be installed quickly, and transportation costs would be reduced by 2 to 3 times. Governments and industrial players would also need to develop technical standards to harmonize the required impurity and compression levels for CO_2 transported across capture points, regions, and countries. Additionally, CCS players will need open access infrastructure such as pipelines, barges, liquefaction plants, and storage to reach critical mass and unlock economies of scale.

Regulatory framework

From a regulatory perspective, the Netherlands needs to establish bilateral agreements with neighboring countries such as Belgium, Germany, and France to share liability for CO_2 storage and potential leakage. Although there's little reason to worry about leakage in well-managed CO_2 storage facilities, the lack of clarity about potential liabilities could hold back development. Under current EU regulations, the country where the depleted fields are located is solely responsible for leakages. This could reduce the Netherlands' willingness to become a storage hub for neighboring countries without cross-border agreements and company tariffs in place.

Storage operators in the Netherlands also face higher costs than other countries like the UK and Norway because the financial reserve they're required to set aside to cover the cost of potential leakages is significantly higher. As the industry learns more about this technology, this will presumably be harmonized between countries.

Changes to the EU Emissions Trading System (ETS) regulations could also enable more CCU projects if it counted new uses of CO_2 towards offsetting emissions.

Funding

Most CCU or CCS projects are not yet financially viable for point source emitters. In the short term, this is because the ETS price is still too low to justify their development. In the medium term, it's because of a lack of confidence that the ETS price will rise above the breakeven price for these projects. As the price increases over time, existing operations will become less competitive. But because of future price uncertainty, it's unclear at what point companies will feel confident about investing in CCS projects. Closing the funding gap and making these projects financially beneficial will require addressing two issues: the upfront capital cost of building the capture and transport infrastructure and the ongoing operational costs of CCS.

In the first case, there's a clear trade-off between building large, economically efficient CCU/S networks capable of handling the emissions of several point sources or entire clusters versus the marginal economic case of the first CO_2 source that could be willing to invest. In the second case, the more efficient the scaling of the required infrastructure is, the less it will cost. But operational costs will need to be consistently lower than the ETS price to make these projects financially attractive.

For these reasons, public funding will be needed to support the development of open-access infrastructure in the Benelux. So far, only the Porthos project in Rotterdam has been awarded financial support beyond assistance with the feasibility studies. That project will receive €102 million in EU funding if final investment decisions (FID) are approved in early 2022.

The Dutch, Belgian, and Luxembourg governments would also need to level the playing field for public support and funding schemes for cross-border projects. Government funding for CCU and CCS is now more generous in the Netherlands than in Belgium, creating unintended consequences for cross-border projects like the Carbon Connect Delta between Ghent in Belgium and Terneuzen and Vlissingen in the Netherlands. It also means that a Belgian ammonia plant could be at a significant disadvantage to a Dutch ammonia plant in competing for funds to launch CCS projects.

Public domain

Historically, CCS projects have suffered from public opposition, and many NGOs are skeptical of their role in reaching carbon neutrality. However, because industry players are convinced that using CCS will be crucial for achieving the EU net-zero targets, this negative perception needs to be addressed. Citizens need to be reassured that these efforts would focus exclusively on offshore CO_2 storage to mitigate potential leakages or landslides related to onshore storage. They should also be informed of the research on the long-term impacts of CO_2 storage. To make a case for CCU/S, the Benelux governments could learn from the UK and Norway, where this technology has more public support.

Box

Lessons from the EU CCS industry project in the 2010s

In 2009, the EU established the European Energy Programme for Recovery (EEPR) and NER300 funds to provide up to €3.1 billion for low-carbon technologies. As much as €1 billion was earmarked exclusively for CCS, which could also compete against bids from other low-carbon technologies for the remaining €2.1 billion. The funding covered both capital expenses and the first ten years of operating expenses. Companies submitted applications for more than ten large-scale projects, and six of them received a total of €400 million in EU funding.

However, between 2010 and 2012, ETS prices dropped 50%, and projects started to unravel. Eventually, all CCS projects were abandoned except for an industrial pilot project in Spain. Since then, not a single large-scale CCS project has been developed in the EU despite the government's substantial funding initiatives.

Several factors contributed to this outcome, including:

- **Carbon price volatility:** Projects developed in 2010 were based on €20 to €40/tCO_2 assumptions, which seemed reasonable at the time given that ETS prices were €30/tCO_2 before the 2008 financial crisis. However, ETS prices did not recover, remaining below €10/tCO_2 from 2012 to 2017.
- **The failure to adapt EU funding mechanisms to changing circumstances:** Even though CCS projects faced an entirely different carbon price environment after 2012, the qualification rules remained the same. For example, policymakers did not adjust the highest percentage of project costs that NER300 could cover despite CCS projects needing more financial support in a below-€10/tCO_2 environment.
- **The conditionality of EU funding:** CCS projects were often required to secure funding from their local governments before being eligible for EU funding, making projects vulnerable to national policy changes.
- **The lack of regulatory framework:** At least one large-scale project failed because the country where it was located was too slow in incorporating EU directives into national laws and enacting its own CCS regime.
- **The complexity of the funding process:** Applying for the EEPR and NER300 funds was a long and complex procedure involving at least five different departments within the EU administration.

Looking back and understanding the underlying reasons for the lack of progress on CCS initiatives can provide insight into the challenges they face and the kinds of pitfalls that policymakers and industry players will need to avoid to make future projects successful.

Role of collaboration

Greater collaboration between public and private CCU/S stakeholders will be essential for implementing CCU/S projects in the Benelux. This collaboration could take many forms, including:

Private-private collaboration examples

- Industry players could develop economies of scale by developing open-access transport and storage infrastructure. Pooling the pipelines, barges, injection points, and other assets required to move and store CO_2 among a larger number of CCS players would lower the costs per unit of CO_2 processed for all participants. For example, pooling funds to construct a pipeline with a capacity of 10 Mtpa instead of 3 Mtpa could reduce transport costs for all users by up to 65% per unit of CO_2. Opportunities for reaching economies of scale are particularly promising in the Rotterdam region, where two rival CCS networks—the H-Vision and Porthos projects—are under consideration.
- Industry players could develop long-term contracts to derisk investments across the value chain, such as establishing ten-year supply contracts between CO_2 capture projects and storage projects.
- CCS users could connect with other CCS users to align the timelines and size of various capture, transport, and storage projects and coordinate planning.
- CCS users could coordinate applications for subsidies and permits as a single project with multiple capture points and open access transport and storage systems to increase the chances of getting them awarded.
- CCU/S users could leverage the skills of other users across the CCU/S value chain to fill knowledge and capability gaps. Few companies have the expertise and resources required to capture, transport, and store CO_2 by themselves, making cooperation critical for implementing these networks.

Private-public collaboration examples

- With the support of scientific partners, the government and industry players could set up a central coordination entity to integrate initiatives beyond CCS into a holistic master plan.
- Governments and industry players could standardize regional technical and quality standards for CO_2 transportation across different projects, regions, and countries to enable open access infrastructure and unlock economies of scale.
- Governments and industry players could collaborate on educating the public about the importance of CCS projects in reducing industrial emissions in the Benelux and retaining jobs, as well as the low risks associated with CCS technologies.
- CCU players, research institutes, and universities could collaborate on improving technologies for CO_2 capture and converting CO_2 and hydrogen into sustainable molecules.
- National governments, private insurers, and financial institutions could come together to expand the range of insurance products available to CO_2 storage sites for potential leakages. Insurance companies already cover most low-probability and

high-cost risks associated with oil and gas extraction, and a similar market could be developed for CO_2 storage.

Public-public collaboration examples

- National Benelux governments could align regulations on cross-border CO_2 transport and storage within the region and beyond to share long-term liabilities for potential leakage from CO_2 storage sites such as those in the Netherlands.
- The Dutch and Belgian governments could harmonize their financing support schemes to create a level playing field and facilitate cross-border CCS projects.

Hydrogen

The vision for hydrogen and sustainable molecules

Hydrogen and sustainable molecules will contribute to the decarbonization journey. As the Benelux strives to achieve the EU's carbon-neutral target by 2050, demand for sustainable molecules like hydrogen will increase. This growth would be driven primarily by greater consumption in non-industry sectors such as buildings and transport. Within the industry sector, demand for sustainable molecules like hydrogen would come primarily from refining, ammonia, iron and steel producers. Existing off-takers of hydrogen like refining and ammonia wouldn't increase their energy demand but replace their current use of carbon-intensive hydrogen with low or zero-carbon hydrogen. However, iron and steel manufacturers and paper mills may become new hydrogen consumers.

Using hydrogen as fuel in high-temperature heat processes such as cement, lime and ethylene production would further reduce industry emissions. However, it's more expensive to decarbonize these processes using hydrogen than other measures like CCS and electrification. On top of being a carbon-neutral feedstock, sustainable molecules could be stored and used to cover seasonal energy shortages.

From now until 2030, the Benelux's current supply of gray hydrogen would need to transition to become a combination of blue and green hydrogen. Therefore the gradual development of an open access hydrogen backbone with prior focus on the industrial clusters has to be started. In the short term, local hydrogen production from fossil fuels will remain more cost-competitive than locally produced green hydrogen (Exhibit 10). Over time, imports of hydrogen and sustainable molecules such as e-methane, e-methanol from low-cost production centers in places like North Africa, the Middle East, and Australia will play a bigger role in fulfilling demand and keeping prices competitive. Alternatively and potentially more financially attractive, Benelux could outsource part of its upstream production processes.

Interest in hydrogen and sustainable molecules development has been growing among EU member states. In 2020, the French government unveiled a national hydrogen strategy to invest €7.2 billion to reach a production capacity of 6.5 GW by 2030.[11] In

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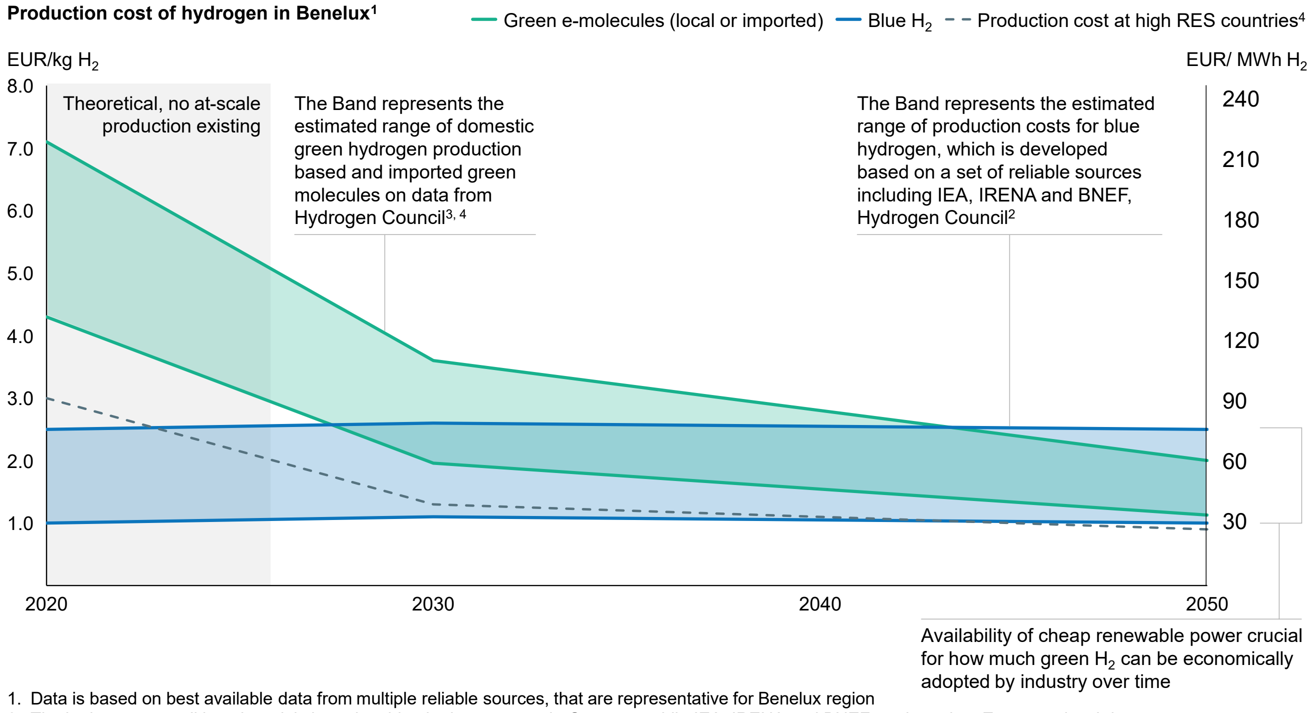
[10] publicly available data consolidated with BBR members; more details about the sources are provided in the appendix.

[11] https://fuelcellsworks.com/news/french-economic-recovery-package-to-include-7-billion-euros-for-hydrogen-industry/.

Exhibit 10

Estimated production costs of green and blue hydrogen in the Benelux[10]



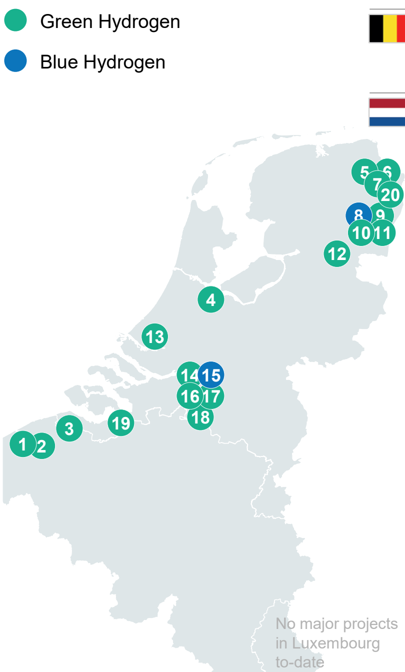
1. Data is based on best available data from multiple reliable sources, that are representative for Benelux region
2. The hydrogen council benchmark is based on blue hydrogen costs in Germany, while IEA, IRENA and BNEF are based on European-level data
3. The upper and lower bounds are estimated based on different renewable power supply in Benelux, including Belgium solar, Dutch on-shore, and Dutch off-shore data
4. Hydrogen import coalition: cost of imported sustainable molecules from Chile, Oman or Morocco (Methanol, Methane, ammonia and H_2)

Source: Florence school of regulation, IEA, IRENA, BNEF, Hydrogen Council, Hydrogen import coalition

Exhibit 11

Overview of H_2 and sustainable fuel projects in the Benelux

Not exhaustive - based on publicly announced projects



Country		Project Name	Capacity	Company Name	End-use
	1	Hypport - Phase 1		DEME, Port of Oostende, PMV	
	2	Hyport - Phase 2		DEME, Port of Oostende, PMV	
	3	Hyoffwind		Eoly (Colruyt), Parkwind, Fluxys	
	4	IJmuiden		Tata Steel, Nouryon, Port of Amsterdam	
	5	Delfzijl Project Phase 1		Nouryon, Gasunie	
	6	Delfzijl Project Phase 2		Nouryon, Gasunie	
	7	DSL-1 (H_2 supplied by Delfzijl Phase 2)		SkyNRG, KLM Royal Dutch Airlines, SHV Energy and Amsterdam Airport Schiphol	
	8	Magnum (H_2M)		Vattenfall, Equinor, Gasunie	
	9	North$_2$		Shell, Gasunie, Groningen Seaports, Equinor, RWE	
	10	RWE Eemshaven power station		RWE	
	11	HyNetherlands		Engie, Gasunie	
	12	SinneWetterstof Hydrogen Pilot Project		Alliander, BayWa re	
	13	PosHYdon pilot		Gasunie, Poseidon Energy, TAQA, EBN B.V., NAM, NOGAT B.V., Noordgastransport B.V, Nextstep, TNO	
	14	H_2 backbone Port of Rotterdam		Port of Rotterdam, Gasunie	
	15	H-Vision Phase 1		Deltalinqs, TNO, Air Liquide, BP, EBN, Engie, Equinor, Gasunie, GasTerra, Linde, OCI Nitrogen, Port of Rotterdam, Shell, TAQA, Uniper and Koninklijke Vopak	
	16	Multiphly		CEA, Neste, Paul Wurth, Engie	
	17	Tweede Maasvlakte at port of Rotterdam		Shell, Eneco	
	18	H_2-Fifty		BP, Nouryon, Port of Rotterdam	
	19	Sluiskil Ammonia plant		Orsted, Yara	
	20	Hystock		Gasunie	

Mapped projects focus on Benelux area

1. Including large-scale projects with focus on infrastructure for heavy industry, but excl. smaller-scale research initiatives (e.g., lab R&D by individual players) or non-industrial end-uses (e.g, fuel cell-based mobility)
2. Significant underestimate likely due to (i) technology maturity (early-stage projects) and (ii) lack of public information

Source: Hydrogen projects database; Hydrogen counsel, Press research, Company statements, European Commission Emissions Database for Global Atmospheric Research 2018

Germany, the government announced plans to invest €9 billion to reach up to 5 GW productioncapacity by 2030.[12]

The Benelux has multiple ongoing hydrogen and sustainable molecules development projects (Exhibit 11). The Netherlands has committed to reaching capacity targets of 0.5 GW of electrolysis by 2025 and 3 to 4 GW by 2030, providing support such as public funding from SDE++. Industrial and non-industrial organizations across Benelux have announced 20 hydrogen projects that could generate about 3 GW of hydrogen by 2030 if all of them come online.[13] The rising interest in green hydrogen is driven by projections that its production costs will drop sharply by 2030 as renewable energy and electrolyzer capital costs.

What it will take

To prepare the Benelux for this sharp increase in hydrogen and sustainable molecules consumption, policymakers and business leaders will need to take steps to develop open-access infrastructure, establish a clear government strategy and regulatory framework, and generate funding.

Infrastructure

Developing blue hydrogen would require new CCS infrastructure to transport CO_2 from industrial clusters in the Benelux to a network of storage sites. Existing natural gas infrastructure could be repurposed to transport CO_2 from industrial clusters towards storage locations. (Details about the required CCS infrastructure are provided in section *The vision for CCU and CCS, page 27)*.

To provide a low-cost renewables power supply for green hydrogen production, offshore wind projects in the North Sea would need to be expanded. Electricity grid connections would also need to increase to keep pace with renewables build-out for transmission from offshore wind farms in the North Sea to hydrogen production sites in Belgium and the Netherlands. However, the need for grid capacity expansion would differ depending on the location of renewable energy supply and green hydrogen production. In the short term, these hydrogen production sites would only need limited capacity because of the low supply of renewable energy in the Benelux. Because of this constraint, importing hydrogen and its derivatives will be cheaper once the European hydrogen backbone is in place (Exhibit 12).

These hydrogen production sites would need to be constructed close to the biggest energy consumers, including industrial clusters in North France, Benelux, and the Ruhr region. Transporting hydrogen to these sites would require building an open-access hydrogen backbone. After 2030, it should be connected to the EU hydrogen backbone and have established shipping routes to other low-cost green hydrogen production locations such as the Middle East and Northern Africa (e.g., Oman, Egypt and Morocco).

To provide short-term storage for sustainable molecules, storage and conversion

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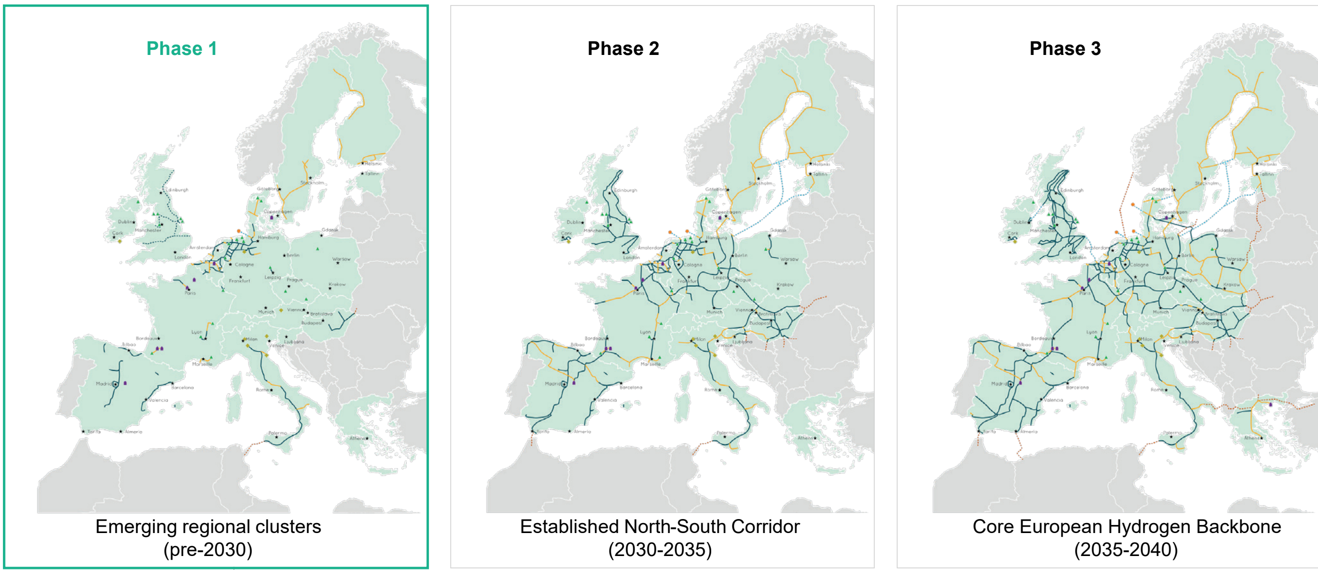
12 https://www.dw.com/en/germany-and-hydrogen-9-billion-to-spend-as-strategy-is-revealed/a-53719746.
13 Publicly available data consolidated with BBR members.

Exhibit 12

European hydrogen backbone

Connecting Northwestern Europe pre-2030 and Western Europe towards 2040



Starting from local clusters, mainly Germany, Benelux, Spain, France, Italy

Source: European Hydrogen Backbone

facilities will need to be developed at Belgian and Dutch ports. Long-term seasonal storage would require geological storage locations. Off-takers would need to connect to the hydrogen grid and perhaps build small local hydrogen buffer tanks. Smaller off-takers may decide to get hydrogen in gaseous or liquid form from distribution trucks like today's hydrogen refueling stations. Some industries might have to invest in building green ammonia plants, green refineries, and green steel plants. All of these projects would require retrofitting equipment and production processes.

Regulatory framework

To kickstart a sustainable molecule build-out, the Benelux governments need to establish a long-term hydrogen strategy that provides certainty about which hydrogen hubs they will prioritize. Tailoring regulation to the maturity level of hydrogen production in a specific region while imposing minimum standards such as unbundling/neutral operator, transparency, and non-discriminatory Third Party Access (TPA) will ensure that hydrogen investments are future proof. This will contribute to increasing the liquidity of the hydrogen market. Incorporating the rules for hydrogen in the gas legislation would be the most efficient way of ensuring regulatory alignment between these closely related energy vectors. It should also accelerate offshore wind development via early-on spatial planning and tendering and standardize hydrogen equipment, components, and operations. Against these priorities, it would help to have clear targets. The targets may differ within member countries based on local access to resources. For instance, the Netherlands has established targets for developing 0.5 GW of electrolysis by 2025 and 3 to 4 GW by 2030. However, there's growing consensus in Belgium to prepare for scaling sustainable molecules imports, although there's no established national strategy yet.

During this process, policymakers will have to make critical decisions about energy security, industry relocation, employment, and GDP growth. In the medium-term, these decisions might shift the balance of whether the region produces hydrogen and its derivatives locally or imports them from other countries.

Funding

In many cases, hydrogen applications do not have a positive business case compared to conventional alternatives, particularly in the short-term. As such, funding will be required to support their development. The existing hydrogen-dedicated funding that Benelux provides is limited compared with their peers, such as Germany and France.

The Netherlands government has dedicated more than €80 million in subsidies through the Demonstrated Energy Innovation (DEI) grant and other scaling instruments. Although general funding sources like the €5 billion SDE++ fund are available,[14] they favor more advanced, cost-efficient technologies like renewables. In practice, hydrogen projects only qualify for a small percentage of this capital.

As a result, governments must determine the specific funding that's needed to develop and scale blue and green hydrogen production in line with national hydrogen targets. Belgium and Luxembourg have defined some support for hydrogen projects, such as IPCEI Hydrogen focused on R&D. It would spark greater investment if these countries established targets for hydrogen's role in their energy systems like the Netherlands with a national hydrogen strategy or roadmap and announced their intentions for providing funding support.

Aside from cost-competitiveness, funding mechanisms need to consider the CO_2 abatement potential of initiatives, which would help boost the development of large-scale hydrogen projects. In addition, funding sources could be diversified to address oversubscription issues, such as incentivizing private investment in hydrogen projects. On top of this, volume guarantees and price guarantees could help alleviate the funding gap.

Volume guarantees focus on guaranteeing the supply and off-take of hydrogen to de-risk large investments. Examples include:

- **Clearinghouse between supply and demand:** An auction-based system to establish a subsidy support level, so the government pays the gap between the supply and take-off price-point.
- **Government-funded end-use applications:** Government demand for hydrogen created through public measures like switching to hydrogen-run city buses.
- **Mandated clean hydrogen certificates for natural gas consumers:** Trading of green hydrogen through certificates with a guarantee of origin. This would allow consumers to offset their fossil-fuel consumption if connecting to a hydrogen network is difficult or impossible.
- **Minimum sector targets:** Targets such as 10% green steel or cement or hydrogen blending quota
- **Insurance for infrastructure delays:** Government insurance for parties involved in projects that depend on each other to go live. For example, to protect an electrolysis

[14] https://english.rvo.nl/subsidies-programmes/sde.

plant developer that's unable to connect to a midstream pipeline because the transport company responsible for building the pipeline fails to complete construction on time.

Price guarantees stabilize the hydrogen market by reducing uncertainty about future hydrogen prices. Examples include:

- **Contracts for difference:** Hedging ETS's floating price.
- **Feed-in tariff:** Guaranteeing the price of green hydrogen for a certain period, such as 10 to 15 years.
- **Price floor for green hydrogen:** Assuring a minimum hydrogen price so that if hydrogen prices drop significantly after the first five to ten years of a commercial contract, the provider can still sell hydrogen at a price that keeps its initial investment viable.

Regardless of the type of funding mechanism, it will be critical to require certificates to guarantee the low-carbon nature of hydrogen and its origins.

Role of collaboration

Greater collaboration between public and private hydrogen stakeholders will be essential to solve challenges, increase synergies, and decrease costs for implementing hydrogen projects. This collaboration could take many forms, including:

Private-private collaboration examples

- Hydrogen players should have access to open access CO_2 and hydrogen pipelines, barges, liquefaction plants, and storage with other businesses to distribute the investment costs.
- Hydrogen players align the timelines and size of their hydrogen production, transport, and storage projects.
- Hydrogen users coordinate with each other to apply for subsidies and permits as a single integrated project with open access transport and storage systems to increase the chances of getting them.
- Hydrogen players leverage the skills of other users across the hydrogen value chain to fill in knowledge and capability gaps. Few companies have the expertise and resources required to produce, transport, and store hydrogen by themselves.
- Hydrogen players create purchasing consortia to jointly procure hydrogen production infrastructure such as electrolyzers and piping with greater purchasing power.

Private-public collaboration examples

- Governments and hydrogen players could collaborate on standardizing regional hydrogen transport standards. Agreement on technical and quality standards across different projects, regions, and countries is crucial to have open access infrastructure, which unlocks economies of scale.

- Governments and industry players could integrate initiatives beyond hydrogen into one holistic, carbon-neutral master plan, such as under a central coordinating entity. They could learn from Germany's plan to establish a national hydrogen council comprised of industry and academia representatives, supported by a hydrogen coordination center.
- Hydrogen players, research institutes, and universities could increase collaboration to accelerate new technology development.

Public-public collaboration examples

- Benelux governments could pave the way for cross-border projects by harmonizing financing support schemes and aligning cross-border hydrogen transport and storage regulations. For example, the Netherlands and Germany have created a plan for using offshore wind resources in the North Sea to produce hydrogen and export it to Germany using the Netherlands' existing gas network. Policymakers in the Benelux countries could coordinate similar efforts.
- Benelux governments could work together to increase the capacity of grid interconnections between Belgium and neighboring countries to ensure North Sea offshore energy can be transmitted to electrolysis plants.

4.

The masterplan for decarbonizing Benelux's industry sector

Key challenges to overcome

Deploying CCU/S and hydrogen production at the level required to decarbonize the Benelux industry sector would require overcoming significant financial, regulatory, public perception, and coordination challenges.

From a financial perspective, many of the levers and technologies needed to reach carbon neutrality don't have positive business cases yet. Adding to that challenge, future carbon prices are unpredictable (e.g., volatility and steep rise of CO2 cost under speculative actions on the EUA market), along with the future supply and demand for things like green hydrogen and CO_2 storage capacity. This is compounded by the fact that public funding for projects is oversubscribed and private investment is limited.

From a regulatory perspective, Benelux industry players don't yet have an integrated carbon-neutral strategy or detailed plan. Nor have policymakers set up the regulatory framework necessary for allowing CO_2 to be transported and stored across the three countries. Each of the three countries offers different levels of public support for initiatives to reach carbon neutrality. On top of that, the number of mechanisms to help industry players manage carbon price, supply and demand uncertainty is limited.

In the public domain, governments and business leaders will need to address public concerns about CCU/S and work together to build cross-border infrastructure. Local policymakers and business leaders now have an opportunity to step up the coordination needed to solve these problems by applying integrated system thinking and sharing risk.

The time is now

Addressing these challenges requires immediate action if the Benelux industry is to achieve carbon neutrality. The decisions that policymakers and industry players make now will determine whether the region will accelerate or hinder the EU's efforts to reach net-zero.

A major concern about the transition to net-zero is the risk of stranded assets—the forced retiring of equipment like blast furnaces before the end of their lifecycles. This is particularly true in the industry sector, where assets have lifetimes of 50 or more years. Investment decisions that manufacturers make now could affect the economic gains of making these changes for years to come. For example, taking a first-time-right design approach is typically less expensive than retrofitting equipment. Thinking through which assets to retire when and how to best replace them could significantly reduce the cost of green investments.

To get the first CCU and large-scale CCS projects online by 2025, industrial players will need to decide which projects to fund in the next 12 months. Lead times for securing permits and constructing the required infrastructure, such as hydrogen and CO_2 pipelines, typically run two to five years. Some projects, such as those involving CCS capture, require first clarifying transport and storage infrastructure solutions and time-lines. So, any delay at each step of the value chain would affect the success of the rest.

Developing a regional regulatory framework for the cross-border transport and storage of CO_2 and hydrogen will take time. Government officials in Belgium, the Netherlands, and Luxembourg need to initiate discussions now to clear the way for the development of the first cross-border hydrogen and CCS/U projects by 2025. Officials also need to review existing regulations such as ETS and REDII to support low-carbon hydrogen, CCU, and sustainable molecules initiatives.

No regret moves in the next 12 months

As it embarks on the pathway to net-zero, the Benelux faces much uncertainty. It's difficult to predict future energy costs and the kinds of technology developments and breakthroughs that will occur in years to come. The role that various emissions reduction solutions will play in the transition is likely to change depending on their cost competitiveness, technological maturity and applicability to different types of businesses. Regardless of the unknowns, the Benelux needs to make the necessary investments and reform regulations to take advantage of the opportunities that green technologies present. The region also needs to pursue rapid technology innovation and deploy all available levers to reach carbon neutrality.

Ensuring these efforts are successful will require greater coordination and cooperation within the Benelux and with neighboring countries. Efficient access to funding and clear agreements are also necessary for building cross-border backbones and other infrastructure for hydrogen production and CO_2 transportation.

Starting today, policymakers and industry players need to take the following actions (Exhibit 13):

- **Facilitate a cross-border holistic energy/molecule system plan** divided into phases and based on progressive insight from policy, industry, and scientific partners.
- **Accelerate the deployment of mature levers**, with a focus on increasing energy efficiency and demand circularity with the best available technologies. Electrify low- and medium-temperature heat production processes to achieve a 15 to 20 $MtCO_2e$ reduction by 2030.
- **Accelerate the build-out and scaling of renewable energy projects** such as offshore wind farms in Borssele, Hollandse Kust, IJmuiden Ver and Belgian offshore developments to transition to a power network fueled primarily by renewables.
- **Develop open-access CO_2 and hydrogen backbones**, including critical cross-border connections within Benelux and to neighboring countries and preparing hydrogen import facilities.
- **Establish a regulatory framework for an open-access cross-border CO_2 and hydrogen import, transport and storage.** These include creating technical and quality standards for CO_2 and hydrogen transport as well as new rules for sharing the long-term liabilities related to potential leakages at CO_2 storage sites. Without access to offshore storage sites in the Netherlands, CCS projects in Belgium will suffer delays.
- **Set up joint task forces across key hydrogen and CCU and CCS projects** to ensure coordination across the value chain, align timelines, leverage economies of scale, and develop the required regulations

Exhibit 13

How to launch the action plan

	Collaboration scope	
Action (critical path)	**Individual member states**	**Benelux, Ruhr, North France**
Speed-up deployment of mature levers today, with a focus on increasing energy efficiency and demand circularity with best available technologies, and electrifying low- and medium-temperature heat production processes, to achieve a 15 to 20 Mt CO_2e abatement by 2030	✓	
Accelerate the build-out and scaling of renewable energy projects such as offshore wind farms in Borssele, Hollandse Kust, IJmuiden Ver, Belgian offshore development to transition to a power network fueled primarily by renewables	✓	✓ Interconnectivity
Develop open access CO_2 and hydrogen backbones, including critical cross-border connections within Benelux and to its neighboring countries and preparing hydrogen/ sustainable molecules import facilities	✓ Country-wide backbone	✓ North France and Ruhr interconnections
Establish regulatory framework for an open access cross border CO_2 and hydrogen transport and storage (including technical and quality standards, new rules for CO_2 storage liability/risk management)		✓
Set up joint task forces across key H_2 and CCU and CCS projects to ensure coordination across the value chain, align timelines, leverage economies of scale, and develop the required regulatory conditions	✓	✓ Cross border projects (e.g., CCS)
Create innovation and pilot platforms across the industry sector, academia and governments to accelerate technological advancements and process breakthroughs, including CO_2 purification technologies, high-efficiency electric furnaces, mineralization and electrolysis solutions	✓	✓
Provide sufficient public funding and determine how to unlock private financing needed to fund long-term projects to reach carbon neutrality	✓	✓

- **Create innovation and pilot platforms across the industry sector, academia, and governments** to accelerate technological advancements and process breakthroughs. This could include CO_2 purification technologies, high-efficiency electric furnaces, mineralization and electrolysis solutions, process design for energy flexibility, and innovative concepts for residual heat use.
- **Assure sufficient funding and determine how to unlock the private financing needed** to fund long-term projects to reach carbon neutrality.

The action plan and key enablers

Like any significant undertaking, Benelux's plan for transitioning to carbon neutrality should be broken down into phases, with key actions that fall into four main pillars:

1. Maximize the deployment of mature levers to reach carbon neutrality.

2. Develop viable business cases for investments to help achieve carbon neutrality.
3. Establish the required regulatory framework.
4. Address public and governmental concerns.

To achieve the objectives of these four pillars, policymakers and industry players need to take the following detailed actions in the next two, five, and ten years:

2021-2022

Pillar 1: Maximize the deployment of mature levers to reach carbon neutrality

- Double down on deploying energy efficiency, electrification, and demand circularity projects.
- Accelerate the build-out and scaling of renewables and improve cross-border electricity connectivity as needed.

Pillar 2:Develop viable business cases for investments to reach carbon neutrality

- Develop business cases for levers to reach carbon neutrality, including local and imported sustainable molecules and CCU/S projects. Explore synergies of scope and scale within Benelux and neighboring countries, and identify financing needs.
- Prepare permits to develop the required CO_2 and hydrogen backbone and cross-border connections.

Pillar 3: Establish the necessary regulatory framework

- Translate the EU's emissions reduction targets into an actionable plan, including setting regional- and sector-level targets for CCU/S and hydrogen development.
- Establish an industrial business logic and leveled playing field within the EU regulatory framework to encourage investments across the Benelux.
- Finalize the regional framework for cross-border transport and storage of CO_2 and hydrogen, including establishing quality and technical standards for CO_2 transport and long-term liabilities for CO_2 storage.
- Examine how the increasing CO_2 cost trajectory can be made more transparent and predictable (i.e., limit volatility from speculative action).

Pillar 4: Address public and governmental concerns

- Educate the public on the importance of hydrogen and CCU/S in reaching emission reduction targets and maintaining industrial jobs in the Benelux.
- Involve the public in early discussions about achieving carbon neutrality and explain the measures being taken to make it safe.
- Invest in public infrastructure for hydrogen and CCS.

By 2025

Pillar 1: Maximize the deployment of mature levers to reach carbon neutrality

- Continue implementing energy efficiency, demand circularity, and electrification initiatives across sectors.
- Rapidly scale the availability of renewables.

Pillar 2: Create viable business cases for investments to reach carbon neutrality

- Develop the hydrogen backbone within industrial clusters and construct the CO_2 backbone with connections between industrial hubs in Belgium and the Netherlands. This development should include sustainable molecules receiving centers in Belgium and the Netherlands to connect Benelux to international export terminals.
- Bring two or more large-scale CCS projects online like for example Porthos, Athos, Antwerp@C, Carbon Connect Delta that focus on capturing high-concentration CO_2 streams during blue hydrogen, ammonia, and steel production. Also, bring the first storage sites online in the North Sea.
- Implement two to three industrial-scale CCU pilots, such as Columbus (green lime and e-methanol), Power to Methane, North-C-Methanol, cement and lime projects to capture and sequestrate CO_2 (such as mineralization)
- Start developing a hydrogen market in the Benelux by combining green and blue hydrogen to decarbonize sectors with the lowest abatement cost, such as oil refining, and begin building the hydrogen backbone.
- Work across industry and academia to accelerate innovation, technological advancement, and process breakthroughs.

Pillar 3: Establish the required regulatory framework

- Create regulations to unlock private funding, such as by leveraging public-private partnerships with EU-backed financial institutions to reduce private investment risks.
- Address the oversubscription of current funding levels.
- Put measures in place to create off-take certainty, such as government-funded end-use applications, and price certainty, such as clean hydrogen certificates for natural gas consumers, ETS hedging, feed-in tariffs, and hydrogen price floors. Simultaneously, take care not to artificially unbalance market functioning with other sustainable solutions like direct electrification.

Post-2025

Pillar 1: Maximize the deployment of mature levers to reach carbon neutrality

- Continue implementing energy efficiency, demand circularity, and electrification projects.

Pillar 2: Create viable business cases for investments to reach carbon neutrality

- Develop more CO_2 hubs with direct pipeline access to storage sites in the North Sea near the main industrial clusters in the Benelux, North France, and the Ruhr region
- Deploy CO_2 capture technologies in smaller industrial clusters, particularly where no alternatives to reach carbon neutrality are available, and ship the captured CO_2 to storage sites
- Scale the hydrogen economy with at-scale imports of sustainable molecules and become an import hub for Europe. Continue developing storage and conversion

infrastructure to support the import and export of sustainable molecules.

Pillar 3: Establish the required regulatory framework

- Bring the CO_2 and hydrogen markets to maturity by increasing liquidity and developing the necessary market instruments, such as spot pricing, hedging, and offering a wider variety of contract financial models to suppliers and off-takers.
- Explore pass-through mechanisms to reduce the CCS and hydrogen's reliance on public funding and share the costs with consumers. This could include emission standards, consumption or distribution mandates, and carbon footprint labeling.