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Final report – Update of context analysis and roadmap study

Towards a carbon-circular, low-CO_2 and competitive Flemish basic industry

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1. Introduction

"How can the Flemish energy-intensive industry make the transition to a low-CO_2 and carbon-circular industry?" In 2020, an answer to that question was formulated in the form of an extensive roadmap study and context analysis containing several possible transition pathways for the Flemish energy-intensive industry. It was also stipulated that the competitiveness of the industry must be safeguarded. The indicative roadmap recommended focusing on four thematic transition pathways by 2050, namely:

1. The use of biomass as energy and raw material
2. Circularity, mainly through the reuse of plastics
3. Electrification and increased use of hydrogen (H_2)
4. The capture, storage and reuse of CO_2 (CCS and CCU)

On the basis of these insights, the Klimaatsprong programme was later launched and anchored in legislation, with the aim of guiding the transition of the energy-intensive industry in Flanders. A first programme note was drawn up and approved by the Flemish Government in June 2023, running until the end of 2025. According to the decree, a new programme note must be prepared every five years, whereby the previous note is evaluated and an approach for the next five years is proposed. In preparation for the new programme note 2026–2030, this study was initiated with the aim of providing sufficient insights into the current situation, societal developments, trends and risks in the field of industrial energy and climate transition, by updating the previous roadmap study and context analysis.

The current report is therefore a critical analysis of the developments that have taken place since the previous roadmap study and context analysis. It analyses the current situation and societal developments within the steel, refining and (petro)chemicals sectors, referred to in this study as the "basic industry". First, an analysis is made of the changes in the policy context at European, federal and Flemish levels in the period 2019–2024. Next, the evolution of activity in the Flemish basic industry is mapped in terms of greenhouse gas emissions, energy consumption and socio-economic parameters (production, employment, investments, imports and exports). This is followed by a competitiveness analysis comparing Belgium with Europe, the United States and China. Finally, the technological options included in the 2020 context analysis and roadmap[1] are evaluated. This assessment looks both at the evolution of the maturity of the various technological options and at the importance of the different transition pathways.

On the basis of these evaluations, an updated roadmap for the climate transition has been drawn up, once again emphasising the preservation of a competitive economy. The ultimate goal remains unchanged, namely to achieve a carbon-circular and low-CO_2 basic industry by 2050. Finally, all insights have been used to formulate a broad set of policy recommendations that can be taken into account in drafting the new programme note within Klimaatsprong.

[1] Towards a carbon-circular and low-CO_2 Flemish basic industry

2. Summary

Since the previous roadmap study, Europe has matched words with deeds and anchored the Paris climate targets in the EU Climate Law, with the aim of reducing emissions by 55% by 2030 and achieving climate neutrality by 2050. Driven by the EU Green Deal and the "Fit for 55" package, the entire policy context for the transition was also significantly altered with the introduction of numerous policy instruments, such as the EU Emissions Trading System (EU ETS), the Carbon Border Adjustment Mechanism (CBAM), the Renewable Energy Directive (RED), the Energy Efficiency Directive (EED) and the Industrial Emissions Directive (IED). These initiatives aim to facilitate the transition to low-carbon production processes by imposing a CO_2 price, tightening sectoral targets and strengthening permitting criteria. CBAM seeks to create a level playing field for imported products compared to producers outside the EU by charging similar CO_2 prices, but it does not sufficiently protect against derived products, nor the competitiveness of export products.

The European ambition to be climate-neutral by 2050 demands enormous efforts from the basic industry. At the same time, the European basic industry faces a decline in competitiveness on the world market, resulting in falling production volumes and a corresponding decrease in greenhouse gas emissions and energy consumption. Amid several crises – the COVID-19 pandemic, the war in Ukraine and high energy prices – the basic industry nevertheless managed to maintain its position as a key sector for the Flemish economy. Since the previous roadmap study, the steel, refining and (petro)chemicals sectors have not lost importance and still represent a significant share of industrial production, investment, employment and exports.

Compared to 2019, the competitiveness of the Flemish basic industry, as in the rest of Europe, is under greater pressure than in the United States and China, due in part to much higher costs for electricity (x2) and natural gas (x4), as well as high costs arising from regulation and environmental protection (including ETS CO_2 costs and higher administrative burdens). In addition, the strong expansion of production capacity in China, among other places, has created overcapacity which, together with stabilising market demand, puts pressure on prices. Combined with various trade conflicts (such as "Liberation Day" in the US), producers from other continents are increasingly targeting the European market.

To address these challenges, the Clean Industrial Deal was announced at European level, aimed at combining measures to achieve climate neutrality by 2050 with measures to strengthen competitiveness and economic resilience. The Flemish Government also emphasises the need for a strong and sustainable industry as an engine for the entire economy and is presenting an integrated action plan for Flemish industry. Despite the various challenges, it is clear that ambition has not been reduced. The transition to a carbon-circular and low-CO_2 industry is seen as essential to reverse these trends and to make industry future-proof.

Despite the greatly altered context, companies in the Flemish basic industry have continued to innovate and invest. The evaluation of the technological options and proposed transition pathways from the 2020 context analysis and roadmap study again highlights the importance of the various transition pathways, namely electrification, CCUS, hydrogen, biomass and circular processes, in realising the climate transition of the Flemish basic industry.

Interest in electrification has increased slightly since the previous roadmap study. There are more opportunities for large-scale heat pumps, e-steam networks and heat storage. The technology for electric cracking of naphtha has also made great strides and is expected to be widely available by 2035. Depending on price competitiveness compared to carbon capture (due to electricity price, efficiency, CO_2 capture price, etc.), this technology will also become available in Flanders. Overall, the high cost of electricity and the need for CO_2-free power remain significant barriers. Additional investments in electrification will also require efforts to avoid congestion problems.

The capture, storage and use of CO_2 remains a crucial technology, especially for processes with high CO_2 concentrations. Planned investments in CCS projects such as Kairos@C, H2BE and ZESTA are essential for emission reductions by 2030–2035. After 2030–2035, the application of CCS can further expand, depending on costs and infrastructure availability. Blue hydrogen, produced via SMR or ATR with CCS, will be the standard in Flanders in the short term.

Green hydrogen production via electrolysis remains limited by high costs and limited availability of carbon-free electricity. The import of hydrogen carriers such as methanol and ammonia offers potential, but uncertainty remains regarding the scale and type of hydrogen imports. The growth and eventual scope of this application will also depend on the available infrastructure for hydrogen.

In addition to mechanical recycling, chemical recycling of plastics, such as pyrolysis or solvolysis, offers potential for emission reductions by keeping the carbon present in the chain longer. However, the availability of sufficient quality plastic waste and the higher cost of recycled plastics remain challenges. Investments in the upstream value chain and logistics are necessary to realise chemical recycling on a large scale. Given the limited quantities of available plastic waste within Flanders, development of the international logistics chain will also be necessary.

In line with the 2020 context analysis, the use of biomass as energy and raw material remains uncertain. Biomass can be used for the production of high-value chemicals and biofuels, but the scale of application remains limited and the availability of sustainable biomass is unclear. A thorough study of the potential of biomass in Flanders is necessary.

Although technological progress has been made, challenges remain in scaling up innovative technologies. Various investment decisions have been postponed due to rising investment costs from inflation and uncertainty about returns. Current infrastructure is also insufficiently prepared for the expected increase in demand for electricity and other energy carriers. The next five years are crucial for making investment decisions and implementing the necessary infrastructure to achieve long-term objectives. The roadmap proposes making significant investments by 2030 in CCS, electrification of heat and the development of a circular value chain for plastics.

To tackle these challenges and accelerate the transition to a carbon-circular and low-CO_2 basic industry, numerous policy recommendations have been formulated. These recommendations are aimed at supporting the industrial transition and strengthening the competitiveness of the Flemish basic industry. The cluster “policy steering and regulation” highlights the importance of cooperation and coordination, including proposals to proactively defend the interests of the basic industry at the European level. The cluster “financing the transition” discusses possibilities for optimising existing financing instruments and explores alternative mechanisms to facilitate investments in decarbonisation projects. In the cluster “infrastructure and energy”, actions are formulated with regard to an integrated vision and approach for collective infrastructure needs, removing barriers and ensuring affordable energy. Finally, the cluster “innovation and talent” focuses on accelerating research and development of key technologies, while underlining the importance of talent and workers.

The policy recommendations provide a framework for achieving a carbon-circular and low-CO_2 industry by 2050, while maintaining competitiveness. Within the context of Klimaatsprong, however, it is not possible to implement all these actions. With a view to developing a new programme note, a selection of policy recommendations has been further specified. This selection is based on actions already assigned to Klimaatsprong in the Flemish Coalition Agreement, supplemented with actions to which Klimaatsprong can make a crucial contribution within the scope of its mandate.

The transition to a carbon-circular and low-CO_2 basic industry in Flanders is feasible, but requires significant investments in technology, infrastructure and policy. The proposed roadmap and policy recommendations provide clear direction for the coming years, with a focus on preserving and strengthening the competitiveness of the Flemish basic industry. By proactively promoting innovation, cooperation and support, Flanders can play a leading role in the industrial climate transition.

2.1. List of abbreviations

Abbreviation	Meaning
ATR	Autothermal Reformer
GDP	Gross Domestic Product
BAT	Best Available Techniques
BE	Belgium
BF-BOF	Blast Furnace-Basic Oxygen Furnace
BIK	Federal Fund for Industry and Climate Action (Germany)
GHG	Greenhouse Gases
BREF	Best Available Techniques Reference Documents
CAPEX	Capital Expenditure
CBAM	Carbon Border Adjustment Mechanism
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilisation
CEEAG	Climate, Energy and Environmental Aid Guidelines
CEF	Connecting Europe Facility
CfD	Contracts for Difference
CH	China
COP	Conference of the Parties
CREG	Belgian Federal Commission for Electricity and Gas Regulation
CSDDD	Corporate Sustainability Due Diligence Directive
CSRD	Corporate Sustainability Reporting Directive
DRI	Direct Reduced Iron
EAF	Electric Arc Furnace
EBO	Energy Policy Agreements
EC	European Commission
EED	Energy Efficiency Directive
ERDF	European Regional Development Fund
E-PRTR	European Pollutant Release and Transfer Register
ERA-NETs	European Research Area Network
ESI	Early Stage Innovation
ESR	Effort Sharing Regulation
ETS	Emission Trading System
EU	Europe
FEED	Front-End Engineering Design
FID	Final Investment Decision

FIT	Flanders Investment & Trade
FOAK	First Of A Kind
GBER	General Block Exemption Regulation
HVC	High Value Chemicals
IEA	International Energy Agency
IED	Industrial Emissions Directive
IMJV	Integrated Environmental Annual Report
INCITE	Innovation Centre for Industrial Transformation and Emissions
IPCEI	Important Projects of Common European Interest
IRR	Internal Rate of Return
JRC	Joint Research Centre
LPG	Liquefied Petroleum Gas
LPI	Logistic Performance Index
LSI	Later Stage Innovation
LULUCF	Land Use, Land Use Change and Forestry
MIEK	Multiannual Infrastructure, Energy and Climate Programme (Netherlands)
MTA	Methanol To Aromatics
MTO	Methanol To Olefins
NACE	Statistical Classification of Economic Activities in the European Community
NBB	National Bank of Belgium
NECP	National Energy and Climate Plans
NIKI	National Investment Scheme for Industrial Climate Projects (Netherlands)
R&D	Research and Development
OPEX	Operational Expenditure
OVAM	Public Waste Agency of Flanders
P2C	Plastics to Chemicals
PDH	Propane Dehydrogenation
PISA	Programme for International Student Assessment
PPA	Power Purchase Agreement
PPWR	Packaging and Packaging Waste Regulation
PRODCOM	Industrial production statistics
PS	Polystyrene
RED	Renewable Energy Directive
RFNBO	Renewable Fuels of Non-Biological Origin
SAF	Sustainable Aviation Fuels
SERV	Social and Economic Council of Flanders
SMR	Steam Methane Reforming

STEM	Science, Technology, Engineering and Mathematics
TRL	Technology Readiness Level
VDAB	Flemish Employment and Vocational Training Service
VEKP	Flemish Energy and Climate Plan
VEKA	Flemish Energy and Climate Agency
VLAIO	Flemish Innovation and Entrepreneurship Agency
US	United States
WEWIS	Department of Work, Economy, Science, Innovation and Social Economy

3. Analysis of the current situation and societal developments in the Flemish basic industry

This chapter provides a summary description of the main developments for the three sectors within the scope of this assignment, namely the (petro)chemicals sector (NACE 20), refining (NACE 19) and steel (NACE 24). Hereafter, these three sectors are also referred to as the "Flemish basic industry" or "basic industry in Flanders".

First, the policy context at European, federal and Flemish levels is described. We look back at the main achievements of the European strategic agenda 2019–2024. We then look ahead to the European strategic agenda for 2024–2029, the federal coalition agreement and the policy memoranda of the Flemish Government that apply to the Flemish basic industry.

This chapter then provides an overview of the evolution in greenhouse gas emissions ("GHG emissions"), energy consumption and socio-economic parameters (production, employment, investment, imports and exports) of the Flemish basic industry. Next, this chapter examines the competitiveness of Belgium in relation to Europe, the United States and China and the underlying factors behind this.

Finally, the technological options included in the 2020 context analysis and roadmap[2] are evaluated as input for revising the roadmap in Chapter 3.

3.1. Current policy context at European, federal and Flemish level for the climate transition in the (petro)chemicals, steel and refining sectors

The policy context for the transformation to climate neutrality has changed significantly since the publication of the previous context analysis and roadmap study in 2020. Given the complexity and scale of the policy landscape, we have chosen in this chapter to limit the explanation to policy initiatives at European, federal and Flemish levels with a thematic focus on emissions and energy and a direct impact on the climate transition in the (petro)chemicals, refining and steel sectors.

First, the European Commission's ("Commission") 2019–2024 strategic agenda is outlined as a starting point for the overall climate objectives. Thereafter, the most impactful policy initiatives for the energy-intensive industry introduced since the previous roadmap study are explained, including the EU Emissions Trading System ("EU ETS"), the Carbon Border Adjustment Mechanism ("CBAM"), the Renewable Energy Directive ("RED"), the Energy Efficiency Directive ("EED") and the Industrial Emissions Directive ("IED"). Each policy initiative is explained broadly with clarification of the implications for the (petro)chemical, steel and refining sectors. Where applicable, we indicate how the initiatives have been transposed at federal and Flemish level.

In a third part, we look ahead on the basis of the announced European strategic agenda for 2024–2029, including the "Competitiveness Compass", the federal coalition agreement and the policy memoranda of the Flemish Government. The chapter concludes with an overview of the most relevant financing instruments for the (petro)chemical, steel and refining sectors.

3.1.1. European strategic agenda 2019–2024

An important development under the European strategic agenda 2019–2024 is the anchoring of the Paris climate targets in the "EU Climate Law" ("climate law")[3]. Under this, Europe aims to reduce its emissions by 55% by 2030 compared to 1990 emissions and to achieve climate neutrality by 2050.

[2] Towards a carbon-circular and low-CO_2 Flemish basic industry
[3] European Climate Law - European Commission

This was followed by the rollout of a broad range of initiatives under the "EU Green Deal" to drastically reduce greenhouse gas emissions and make Europe's economy sustainable and innovative. A target has been floated to reduce emissions by 90% by 2040, but this has not yet been confirmed.

Under the climate law, Member States were obliged to implement "National Energy and Climate Plans" ("NECPs") in line with the European objectives and, consequently, the Paris climate target. These NECPs form the basis for the transition to a sustainable, secure and affordable energy system.

An overview of the major workstreams under the EU Green Deal is included below in Figure 1. The most impactful initiatives in the context of this study are indicated in blue.

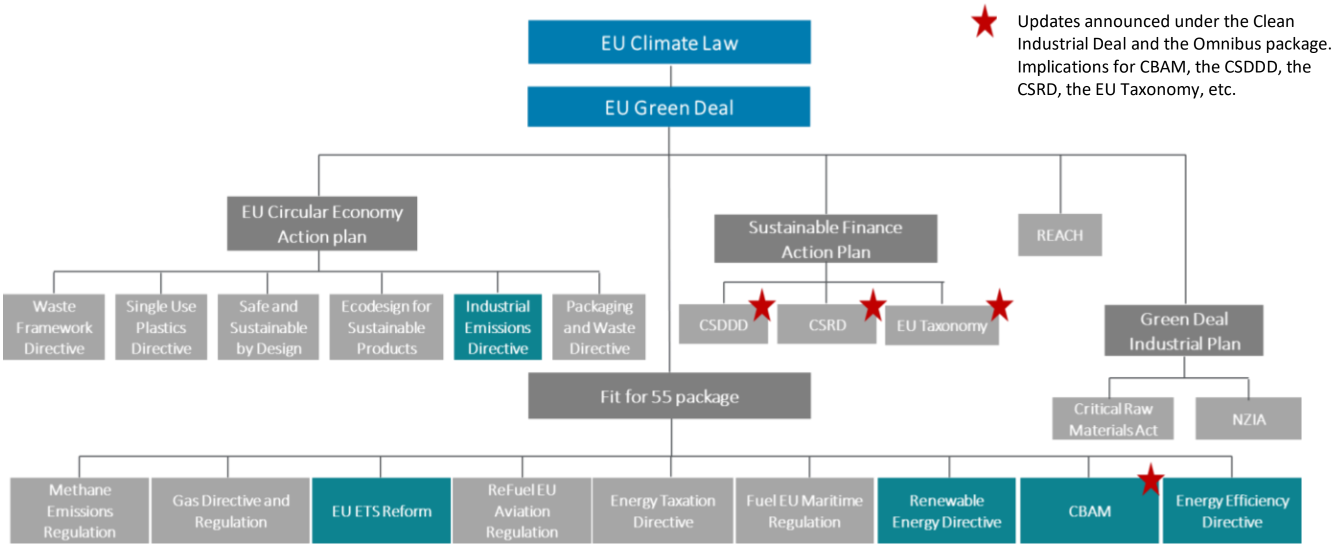

Figure 1: Overview of policy initiatives at European level

Transposition at federal and Flemish level

In Belgium, the NECP is implemented both by the federal government and by the various regional governments. The NECP was drawn up for the period 2021–2030 and revised in November 2023. This long-term strategy flows from the European strategic vision and is aligned with the objectives set at European level. As part of Belgium's NECP, the Flemish Government has its own plan within the Flemish Climate Strategy 2050[4], namely the Flemish Energy and Climate Plan ("VEKP")[5]. The Flemish Climate Strategy 2050 was approved on 20 December 2019 and submitted to the European Commission as part of the Belgian strategy. The first Flemish Energy and Climate Plan was drawn up in 2019 and a revised draft was approved by the Flemish Government on 12 May 2023. The final update of the VEKP still has to be approved and submitted to the European Commission.

This plan tightens efforts in the ESR sectors: transport, buildings, agriculture, (light) industry and waste. Flanders sets itself various targets for greenhouse gas reductions in the ESR sectors and the LULUCF sector, as well as for energy savings and the generation of renewable energy. For Belgium, a reduction target of −47% in 2030 (compared with 2005) has been set. The (petro)chemicals, refining and steel sectors also contribute to the plan, but fall primarily under the European objectives pursuant to the EU ETS.

[4] Flemish Climate Strategy 2050 | Vlaanderen.be
[5] Flemish Energy and Climate Plan (VEKP) 2021–2030 | Vlaanderen.be

3.1.2. Most impactful new EU policy initiatives in the period 2019–2024

Following the European strategic agenda 2019–2024 and the EU Green Deal, important legislative proposals with direct implications for the (petro)chemical, steel and refining sectors were tabled. These proposals were grouped under various action plans. The package containing the most impactful initiatives for (petro)chemicals, refining and steel is the "Fit for 55" package. The implementation of this package is seen as one of the major achievements of "Von der Leyen I".

The "Fit for 55" package provides measures to achieve the 55% emission reduction target relative to 1990 in a fair, cost-effective and competitive manner. Below, we discuss the most relevant initiatives for the (petro)chemical, steel and refining sectors – specifically the EU Emissions Trading System, the Carbon Border Adjustment Mechanism, the Renewable Energy Directive, the Energy Efficiency Directive and the Industrial Emissions Directive. The link to implementation at federal and Flemish level is also provided.

As noted earlier, however, the European policy context is much broader. Over the same period, the Commission also launched action plans for sustainable finance and the circular economy. The rollout of the sustainable finance action plan has led to increased sustainability reporting obligations through initiatives such as the EU Taxonomy, the Corporate Sustainability Reporting Directive ("CSRD") and the Corporate Sustainability Due Diligence Directive ("CSDDD").

Under the circular economy action plan, the focus has been on making sustainable products the norm and supporting purchasing decisions through initiatives such as the Sustainable Products Regulation, the Ecodesign Directive and the Green Claims Directive. In addition, there has been an emphasis on efficient material use and waste management, and on preventing pollution through initiatives such as the Packaging and Packaging Waste Regulation, the Battery Regulation, the Industrial Emissions Portal Regulation, the Waste Shipment Regulation, etc.

These initiatives aim, among other things, to accelerate and support the climate transition. Their impact is important but rather indirect for the (petro)chemicals, refining and steel sectors. In this study we have chosen not to provide a detailed discussion of these initiatives, in order to focus on the most impactful EU policy initiatives. In the chapter on policy recommendations, these initiatives are taken into account where relevant for the explanation or for defining the boundary conditions (e.g. market stimulation through obligations concerning the purchase of circular products).

EU Emissions Trading System[6]

The EU Emissions Trading System ("EU ETS") was launched in 2005 as the world's first carbon market and remains one of the largest in the world. The aim of the system is to reduce total European greenhouse gas emissions while financing the green transition by making polluters pay for their greenhouse gas emissions. EU ETS 1 covers emissions from electricity and heat generation, industrial production, aviation and – since the reform under the "Fit for 55" package in 2023 – maritime transport.

The 2023 reform also increased ambition, targeting a 62% reduction in emissions by 2030 relative to 2005. Free allocations for companies will decline further and now also depend on production volumes. EU ETS 1 revenues must be used to support the energy transition. These investments help reduce emissions and thus carbon costs for companies. Another portion of EU ETS 1 revenues supports low-carbon innovation and Europe's energy transition via the Innovation Fund and the Modernisation Fund.

The total volume of greenhouse gases that installations and operators within EU ETS 1 may emit is limited by a cap. This cap corresponds to the number of allowances issued over a given period. Each allowance entitles the holder to emit one tonne of CO_2e. The cap is reduced annually in line with Europe's climate objectives, with an annual reduction factor determining the pace of the reduction. Until 2020, the reduction factor was 1.74% per year. From 2021 it increased to 2.2% per year. Following the 2023 revision of the EU ETS Directive, the reduction factor has been raised to 4.3% per year for 2024–2027 and to 4.4% per year from 2028. There are also two planned cuts (recalibrations) to the cap before 2030: namely 90 million allowances in 2024 and 27 million allowances in 2026.

[6] About the EU ETS - European Commission

Many energy-intensive companies are subject to the EU ETS Directive. In addition to a reporting obligation, they are pushed towards lower emissions by an ever-rising CO_2 price. At federal and Flemish levels, transposition of the revision of EU ETS 1 has been completed.

Carbon Border Adjustment Mechanism[7]

The Carbon Border Adjustment Mechanism ("CBAM") complements the EU ETS with the ambition of applying equivalent rules to the import of carbon-intensive goods into the Union's customs territory. The scope is currently limited to cement, electricity, fertilisers, hydrogen, aluminium, steel and iron.

During the transition phase between 2023 and 2025 there is only a reporting obligation for embedded emissions; CBAM is definitively implemented from 2026. EU importers must register with national authorities and purchase CBAM certificates based on the weekly average auction price of EU ETS allowances. They must declare the embedded emissions of the imported products and surrender the corresponding certificates annually. If a carbon price has already been paid during production in the country of origin, importers may deduct the corresponding amount.

Between 2026 and 2030, the aim is to extend CBAM to additional imported goods that are also produced by EU ETS sectors. The entry into force of CBAM goes hand in hand with the phased reduction of free emission allowances in EU ETS 1. CBAM will fully replace these free allowances in CBAM sectors by 2034. Under the Clean Industrial Deal it is proposed to simplify the EU CBAM (see Section 3.1.3).

Although CBAM helps impose equivalent rules on imported products, it is not yet a comprehensive measure for increasing the competitiveness of EU producers (see also Section 3.3.2). CBAM focuses only on imports and does not make European products more competitive on the world market. Moreover, there is a risk of loopholes through "resource shuffling" or imports of semi-finished and finished products. In addition, CBAM does not yet apply to all sectors within the scope of this study, including the chemicals sector.

Renewable Energy Directive[8]

The Renewable Energy Directive ("RED") has been in place for some time, but has undergone several revisions. In the most recent revision, RED III, a general target for the use of renewable energy of at least 42.5% – binding at EU level for 2030 – has been set. This is a 10% increase compared with RED II. Informally, a 45% target is pursued. Beyond increasing renewable energy use, RED III also aims to boost developments in low-carbon technologies. To achieve this, the Commission has published a set of recommendations. To help countries transpose the various elements of the revised directive into national law, the Commission issued guidance to EU countries. This covers the following energy themes: heating and cooling, energy system integration and "renewable fuels of non-biological origin" ("RFNBOs").

All Member States must also contribute to achieving more ambitious sector-specific targets, including in industry. In relation to heating and cooling, industries must achieve an average annual increase in renewable energy use of 1.6% between 2021–2025 and 2026–2030 compared with 2020[9]. In addition, in industry, by 2030, 42% of the hydrogen and hydrogen derivatives used must be from RFNBOs, rising to 60% by 2035. For RFNBOs there is also a minimum requirement that 1% of the energy mix supplied to the transport sector in 2030 consists of RFNBOs; for the maritime sector, this target is at least 1.2% by 2030.

Implementation of RED III forms part of the policy memoranda on Energy and Climate, Environment and Economy, Science, Innovation and Industry, as well as of the federal coalition agreement. The ambition is to realise the transposition of RED III, while requesting at EU level that more than only green hydrogen and hydrogen derivatives be allowed to count towards the RFNBO target. An action plan should be provided via VLAIO to give effect to the provisions concerning the integration of renewable energy in industry (including the RFNBO target).

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[7] Carbon Border Adjustment Mechanism - European Commission

[8] Renewable Energy Directive

[9] Guidance document on heating and cooling accounting in Articles 15a, 22a, 23 and 24 of the revised DIRECTIVE (EU) 2018/2001 on promotion of energy from renewable sources

Energy Efficiency Directive[10]

The revised Energy Efficiency Directive ("EED") raises Europe's ambition on energy efficiency. "Energy efficiency first" is enshrined as a fundamental principle of Europe's energy policy, giving it legal status for the first time. In practice, this means that the EU Member States must take energy efficiency into account in all relevant policy and investment decisions taken in the energy and non-energy sectors.

Full implementation of the EED is important for Europe to meet the target of the "Global Renewables and Energy Efficiency Pledge" (COP28)[11], namely to double the global rate of energy efficiency improvements by 2030 from around 2% to over 4%. The energy efficiency objective is to achieve at least 11.7% energy savings at EU level by 2030, relative to the projected energy consumption in 2030 (based on the 2020 reference scenario).

EU Member States, including Belgium, can choose how to implement the requirements in the way that best fits their national situation. Nevertheless, Member States are obliged to achieve an average annual energy saving of 1.49% between 2024 and 2030[12]. Changes resulting from the revised EED will be incorporated into the final update of the VEKP (Energy and Climate policy note).

Even before the EED existed at EU level, on 4 April 2014 the Flemish Government approved the Energy Policy Agreements ("EBOs") for the period 2015–2022 to improve energy efficiency in Flanders' energy-intensive sectors and make it more sustainable[13]. The primary goal is for these companies to achieve or maintain excellence in energy efficiency.

Given the positive contribution of the EBOs to Flemish energy efficiency and emissions targets (2015–2022), the Flemish Government decided to continue cooperation with the energy-intensive sectors for a new four-year cycle through to 2026. The new agreements again set stricter thresholds than the Energy Planning Decree for both profitable and potentially profitable investments. For companies with tradable emission rights ("ETS companies"), the internal rate of return ("IRR") thresholds are now 12% for profitable investments and 10% for potentially profitable investments. In addition, the new EBOs contain several extra obligations. Participating companies must now provide data on their heat demand and residual-heat potential. ETS companies were also required to draw up a climate roadmap by the end of 2024 with a view to low-carbon production by 2050. The 2024–2029 policy note on economy, science, innovation and industry includes that, on the basis of these climate roadmaps and the inventories already prepared of specific heat demand and residual heat supply, consideration will be given within Klimaatsprong to whether a programmatic cluster approach can be developed.

Industrial Emissions Directive[14]

The revised directive on emissions from industry and livestock rearing ("IED 2.0") aims to prevent and limit pollutant emissions from industrial installations. In force since 4 August 2024, the directive places greater emphasis on innovation, material efficiency and CO_2 reduction to help realise Europe's climate ambitions. The main objectives of IED 2.0 include:

- promoting innovation through mandatory inclusion of effective emission reduction techniques;
- tightening emission limit values and the conditions for derogations;
- streamlining permitting via the new Industrial Emissions Portal Regulation to improve access to environmental data;
- providing instruments to promote the circular economy and efficient use of resources, and to reduce the use of hazardous chemical substances;
- covering more activities to reduce unregulated emissions.

[10] Directive (EU) 2023/… of the European Parliament and of the Council of 13 September 2023 on energy efficiency and amending Regulation (EU) 2023/955 (recast)
[11] COP28 Global Renewables and Energy Efficiency Pledge
[12] Energy efficiency targets
[13] The EBOs | EBO Flanders
[14] Industrial and Livestock Rearing Emissions Directive (IED 2.0) - European Commission

Environmental permits are granted by national authorities, with Best Available Techniques ("BAT") playing a key role. BAT are established per sector via the Sevilla process, managed by the European Commission's Joint Research Centre ("JRC"). This results in BAT reference documents[15] ("BREFs") and BAT conclusions ("BATCs"), which form the basis for permit conditions. Permits must contain binding requirements for resource efficiency for materials, water and energy. Compliance is ensured through harmonised environmental inspections every one to three years, depending on the risks linked to the activity. Under IED 2.0 there is a tightening of the BAT-associated environmental performance levels (BAT-AEPLs), including emission levels (BAT-AELs) and energy-efficiency levels (BAT-AEELs), and of the role of bandwidths in the context of permit conditions. It is expected that the BREFs for iron and steel will start in 2026, that the chemical BREFs will be reviewed from 2027 (the Commission's strategy is to be discussed in June 2025) and that the BREFs for refineries will start from 2027–2028.

As indicated, the directive now also includes an incentive for innovation through the preparation by "IED installation" operators of a transition plan for the period 2030–2050. There will also be more flexibility in permit duration when implementing innovative techniques. This is further supported by the establishment of the European Innovation Centre for Industrial Transformation and Emissions ("INCITE")[16], within which sectoral workshops are also organised[17].

IED 2.0 also requires Member States to ensure that operators of energy-intensive installations draw up, by 30 June 2030 at the latest, an indicative transformation plan containing information on how the operator will transform the installation over 2030–2050 to contribute to the creation of a sustainable, clean, circular, resource-efficient and climate-neutral economy by 2050.

This directive will be reflected in the update of environmental regulation under the Environment policy note. Specifically, new BREFs and BAT conclusions must be transposed as soon as they are published by the EU.

3.1.3. Announcements for the coming policy periods

In recent years, Europe has seen major closures of industrial installations due to the energy and demand crisis, particularly in the (petro)chemicals sector. The EU industry is experiencing a decline in competitiveness (see also Section 3.3), which also puts pressure on the industrial climate transition. For this reason, competitiveness has a heightened focus in the new European, federal and Flemish policies. The latest geopolitical developments – namely increased US import tariffs (including 25% on steel and aluminium from the EU) – further intensify this pressure on competitiveness.

European policy

The new European strategic agenda for 2024–2029 aims to combine measures to achieve climate neutrality by 2050 with measures to strengthen competitiveness and economic resilience. On that basis, the Commission published the "Competitiveness Compass for the EU" on 29 January 2025[18]. In this document, the Commission proposes an approach with a selection of measures that translate the three transformational requirements identified by the Draghi report to stimulate competitiveness:

- closing the innovation gap;
- a joint roadmap for CO_2 reduction and competitiveness;
- reducing excessive dependencies and increasing security.

To put each of these requirements into practice over the coming years, the Competitiveness Compass outlines a timeline and a list of planned initiatives linked to each requirement.

The focus on competitiveness is linked to recent actions following the European elections and the appointment of the new "Von der Leyen II" Commission for 2024–2029, namely:

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[15] BAT reference documents | EU-BRITE
[16] European Innovation Centre for Industrial Transformation and Emissions | INCITE
[17] 1st INCITE Workshop - Iron and Steel Sector 13th to 15th of May | INCITE
[18] EU competitiveness - European Commission

1) **February 2024**: The Antwerp Declaration is signed, calling for a European Industrial Deal to complement the EU Green Deal and protect employment in Europe, presented in ten points.
2) **April 2024**: The Letta report provides a thorough diagnosis of the current European situation and puts forward an initial set of proposals to revitalise the European economy.
3) **June 2024**: The EU Strategic Agenda 2024–2029 outlines a strategic framework to strengthen competitiveness, emphasising innovation, CO_2 reduction, circularity and sustainable industrial practices.
4) **July 2024**: The new political guidelines of the European Commission are published, focusing on the green transition and competitiveness, with energy efficiency and sustainability at the centre.
5) **September 2024**: Mario Draghi publishes the "Draghi report". It sets out a strategic framework to address competitiveness challenges, emphasising innovation, decarbonisation and supply chain vulnerabilities. It contains eleven proposals for energy-intensive sectors and highlights the need for substantial investment.
6) **September–October 2024**: New Commission missions are published, outlining Europe's main priorities, such as promoting innovation and sustainability.

In addition to the Competitiveness Compass for the EU, the Clean Industrial Deal was announced on 26 February 2025 with a variety of actions relevant to strengthening industrial competitiveness, including a simplification of CBAM. The Clean Industrial Deal is explained in more detail below.

Clean Industrial Deal[19]

The Clean Industrial Deal presents measures to stimulate every stage of production, focusing on energy-intensive sectors (including steel and chemicals) and the cleantech sector. There are six focus areas under the deal: (1) affordable energy, (2) financing the clean transition, (3) stimulating demand for clean products, (4) circularity and access to materials, (5) operating on a global scale and (6) skills and quality jobs.

The Commission has announced the "Affordable Energy Action Plan" to accelerate the rollout of clean energy and electrification, to complete the internal energy market, to use energy more efficiently and to reduce dependence on imported fossil fuels.

In addition, more than €100 billion will be deployed to support clean manufacturing in Europe through the creation of an Industrial Decarbonisation Bank. There will also be a "Clean Industrial Deal State Aid Framework" and a strengthening of the EU Innovation Fund.

A further objective of the Deal is to increase demand for EU-made clean products. To this end, in 2026 the Commission will revise the public procurement framework by introducing criteria on sustainability, resilience and European preference.

On circularity and access to materials, the Commission intends to set up "Clean Trade and Investment Partnerships", enabling European companies to pool their demand for critical raw materials. The Commission plans to establish an "EU Critical Raw Material Centre" and, in 2026, to adopt a "Circular Economy Act" to accelerate the circular transition.

The Commission will further simplify and strengthen CBAM to put a fair price on the CO_2 emissions of carbon-intensive goods (e.g. simplifying the authorisation of declarants) and will consider other trade defence instruments to keep the European economy resilient in the face of global competition and geopolitical uncertainty.

Finally, the Commission will establish a "Union of Skills" to invest in workers and to strengthen education and training programmes via Erasmus+. The goal is to build a flexible labour market and address shortages in key sectors, with up to €90 million in funding.

[19] Clean Industrial Deal - European Commission

Federal policy[20]

On 31 January 2025, agreement was reached on the federal coalition agreement. Overall, the government's energy policy is aimed at phasing out dependence on fossil fuels and increasing the country's open strategic autonomy.

Below we list the main objectives from the federal coalition agreement that apply to the (petro)chemicals, refining and steel sectors:

1. Evaluation and revision of the National Energy and Climate Plan for 2030. In doing so, account must be taken of the climate judgment[21], which requires at least a 55% reduction in greenhouse gas emissions by 2030.
2. Establishment of an autonomous High Council for Energy Supply, independent of the sector. The High Council will, among other things, annually compile the current and projected evolution of consumption, capacity and production of all energy vectors, in light of the most recent data and project progress. It will deliver a first interim report during 2025. On the basis of this report, the federal share of the NECP will be updated.
3. Promoting carbon-free consumption through a favourable price signal for electricity and carbon-neutral fuels, and the opposite for fossil fuels.
4. Increasing energy efficiency. Companies must take measures to optimise their energy consumption and make it more efficient, thereby reducing operating costs and dependence on fossil fuels.
5. Supporting and subsidising investments in sustainable technologies and energy efficiency, which can help companies make the transition without losing their competitive position.
6. Cooperation with the regions on infrastructure provision to support the transition and contributing to the (European) cross-border infrastructure agenda, specifically energy and hydrogen corridors.

Linked to this, the following specific measures are planned, among others:

- Transposition of RED III, with a strongly stimulating obligation (a sub-mandate) without limitations for the use of RFNBO hydrogen as an intermediate product (the so-called refining route), and a request at EU level to allow more than only green hydrogen and hydrogen derivatives to count towards the RFNBO target (industry, not transport).
- Harmonisation of the increased investment deduction for the energy, mobility and environment lists (annex to the Royal Decree/Income Tax Code 1992) to 40%.
- Reduction of VAT to 6% for the supply and installation of heat pumps.

Flemish policy[22]

The new Flemish Government continues to support the Paris Agreement and will therefore examine whether it can raise its climate ambition to a CO_2 emissions reduction of −47% by 2030 in the ESR sectors. For each additional climate measure proposed, the long-term costs and benefits of that measure will be weighed against its impact on emissions, the capacity of citizens to bear the costs and the competitiveness of our companies.

To comply with European regulations, the Flemish authorities have their own Flemish Energy and Climate Plan (VEKP) for the period 2021–2030 and a Flemish Climate Strategy 2050. Flanders will prepare in good time a Flemish Energy and Climate Plan for the period 2031–2040, in which Flanders will make a fair contribution to the European target.

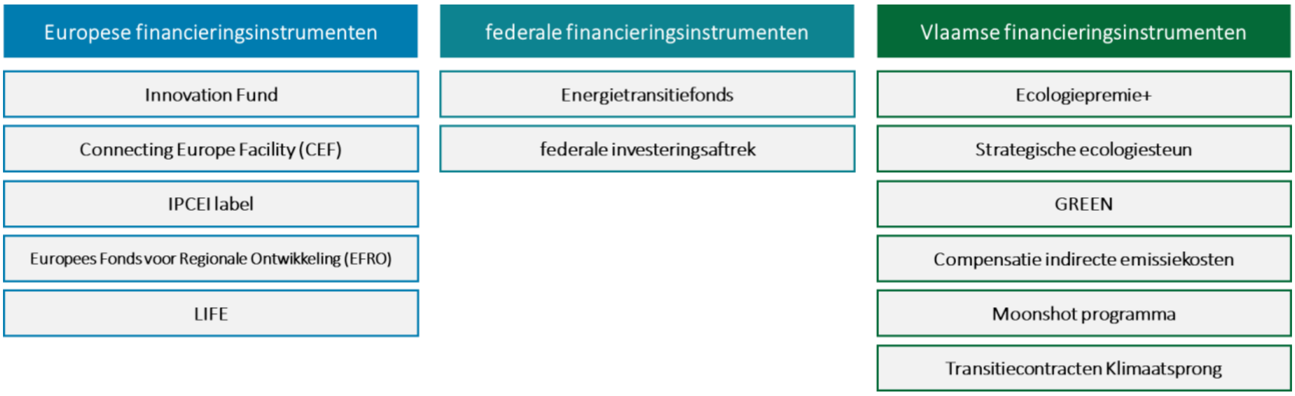
Klimaatsprong will be further developed as the coordinating action programme for the Flemish industrial climate transition, both in terms of process transformation and infrastructure and energy needs. Specifically, Klimaatsprong must develop a programmatic cluster approach and initiate a participatory process between infrastructure managers, large industrial clusters, major SME zones and the government to determine infrastructure needs and to examine how these can be realised through collective infrastructure.

[20] Federaal-regeerakkoord-2025-nl.pdf
[21] The court case: where we stand today | Klimaatzaak
[22] Policy notes of the Flemish Government 2024–2029 | Vlaanderen.be

To achieve the outlined objectives, the government will seek the right financing mechanisms, namely Contracts for Difference ("CfDs") that the Flemish basic industry needs in the transition to low-carbon processes. In addition, the EBOs have been extended for Flemish energy-intensive companies until the end of 2026. An evaluation of further continuation is planned for the end of 2025. Furthermore, the Flemish Government also plans to update the hydrogen strategy to take account of the most recent developments.

3.1.4. Financing instruments[23]

In addition to regulation, financing instruments are also an essential component for accelerating the transition. This section outlines the main financing mechanisms relevant to the (petro)chemicals, refining and steel sectors and available at European, federal and Flemish level (see Figure 2).



European financing instruments
Innovation Fund
Connecting Europe Facility (CEF)
IPCEI label
European Regional Development Fund (ERDF)
LIFE

Federal financing instruments
Energy Transition Fund
Federal investment deduction

Flemish financing instruments
Ecology Premium+
Strategic Ecology Support
GREEN
Compensation for indirect emission costs
Moonshot programme
Klimaatsprong transition contracts

Figure 2: Overview of financing instruments at European, federal and Flemish level

Europe

Innovation Fund[24]

The Innovation Fund, managed by CINEA, aims to support the transition to climate neutrality in European industry while promoting its competitiveness by bringing innovative solutions to market.

The Innovation Fund was launched in 2020 and organises annual calls for projects. The fund finances innovative projects aimed at:

- innovative low-carbon technologies and processes in energy-intensive sectors, including products that can replace carbon-intensive technologies and processes;
- carbon capture and utilisation (CCU);
- the construction and operation of facilities for carbon capture and storage (CCS);
- innovative renewable energy generation; and
- energy storage.

In the most recent call of 3 December 2024, the Commission launched two calls, namely the "IF24 Call" with €2.4 billion available for net zero technologies and "IF24 Battery" with €1 billion available for the production of battery cells for electric vehicles. The Innovation Fund is financed by revenues from the EU ETS and the total investment budget for 2020–2030 is estimated at €40 billion (depending on the carbon price). The support offered can cover up to 60% of both CAPEX and OPEX (minus revenues) over an operational period of 10 years.

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[23] In future reports, an additional distinction can be made between the instruments according to the stage of technological development for which they are intended.
[24] Innovation Fund - European Commission

In addition to the regular calls, since 2023 the Innovation Fund has also organised separate auctions for the production and use of RFNBO hydrogen via the European Hydrogen Bank. Under this scheme, the Innovation Fund provides a fixed premium in EUR per kg over the duration of the most competitive projects. The fund also offers an "auctions-as-a-service" option, whereby Member States can support projects that were not selected.

Connecting Europe Facility[25]

The Connecting Europe Facility ("CEF") supports the development of high-performing, sustainable and efficiently connected trans-European networks in the fields of transport, energy and digital services. In addition to grants, CEF provides financial support to projects through innovative financial instruments such as guarantees and project bonds, which attract additional funding from the private and public sectors.

For 2021–2027, the CEF energy budget amounts to €5.84 billion. Europe aims to make European energy systems more interconnected, smarter and more digitalised, with a focus on cross-border renewable energy projects, network interoperability and better integration of the internal energy market.

Important Projects of Common European Interest[26]

When private initiatives to support breakthrough innovation and infrastructure fail due to the significant risks associated with such projects, EU state aid rules allow Member States to jointly fill the gap to remedy this market failure with an "Important Project of Common European Interest" ("IPCEI"). IPCEIs are ambitious, cross-border, integrated projects that are important because they contribute to European objectives, limit potential distortions of competition and ensure positive spillover effects for the internal market and the Union. Several IPCEIs have already been approved, including four in the field of hydrogen[27].

State aid[28]

The Commission is revising state aid rules in a number of priority areas, including climate, energy and the environment. The current EU state aid framework consists of three documents, plus a fourth referring to the compatibility of state aid with IPCEIs:

- the Climate, Environmental Protection and Energy Aid Guidelines ("CEEAG");
- the General Block Exemption Regulation ("GBER");
- the Temporary Crisis and Transition Framework for state aid;
- the communication on the criteria for assessing the compatibility with the internal market of state aid to promote the implementation of Important Projects of Common European Interest.

The revision of the state aid rules will facilitate public support for the development of industrial sectors and innovative value chains through potentially increased financing channels and amounts.

European Regional Development Fund[29]

The European Regional Development Fund ("ERDF") strengthens sustainable growth and competitiveness in Flanders and accelerates the transition to a low-carbon, circular and energy-efficient economy. For 2021–2027, Flanders has received €276 million in EU funds for the implementation of the ERDF programme; €112 million of this is allocated to Limburg, which enjoys special status as a transition region. The target groups of the ERDF programme are very broad and depend on the programme topic or priority axis.

[25] About the Connecting Europe Facility - European Commission
[26] IPCEI - European Commission
[27] Approved IPCEIs - European Commission
[28] Overview - European Commission
[29] Who can submit a project? | VLAIO

LIFE[30]

LIFE is a European financing instrument for environment and climate action and issues calls every year. The programme includes strands on energy transition, climate mitigation and the circular economy that are relevant within the scope of this study. It offers, among other things, support for pilot, demonstration and best-practice projects that contribute to reducing greenhouse gas emissions. Support is typically limited to €5 million and 60% of costs (including personnel and purchase costs).

Federal

Energy Transition Fund[31]

Operational since 2017 at federal level, the Energy Transition Fund supports research and development within the scope of federal energy competences, such as offshore renewables, hydrogen, nuclear energy, security of supply and grid balancing. In 2023 the budget amounted to €25 million, awarded to 20 innovative projects to accelerate the energy transition[32].

Federal investment deduction[33]

In addition to financing instruments, the federal government can also facilitate investment through the investment deduction. Further reforms of this instrument are included in the new federal coalition agreement. Currently, the basic deduction ranges between 10% and 40%, depending on company size, the theme and the category of investment. According to the new federal coalition agreement, the rates for the increased investment deduction for energy, mobility and environmental investments will be harmonised at 40%[34]. The cap on EU public support for CCS-CCU investments will be removed.

Flanders

Ecology Bonus+[35]

The Ecology Bonus+ is a capital expenditure (CAPEX) investment subsidy for companies wishing to make their production process more environmentally friendly and energy-efficient. The Flemish authorities cover part of the additional investment costs. Companies can obtain financial support via Ecology Bonus+ for technologies listed on the technology list.

Strategic ecology support[36]

With Strategic Ecology Support, the Flemish authorities aim to encourage SMEs and large companies to invest in technologies which, due to their unique, company-specific character, cannot be standardised and therefore do not appear on the limited technology list of Ecology Bonus+. This concerns a CAPEX investment grant for major ecological investments (a minimum of €1.5 million in eligible investments).

GREEN[37]

This is a capital expenditure investment subsidy for small ecological investments that do not fall under Ecology Bonus+ or Strategic Ecology Support. This financial support is intended for companies making investments in greener and more efficient energy use. The subsidy amounts to 20% to 55% of the additional ecological costs compared with a standard investment.

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[30] Programme for the Environment and Climate Action (LIFE) - European Commission
[31] Energy Transition Fund | FPS Economy
[32] Energy Transition Fund: €25 million for 20 innovative projects to accelerate the energy switch – Tinne van der Straeten
[33] Reform of the investment deduction from 1 January 2025 | VLAIO
[34] Federaal-RegeerAkkoord-2025-NL.pdf
[35] Ecology Premium+ | VLAIO
[36] Strategic ecology support | VLAIO
[37] GREEN: support for greener and more efficient energy use | VLAIO

Compensation for indirect emission costs[38]

Companies in energy-intensive sectors may have a higher electricity bill as an indirect consequence of the EU Emissions Trading System. The Flemish authorities seek to eliminate this competitive disadvantage by compensating 14 sectors for these CO_2 costs through an operating expenditure (OPEX) subsidy. These sectors include, among others: manufacture of refined petroleum products; hydrogen and inorganic oxygen compounds of non-metals; manufacture of other inorganic basic chemicals; polyethylene glycol and other polyether alcohols, in primary forms; and manufacture of iron, steel and ferro-alloys.

Moonshot programme[39]

Launched in 2019, the Flemish Moonshot programme aims to promote research and innovation to support the development of low-carbon technologies for the Flemish basic industry. This initiative seeks to develop knowledge with a long-term perspective, with an annual budget of €20 million over 20 years. The Moonshot programme consists of four fundamental and interconnected research lines:

- bio-based chemistry;
- circularity of carbon materials;
- electrification and radical transformation of processes; and
- energy innovation.

Klimaatsprong Transition Contracts[40]

The Flemish Government is making €70 million available for a support period of 10 years to support investments in large-scale electric boilers and heat pumps through a new subsidy, "Klimaatsprong Transition Contracts". This call for projects is a test case and contributes to the transition pathway to electrify business processes. It is the only Flemish subsidy instrument in this context that provides OPEX support.

The resources within the "Klimaatsprong Transition Contracts" call are allocated via a new type of instrument, Contracts for Difference ("CfD"). The subsidies are not fixed, but are linked to the evolution of energy costs and emission allowances. In this way, the system offsets external factors to guarantee the investment's return within certain bounds and over a support period of 10 years.

3.1.5. Conclusion

Over the past five years, the policy context for the basic industry has changed significantly, mainly due to the rollout of a broad range of initiatives under the EU Green Deal to achieve the 2030 target (i.e. a 55% emissions reduction compared with 1990). The most relevant initiatives for the (petro)chemical, steel and refining sectors were the changes to the EU ETS, RED, EED and IED, and the introduction of CBAM. In general, these policy instruments aim to facilitate the transition to low-carbon production processes by imposing a CO_2 price (EU ETS), tightening sectoral targets (RED and EED) and strengthening permitting criteria (IED). CBAM seeks to create a level playing field for imported products vis-à-vis producers outside the EU by charging similar CO_2 prices, but it does not provide sufficient protection for derivative products and "resource shuffling", nor for the competitiveness of export products. In addition, CBAM does not yet apply to all sectors within the scope of this study, including the chemicals sector.

The competitiveness of European industry is therefore under pressure, which is why the new European strategic agenda for 2024–2029 focuses on combining measures to achieve climate neutrality by 2050 with measures to strengthen competitiveness and economic resilience, including through the Clean Industrial Deal. The actions included in the Clean Industrial Deal are aligned with the intended objectives; it will be important to roll them out with sufficient speed and impact.

[38] Only for enterprises in 14 sectors | VLAIO
[39] About Moonshot: from Ambition to Action | Moonshot Flanders
[40] €70 million for "Klimaatsprong transition contracts": investments in large-scale electric boilers and heat pumps | VLAIO

To comply with European regulations, the Flemish authorities have their own Flemish Energy and Climate Plan (VEKP) for the period 2021–2030 and a Flemish Climate Strategy 2050. Flanders is preparing in good time a Flemish Energy and Climate Plan for 2031–2040 in which Flanders will make a fair contribution to the European target. To protect the capacity of citizens to bear costs and the competitiveness of companies, the Flemish Government has undertaken, for each additional climate measure proposed, to weigh the long-term costs and benefits of that measure against its impact on emissions. For the Flemish industrial climate transition, it has been decided to further develop Klimaatsprong as the coordinating action programme, both in terms of process transformation and of infrastructure and energy needs.

In terms of financing instruments, there was already a broad palette at European, federal and Flemish levels. Future policy plans to broaden this further, including by continuing at Flemish level with the CfD instrument “Klimaatsprong Transition Contracts” and at EU level by launching the Industrial Decarbonisation Bank.

3.2. Evolution of Flemish industrial activity in the (petro)chemicals, refining and steel sectors

This section sets out the evolution of Flemish industrial activity, specifically in terms of emissions, energy use, production volumes and imports and exports. In addition, the trends in socio-economic factors linked to industrial activity are presented, namely value added, employment, investment and trade volumes. The required data was collected up to February 2025. More recent data published thereafter is not included in the overview.

3.2.1. Evolution of emissions in the (petro)chemicals, refining and steel sectors

In Flanders, approximately 200 greenhouse gas installations currently fall under the EU ETS[1], which together in 2023 emitted 26 Mt CO_2e. The share of the (petro)chemicals, refining and steel sectors amounts to 20.6 Mt CO_2e, which corresponds to 79% of total EU ETS emissions in Flanders (see figures below). The three sectors together recorded a 25% decrease compared with emissions in 2005 (27.4 Mt CO_2e). In the individual sectors chemicals, refining and steel, the decline is 34%, 15% and 19% respectively. Total EU ETS emissions in Flanders fell by 40% in 2023 compared with 2005, linked to the larger emissions reductions that took place in the electricity sector. With the renewed EU ETS instrument, the EU aims for a 62% reduction by 2030 compared with 2005 for the Union as a whole. In 2022, the share of EU ETS emissions was 42% of total emissions in Flanders.

Until the COVID-19 pandemic, the combined emissions of the chemicals, refining and steel sectors consistently hovered around 24 Mt CO_2e. Driven by the COVID-19 pandemic, the war in Ukraine, the temporary maintenance of a blast furnace and high energy prices, emissions began to decline from 2020. This decline continued through 2023, with emissions 16% lower than in 2019 (20.6 Mt CO_2e). The following sections show that this decrease is mainly attributable to lower production and the associated lower energy use.

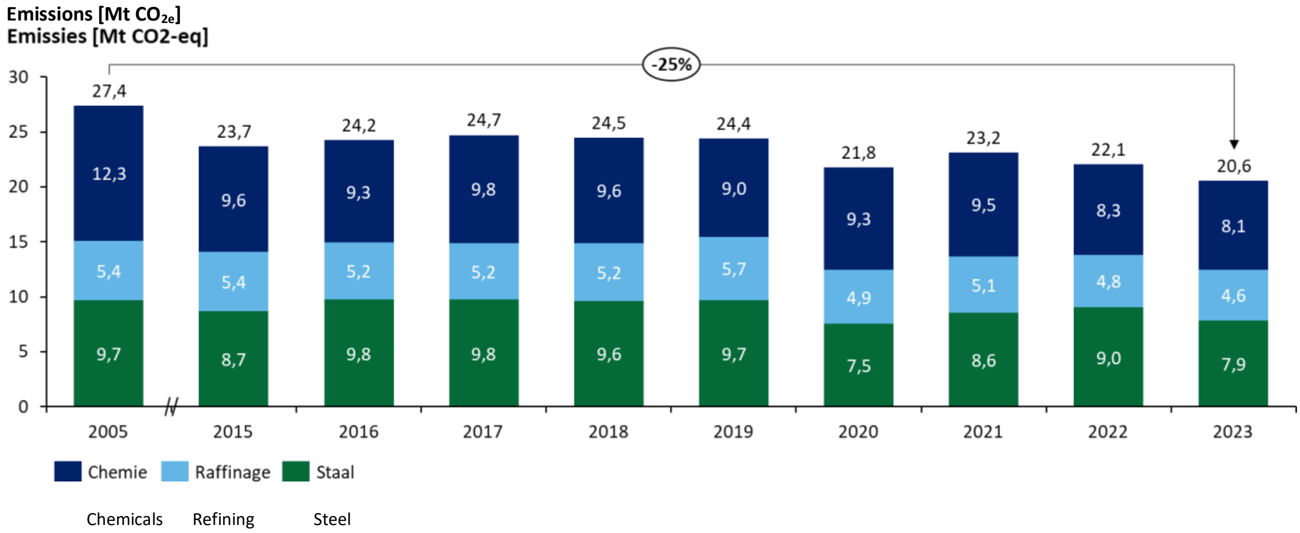

Figure 3: Evolution of ETS emissions for the chemicals, refining and steel sectors since 2005 (EU ETS fixed installations in Flanders: data overview | Vlaanderen.be)[41]

[41] Data based on ETS data as published on VEKA's website. As in the previous roadmap, all emissions from the Knippegroen and Rodenhuize power stations are attributed to the steel sector, as these mainly arise from the combustion of metallurgical gases. It is also assumed that roughly 900 kt CO_2e per year in refineries is linked to the naphtha cracker within the refineries; in these graphs these have been shifted from the refining to the chemicals sector.

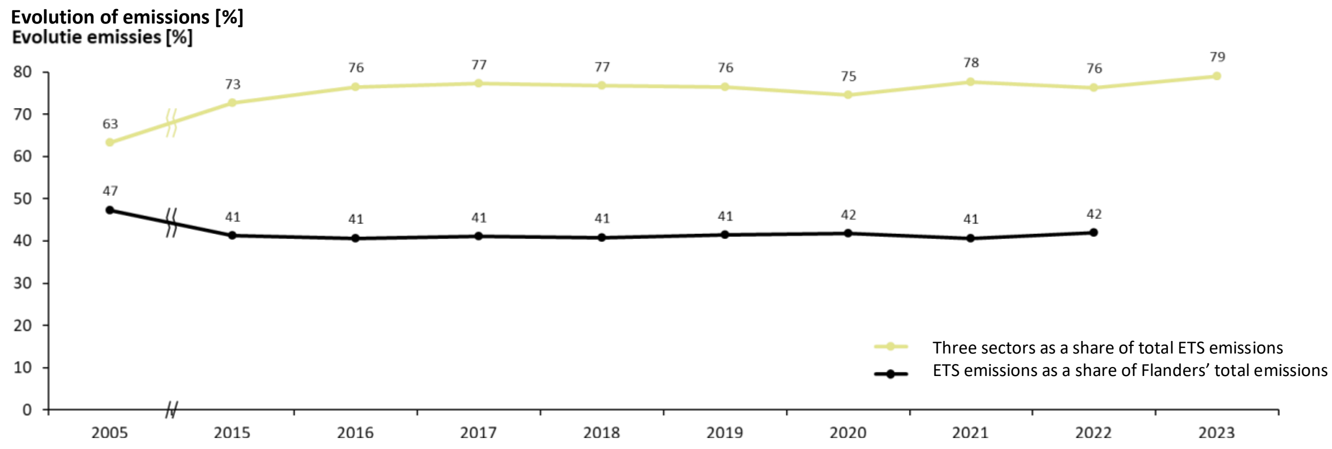

Figure 4: Evolution of the emission share of the chemicals, refining and steel sectors in the EU ETS total and the overall total in Flanders (EU ETS fixed installations in Flanders: data overview | Vlaanderen.be; Greenhouse gas emissions | VMM)

3.2.2. Evolution in energy use in the (petro)chemicals, refining and steel sectors

Final energy consumption for the three sectors (petro)chemicals, refining and steel in 2023 was 284 PJ, a decrease of 13% compared with 2005 (327 PJ), and a decrease of 12% compared with 2019 (323 PJ). The trends in total energy use in the period 2015–2023 are similar to the decline in emissions, also at sector level. The following paragraphs delve deeper into the changes that took place in the consumption of the underlying energy sources and feedstock for each of the three sectors.

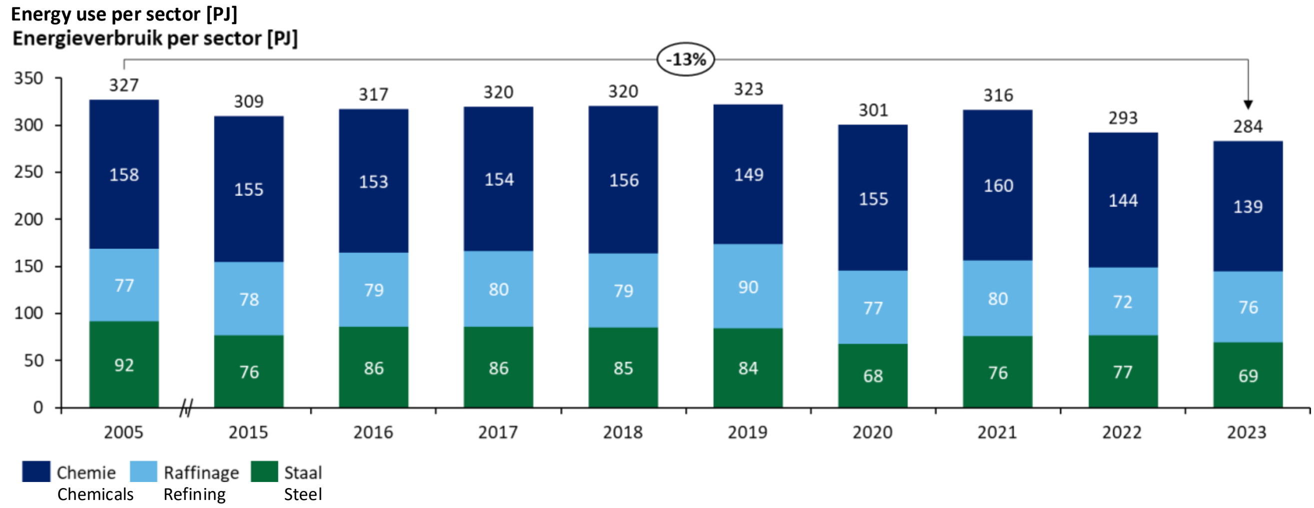

Figure 5: Evolution of energy use for the chemicals, refining and steel sectors since 2005 (Flemish Energy Balance | Vlaanderen.be)

Energy and feedstock use in the (petro)chemicals sector

The energy mix in the chemicals sector, as shown in Figure 6, remained largely constant between 2019 and 2023, namely mainly residual gases and natural gas (±73%) supplemented with electricity (±25%) and a small share of other fuels (±2%). This was also the case in 2005, but then there was a lower contribution from electricity (−3%) and a higher contribution from other fuels (+3%). Within "other fuels", however, larger shifts can be observed. In 2005, fuel oil still accounted for 3.6% of the total energy mix, whereas by 2023 this had been reduced to 0.2%. The other fuels consist mainly of refinery gases or LPG and, to a lesser extent, petroleum coke. The share of biomass has remained constant at 0.2% of the total.

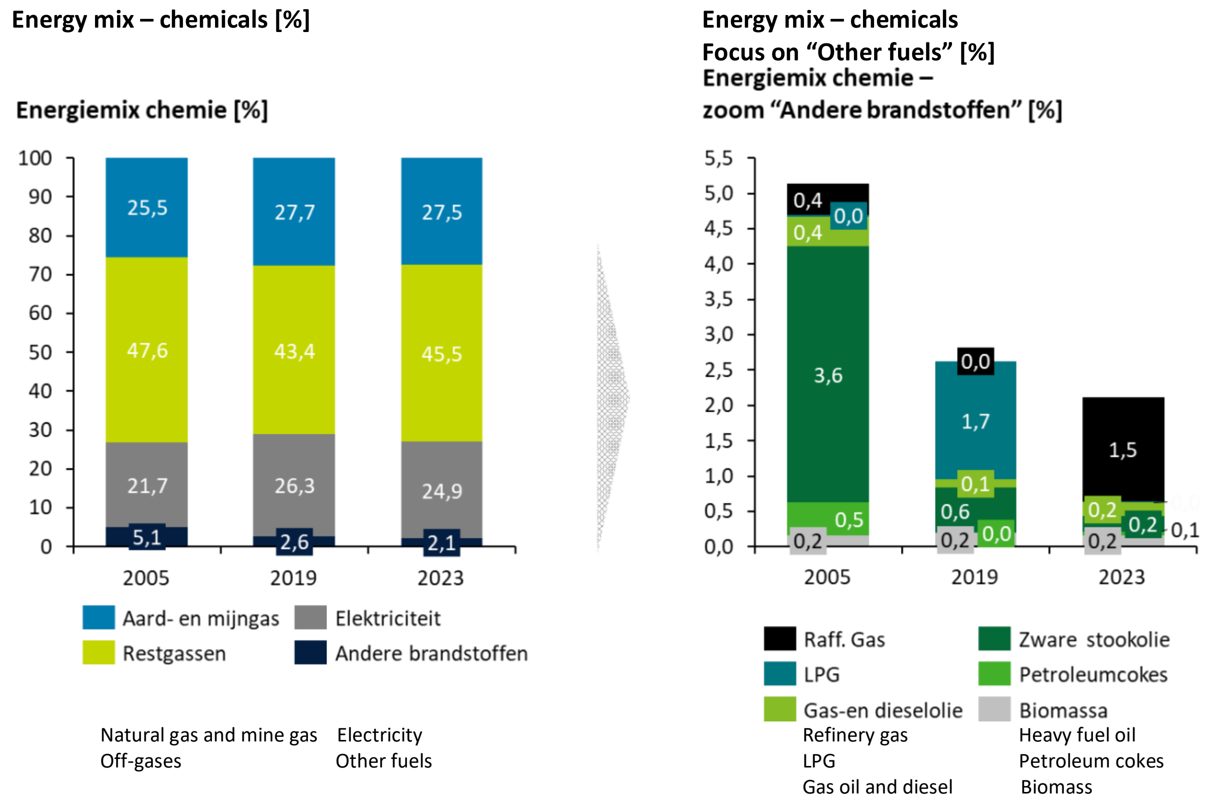

Figure 6: Representation of the energy mix for the chemicals sector in 2005, 2019 and 2023 (Flemish Energy Balance | Vlaanderen.be)

Feedstock for the (petro)chemicals sector in 2023 consisted mainly of naphtha (53%), LPG (29%) and natural gas (13%), and to a lesser extent coal tar (4%). The relative contribution of naphtha in the feedstock mix decreased between 2005 and 2023 (−21%), partly offset by higher LPG consumption (+18%). Between 2019 and 2023 there is also a general decline in feedstock consumption (−21%), which goes hand in hand with lower production volumes and consequently lower energy needs and emitted emissions.

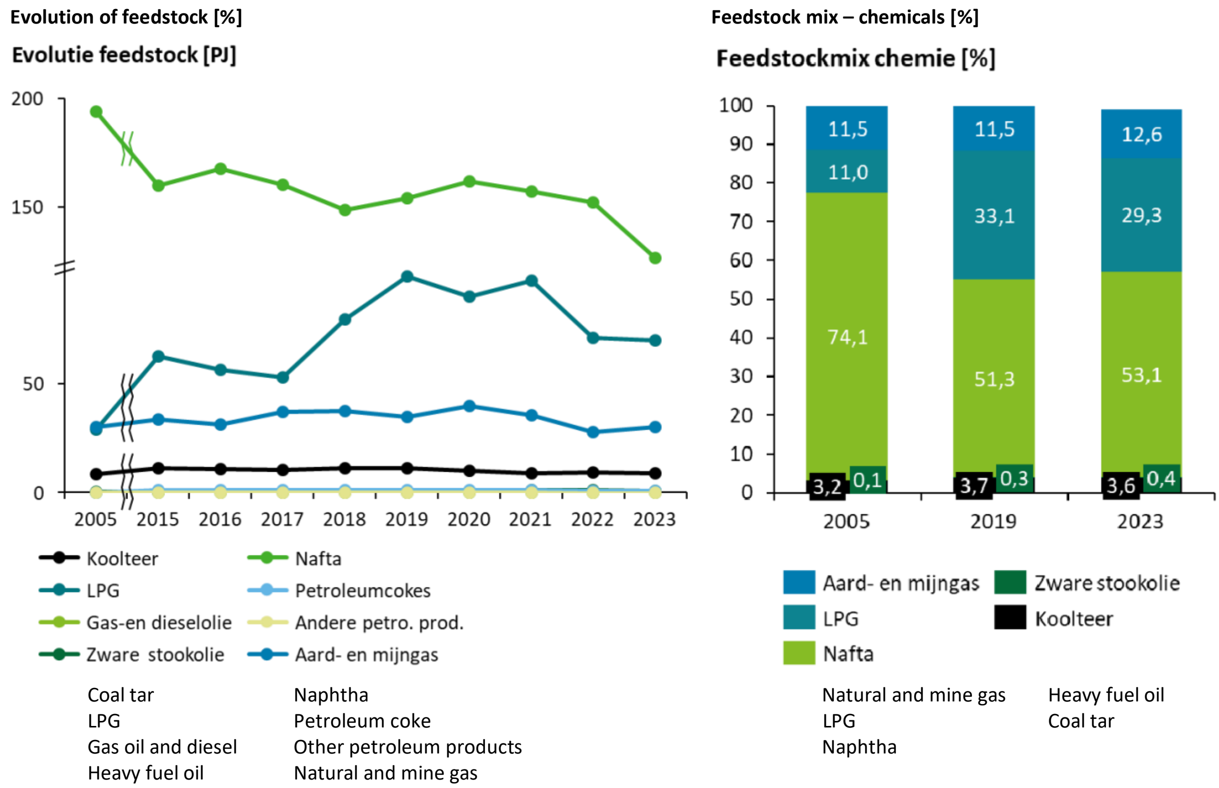

Figure 7: Evolution of feedstock and the feedstock mix in the chemicals sector (Flemish Energy Balance | Vlaanderen.be)

Energy use in the refining sector

In the refining sector, energy consumption in 2023 consisted mainly of refinery gases (56%), natural gas (33%) and petroleum coke (12%). The use of electricity is limited here. In 2023, electricity was even generated on a net basis through combined heat and power. Compared with 2019, the energy mix has changed slightly: the share of refinery gases has increased (+18%) to compensate for natural gas (−15%) and residual gases (−2%), and the share of petroleum coke has decreased slightly (−1.5%). The change in the energy mix is larger compared with 2005. In 2005, fuel oil (15%), heat (9%) and electricity (6%) were still used, which in 2023 has mainly been replaced by natural gas.

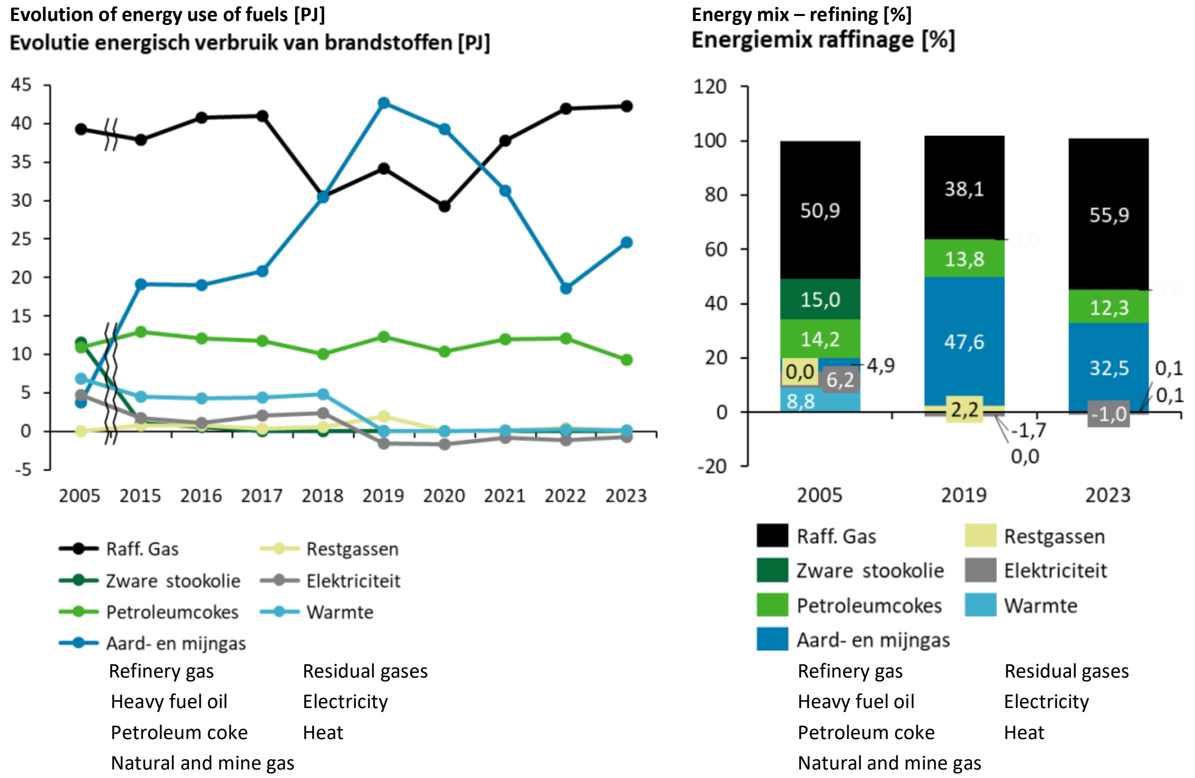

Figure 8: Evolution of energy consumption and the energy mix of the refining sector (Flemish Energy Balance | Vlaanderen.be)

Energy use in the steel sector

Energy consumption in the steel sector is dominated by coal and coke. Their combined consumption remained fairly constant between 2005 and 2023 at around 80% of total energy demand. Consumption of electricity and natural gas during this period was around 10% each. In 2023, a slight increase in the share of electricity and natural gas consumption is noticeable compared with 2019.

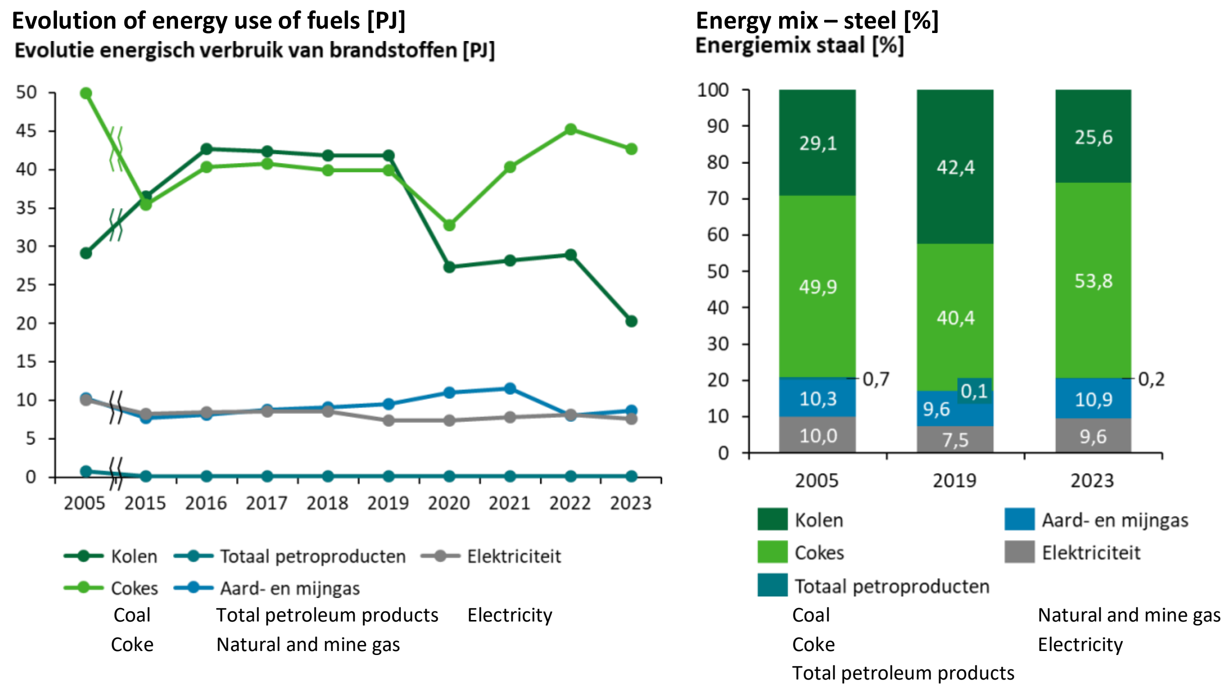

Figure 9: Evolution of energy consumption and the energy mix of the steel sector (Flemish Energy Balance | Vlaanderen.be)

3.2.3. Evolution in production volumes of the (petro)chemicals, refining and steel sectors

To map the evolution of production volumes in the chemicals, refining and steel sectors, the best available public data was used. For the chemicals sector (polymers only), the PRODCOM database was used, which is available only at Belgian level. For refining, production output was taken from the energy balance, and for steel from the available Belgian data on the Worldsteel international website.

(Petro)chemicals

The production volume of polymers fell significantly in 2023 compared with 2019 (−15%) for all products except "Other"[42]. This is in line with the decline in Flemish emissions (−10%) and energy use (−7%) in the chemicals sector between 2019 and 2023. The chemicals sector is of course much broader than polymer production alone, which accounts for roughly one third of total value[43], but polymer production is linked to a larger share of the chemicals sector (e.g. acyclic and cyclic hydrocarbons) and thus reflects a general trend in the evolution of absolute production volumes.

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[42] "Other" is the sum of the following polymers: silicones; synthetic rubber; polymers of vinyl acetate or of other vinyl esters, and other vinyl polymers; urea resins, thiourea resins and melamine resins; acrylic polymers; polyacetals, other polyethers and epoxy resins, polycarbonates, alkyd resins, polyallyl esters and other polyesters; polyamides; and polymers of vinyl chloride or of other halogenated olefins.

[43] In compiling the value share, the value of the different polymers was compared with the total value of the chemicals sector (NACE 20) in the PRODCOM database (Industrial production | Statbel).

Production of polymers in primary forms in Belgium (million tonnes)

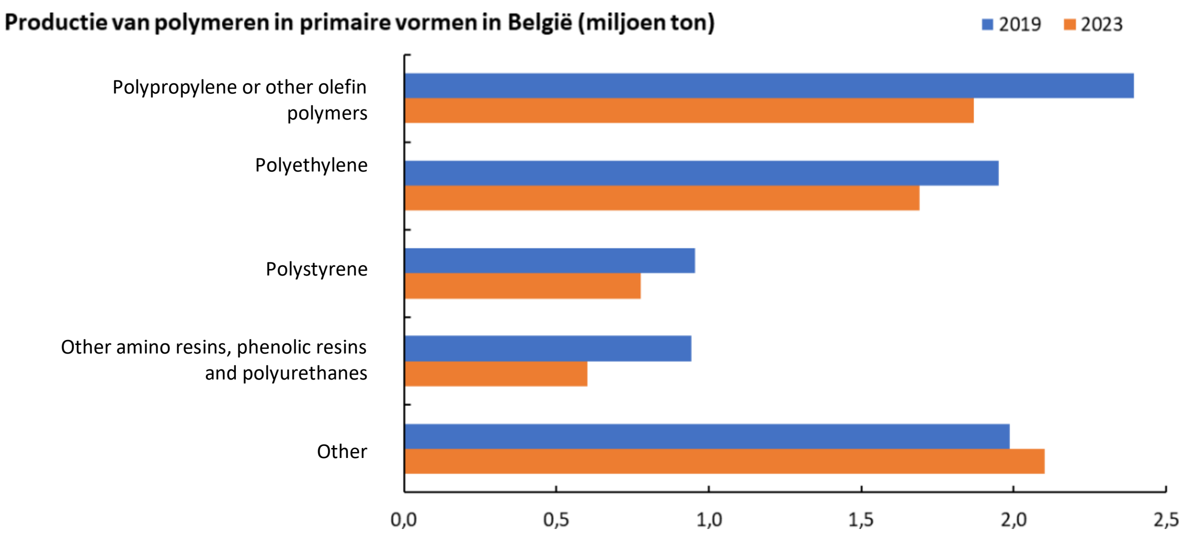

Figure 10: Production volumes of polymers in Belgium in 2019 and 2023 (Industrial production | Statbel)

Refining

Refining production output fell to 1,314 PJ in 2023 from 1,573 PJ in 2005 (−16%). The largest decline in production output, however, only began after 2019 (−11%), which is also in line with the decline in emissions (−19%) and energy use (−16%). The stronger decline in emissions may stem from lower use of petroleum coke and natural gas and higher use of refinery gases (see Figure 11). Due to the expected decline in demand for motor fuels, demand for refining activities in Europe will fall. Given the strategic location and efficiency of Flemish refineries, they are expected to remain open longer, and a shift is expected in production from motor fuels to chemical feedstocks[44].

Refining production output in Flanders [PJ]

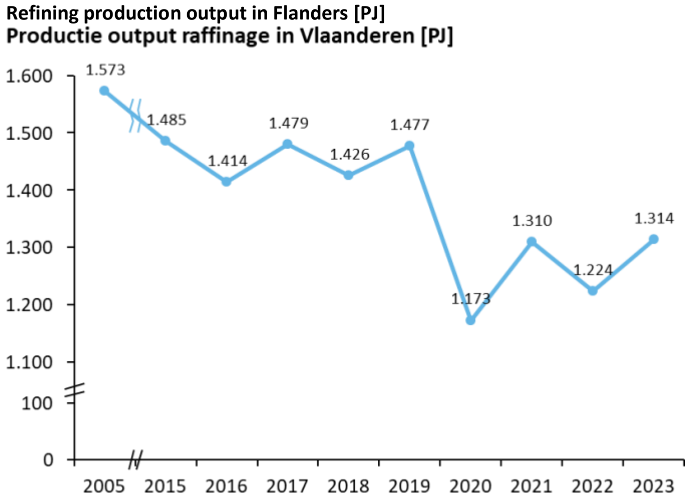

Figure 11: Refining production output in Flanders (Flemish Energy Balance | Vlaanderen.be)

Steel

In the steel sector, Belgian production volumes also declined between 2019 and 2023 (−24%). This is likewise in line with the trends in Flemish emissions (−19%) and energy use (−18%) over the same period. Production volumes first recovered in 2021–2022 after the COVID-19 pandemic, but suffered a sharp decline again in 2023. This can be linked to decreasing competitiveness due to high energy prices, declining market demand and increased foreign imports (mainly from China) (see also Section 3.3).

[44] ENERGIA studie raffinaderijen in Belgie.pdf

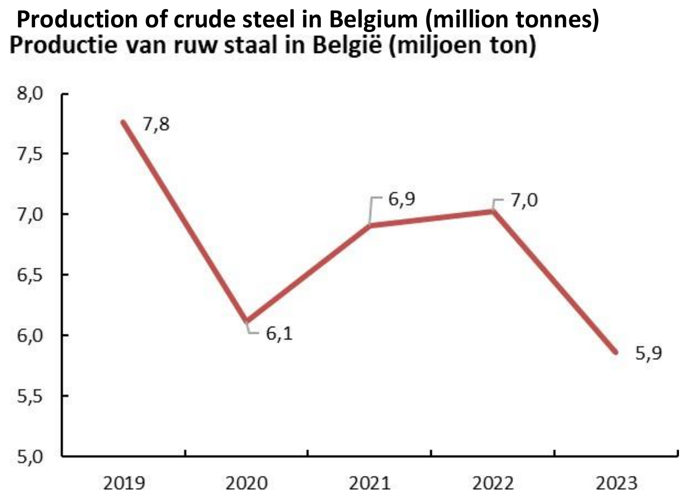

Figure 12: Crude steel production volume in Belgium between 2019 and 2023 (Data – worldsteel.org)

3.2.4. Trends in value added, employment, investment and trade volumes in the (petro)chemicals, refining and steel sectors

The data used to chart the trends in value added, employment, investment and trade volumes in Flanders was obtained from the National Bank of Belgium (NBB). The figures on value added, investment and trade volumes are expressed in current prices and are therefore not corrected for inflation. To put this into perspective, the evolution of inflation for Belgium is included below. Cumulative inflation between 2005 and 2023 amounted to 52.6%.

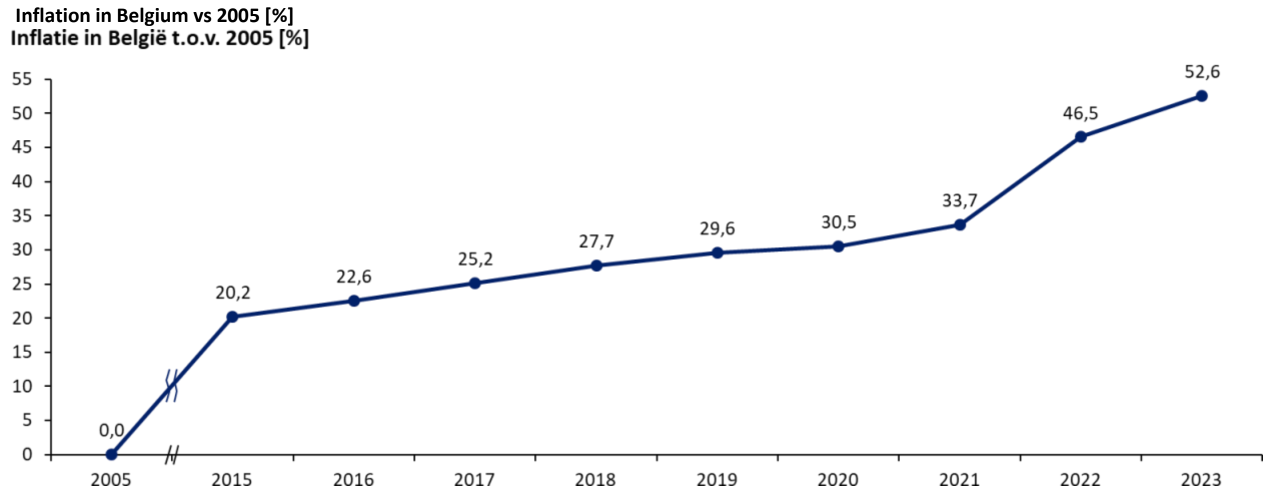

Figure 13: Evolution of inflation in Belgium since 2005 (Inflation in Belgium | Statbel)

Gross value added

Across the three sectors combined, gross value added hardly increased between 2005 and 2023 (+9%) and thus lies significantly below inflation (52.6%). Only in 2022 did value added rise sharply, after which it fell back in 2023. This trend is also observable for each of the three sectors separately. As a result, the share of the three sectors in total manufacturing fell from 36% to 28% between 2005 and 2023. The share of manufacturing itself in the total economy also declined from 22% to 15% between 2005 and 2023.

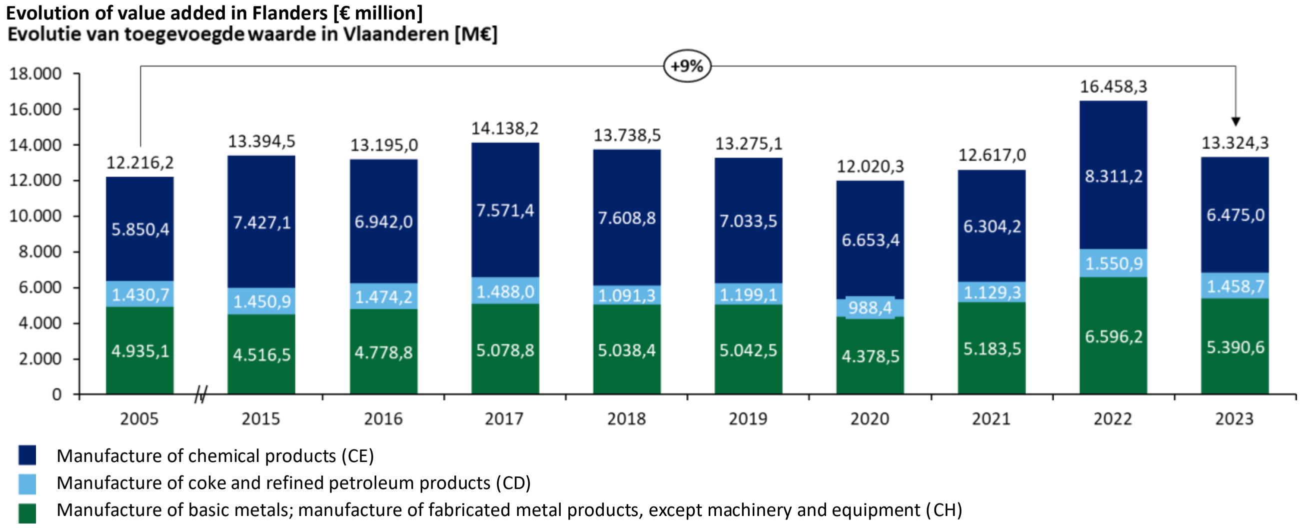

Figure 14: Evolution of Flemish value added for the chemicals, refining and steel sectors since 2005 (NBB – Regional accounts by A38 – NUTS 2)

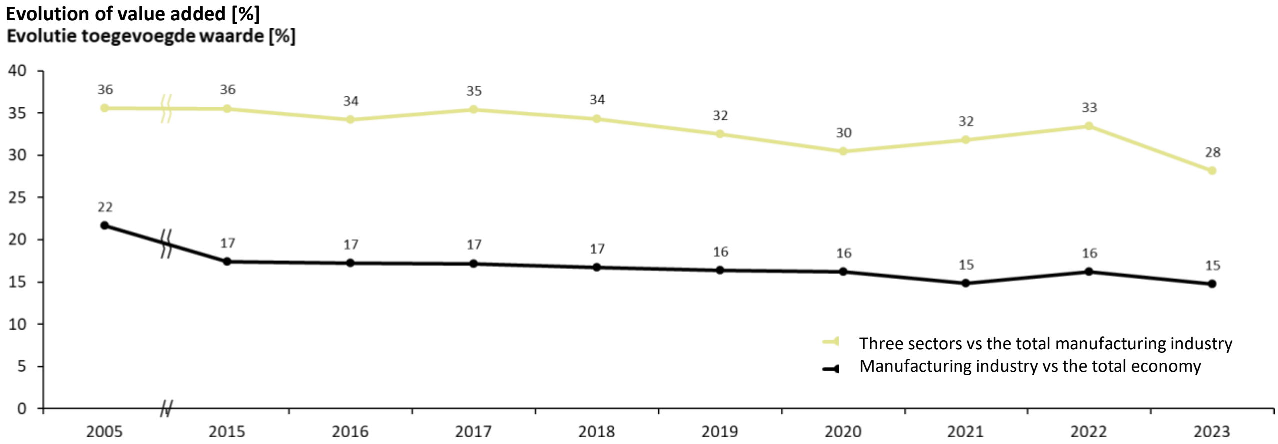

Figure 15: Evolution of the share of value added of the chemicals, refining and steel sectors relative to total manufacturing and the total economy in Flanders (NBB – Regional accounts by A38 – NUTS 2)

(Direct) employment

Direct employment across the three sectors decreased between 2005 and 2023 (−19%), mainly characterised by a strong decline in the manufacture of metals between 2005 and 2015 (−23%). In the period 2019–2023, only a slight decrease is visible (<1%), despite the significant drop in production (>10%). The share of the three sectors in total manufacturing remained relatively constant between 2005 and 2023 at approximately 26%. The share of manufacturing itself in the total economy fell more markedly from 17% to 12% between 2005 and 2023, mainly in the period 2005–2015.

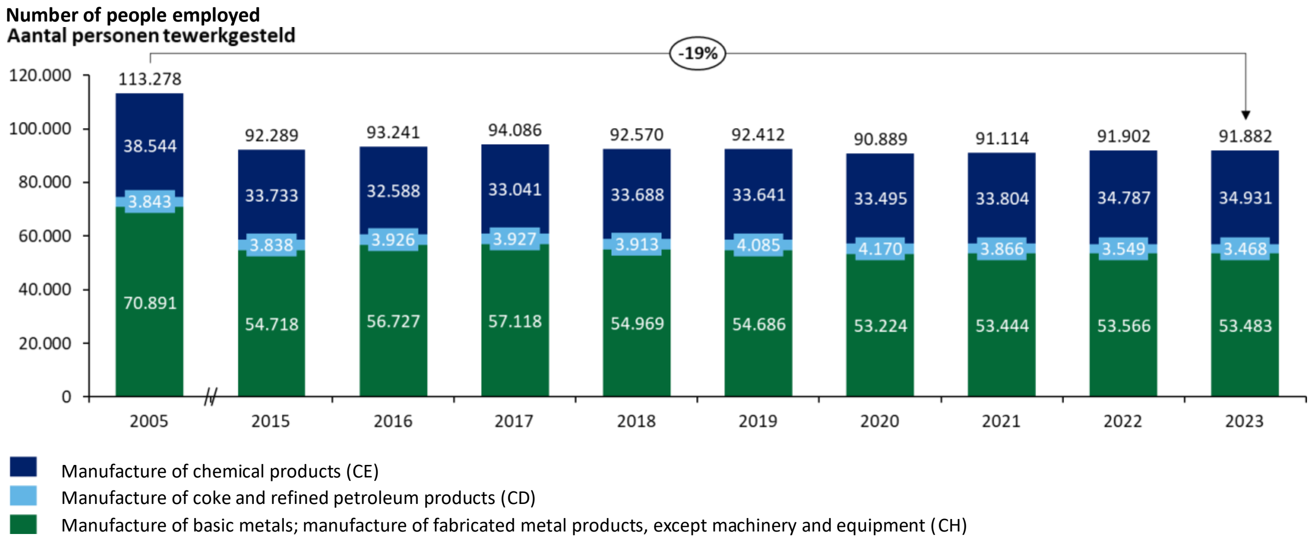

Figure 16: Evolution of Flemish employment for the chemicals, refining and steel sectors since 2005 (NBB – Regional accounts by A38 – NUTS 2)

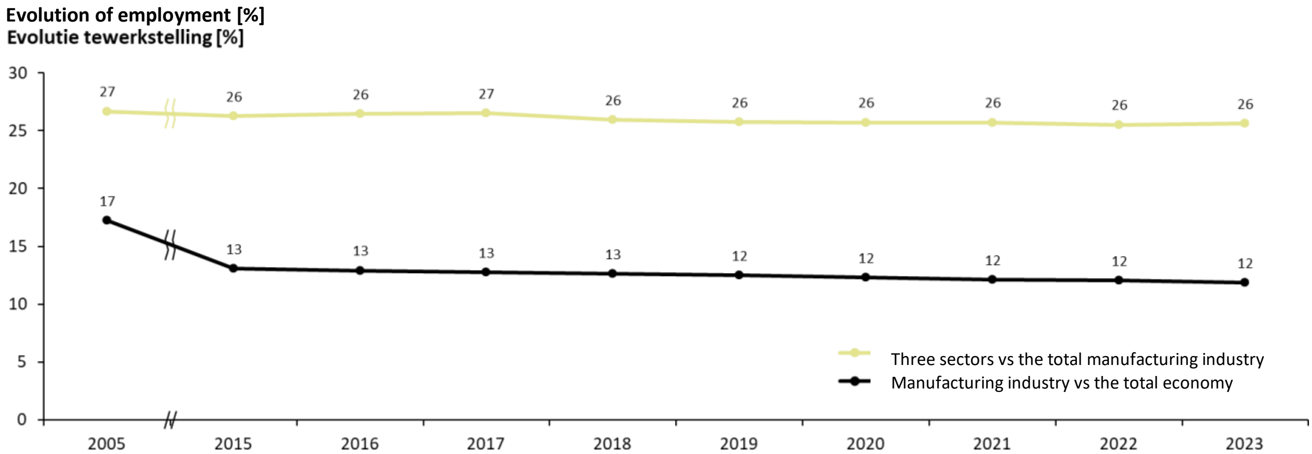

Figure 17: Evolution of the share of employment of the chemicals, refining and steel sectors relative to total manufacturing and the total economy in Flanders (NBB – Regional accounts by A38 – NUTS 2)

Investment

Total investment in the three sectors rose by 81% in 2022 compared with 2005, which is above inflation (46.5% in 2022 vs 2005). There are large differences between sectors. Chemicals (+100%) and metals (+67%) saw the largest increases. The increase in the refining sector is more limited (+27%), but did peak in the period 2014–2017. The share of the three sectors in total manufacturing remained relatively constant between 2005 and 2022 at around 30%. The share of manufacturing itself in the total economy fell from 18% to 16% between 2005 and 2022, but less sharply than gross value added.

It is important to note that investment always responds to economic reality with a delay. Investments in a given year are often the result of decisions taken under the investment climate of previous years.

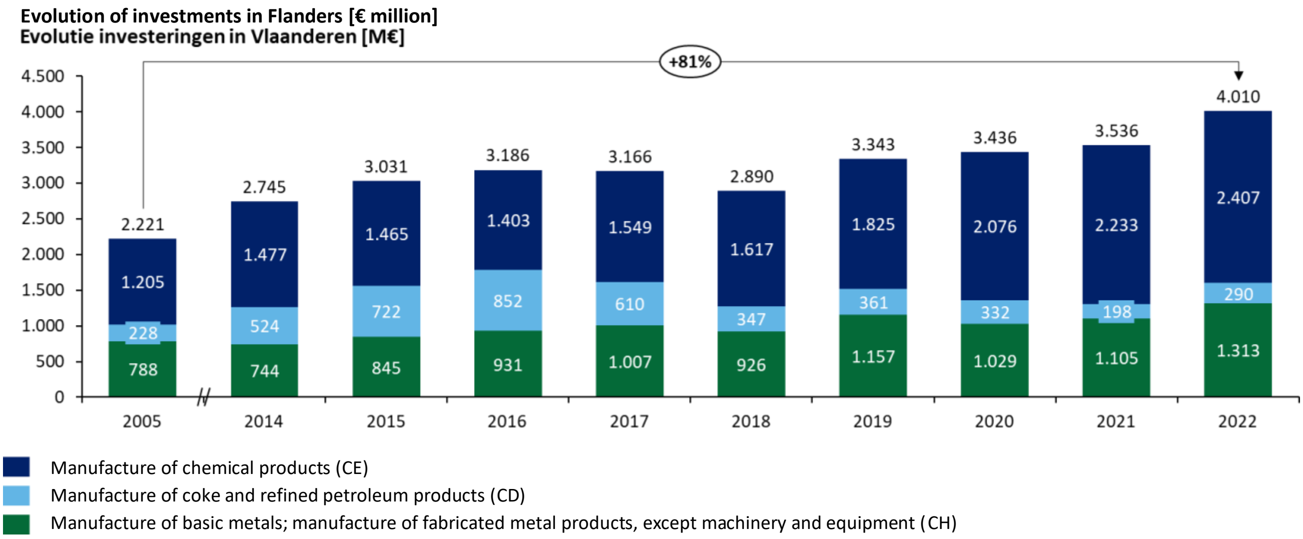

Figure 18: Evolution of Flemish investment for the chemicals, refining and steel sectors since 2005 (NBB – Regional accounts by A38 – NUTS 2)

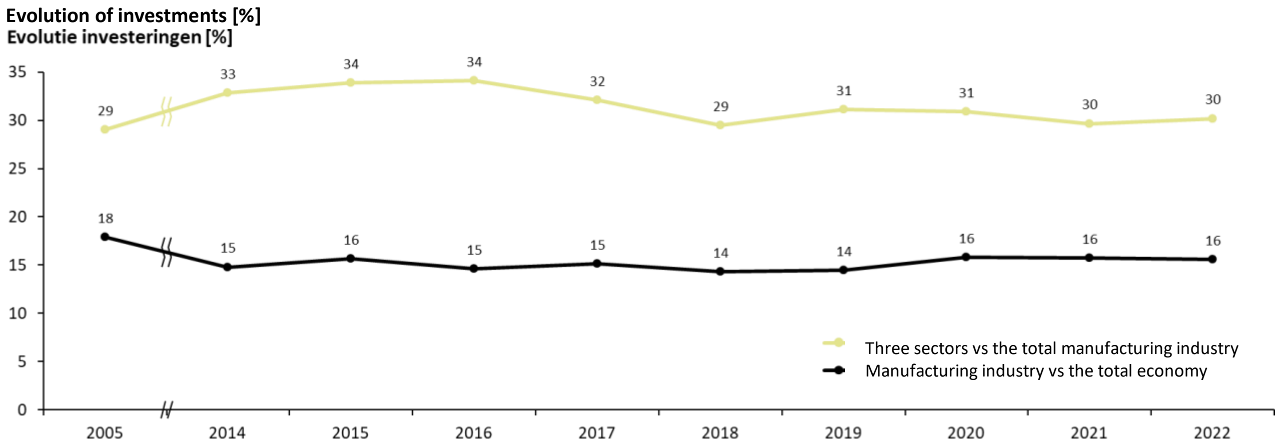

Figure 19: Evolution of the share of investment of the chemicals, refining and steel sectors relative to total manufacturing and the total economy in Flanders (NBB – Regional accounts by A38 – NUTS 2)

Exports and imports of goods

The monetary value of exports of Flemish goods in the three sectors combined increased by 88% in 2022 compared with 2005, also higher than inflation (46.5%). The increase in imports over the same period was even larger, at 132%. In absolute terms, the difference between exports and imports for the three sectors combined remained almost constant over 2005–2022 (± €11 billion). The chemicals and metals sectors are net exporters, while the refining sector is a net importer. The share of the three sectors in total manufacturing exports remained almost constant at 43% over 2005–2022. The share of manufacturing in the total economy fell from 63% to 51% between 2005 and 2022.

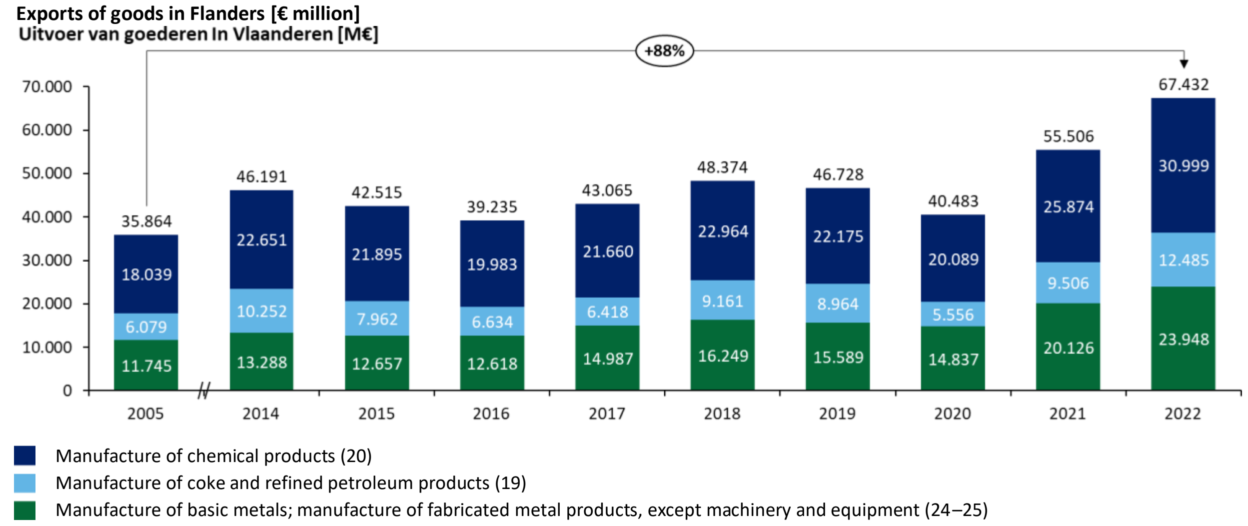

Figure 20: Evolution of Flemish exports for the (petro)chemicals, refining and steel sectors since 2005 (NBB – Regional distribution of imports and exports – NUTS 1)

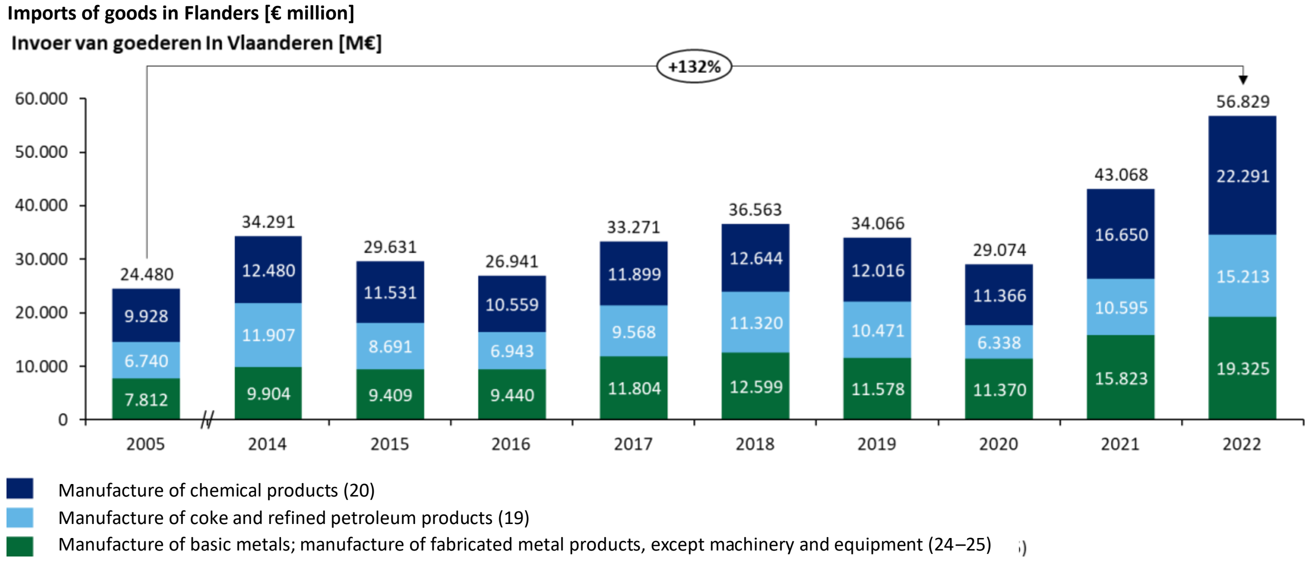

Figure 21: Evolution of Flemish imports for the (petro)chemicals, refining and steel sectors since 2005 (NBB – Regional distribution of imports and exports – NUTS 1)

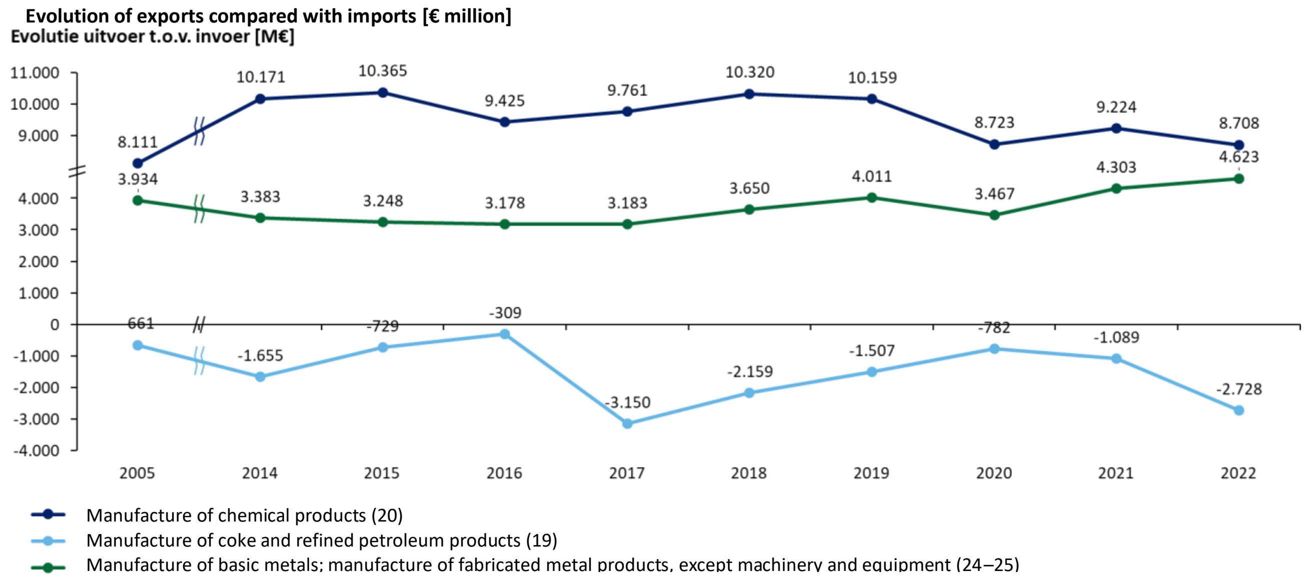

Figure 22: Evolution of the difference between exports and imports of goods in the chemicals, refining and steel sectors (NBB – Regional distribution of imports and exports – NUTS 1)

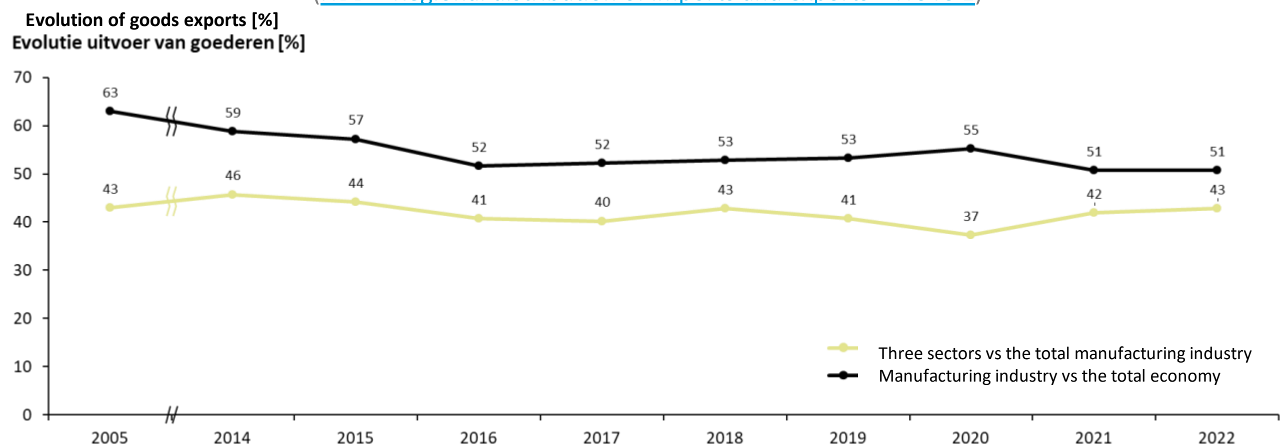

Figure 23: Evolution of the share of goods exports of the chemicals, refining and steel sectors relative to total manufacturing and the total economy in Flanders (NBB – Regional distribution of imports and exports – NUTS 1)

3.2.5. Conclusion

As a general overview, the reference values of the various parameters examined are set out in the table below for the years 2005, 2019, 2022 and 2023. For investment, exports and imports only 2022 values were used, as 2023 data was not yet available on the NBB website[45].

The previous roadmap study had emissions data up to 2019. Since 2019, Flemish emissions in the chemicals, refining and steel sectors have continued to decline – by 16% in 2023. This brings the total emissions reduction in 2023 for these three sectors to 25% compared with 2005. The stronger reduction in emissions between 2019 and 2023 is not only due to a switch to new processes, but largely to lower production and the associated lower energy use[46]. The lower emissions are therefore largely linked to declining competitiveness in the three sectors. The next section of this chapter explores this further.

[45] The final data for the report was retrieved from the NBB, VEKA, Statbel and Worldsteel websites in February 2025.
[46] This also follows from the 2022 annual report of the EBOs, which shows that for all ETS companies the avoided emissions achieved through energy-saving measures between 2019 and 2022 amounted to roughly 500 kt CO_2, corresponding to an energy saving of 6.9 PJ (Annual Report 2022 | EBO Vlaanderen). Compared with 2019, this represents a saving of around 2%.

This lower production has not (yet) led to a sharp decline in employment, but it has resulted in stagnation of value added and investment. Lower production stems from declining competitiveness, which is also reflected in imports of goods rising faster than exports.

Table 1: Overview of reference values in 2005, 2019, 2022 and 2023 for the different parameters examined on the evolution of Flemish activity in the chemicals, refining and steel sectors

Parameter	**2005** (base year)	**2019**	**Δ% (2005-2019)**	**2022**	**Δ% (2019-2022)**	**2023*** **	**Δ% (2022-2023)**
Emissions in Mt CO_2e	27.4	24.4	-11%	22.1	-9%	20.6	-7%
Energy use in PJ	327	323	-1%	293	-9%	284	-3%
Steel production in Mt**	10.4	7.8	-25%	7.0	-10%	5.9	-16%
Refining production in PJ	1,573	1,477	-5%	1,224	-17%	1,314	+7%
Polymer production in Mt**	8.3*	8.2	-1%	6.5	-21%	7.0	+8%
Belgium inflation in % versus 2005	0%	29.6%	+29.6%	46.5%	+13.0%	52.6%	+4.2%
Gross value added in € billion	12.2	13.3	+9%	16.5	+24%	13.3	-24%
Employment in thousand persons	113	92	-19%	92	-1%	92	-0%
Investment in € billion	2.2	3.3	+50%	4.0	+21%	/***	/
Exports in € billion	35.9	46.7	+30%	67.4	+44%	/***	/
Imports in € billion	24.5	34.1	+39%	56.8	+67%	/***	/

* For plastics production, 2009 was used instead of 2005

** For plastics and steel production, Belgian data was used instead of Flemish data

*** For investment, exports and imports, only data for 2022 was available, not yet for 2023

3.3. The position of the chemicals, refining and steel sectors in Flanders in relation to other world economies

As indicated in the previous section, the Flemish energy-intensive sectors are under competitive pressure, resulting in a substantial decline in production. This section explores this further by, on the one hand, comparing Belgium's industrial performance with Europe, the United States and China in terms of production, emissions, energy use and socio-economic factors. On the other hand, it examines the underlying factors putting this competitiveness under pressure, such as energy costs, labour costs, regulation, state aid, permitting lead times, etc. The required data was collected up to February 2025. More recent data published thereafter is not included in the overview.

It is important to note that the period 2020–2025 was marked by several crises (COVID-19, wars, volatile energy prices, inflation and trade conflicts) that also affected competitiveness.

3.3.1. Observed trends in production share, emissions, energy use and socio-economic factors

In the competitiveness analysis, the status of Belgium – rather than Flanders – is compared with Europe, the United States and China. International datasets often report only at national level. Hence the choice of Belgium to make use of as many identical datasets as possible to compare the various parameters. This analysis provides a snapshot of Belgium's current performance relative to the other regions in terms of production, energy use, emissions and socio-economic factors. Table 2 summarises all these analyses and indicates whether performance in Belgium is better (green), equal (yellow) or worse (orange and red) than in Europe. It also shows how Europe scores relative to the United States and China. The conclusions from the table are summarised below.

Production[47]

In the three sectors – refining, (petro)chemicals and steel – production volumes fell slightly in Belgium over 2014–2023[48], comparable to Europe but faster than in the United States. China, in particular, was the only region with large production increases, thereby taking an ever larger share of the world market.

In refining, production in Belgium fell slightly between 2014 and 2023 (−6%), less so in Europe (−2%), while it rose in the United States (+1%) and especially in China (+49%). As a result, China became the second largest processor instead of Europe, with a share of 18% versus 12%. In steel, China's production rose by 24% over 2014–2023, while Belgium's fell by 19%. In the chemicals sector's sales figures, China recorded enormous growth of 482% over 2008–2023 compared with 28% growth in Belgium. This brought China's market share to 43% in 2022, an increase of 126% compared with 2008, in contrast with declining market shares in Belgium (−50%), Europe (−46%) and the United States (−39%).

Industrial energy use and associated CO_2 emissions[49]

On emissions from industrial energy use, Belgium performs strongly (69 tCO_2/TJ). In 2022 Belgium's emissions were 18% lower than Europe's. Emissions associated with the industrial energy mix in Europe (84 tCO_2/TJ) are themselves also lower than in the United States (94 tCO_2/TJ) and especially China (146 tCO_2/TJ). One explanation is that the emissions associated with electricity use – expressed at source in gCO_2/kWh rather than tCO_2/TJ – were much lower in Belgium (140 gCO_2/kWh) in 2022 than in Europe (292 gCO_2/kWh), the United States (386 g CO_2/kWh) and China (586 gCO_2/kWh). Electricity use in the industrial energy mix increased in all regions between 2013 and 2022, with the exception of the United States (−6%). The share of electricity in the energy mix in 2022 is also lowest in the United States at 26%; in the other three regions it is 34%. China in particular saw a strong increase in the share of electricity use (+33%) between 2013 and 2022; in Belgium the increase was +11%.

[47] Production data was retrieved from the following sources: refining – Energy Institute; steel – Worldsteel; chemicals – Cefic and Eurostat (Gross value added and income by detailed industry (NACE Rev.2)).
[48] Since the Cefic study compared only 2008 figures with 2023, this has been presented accordingly instead of a comparison between 2014 and 2023.
[49] The data on industrial energy use and emissions was sourced from the IEA. This dataset did not contain sufficient information for Europe at the EU-27 level; therefore, Europe as a region was used. Industrial emissions include the energy-related emissions of manufacturing, construction and the energy industry, excluding electricity and heat production for the transport, residential and commercial sectors. The electricity emissions were taken from Our World in Data.

Socio-economic factors[50]

For socio-economic factors, the analysis considered gross value added, employment and investment in manufacturing. For all three parameters, the period 2013–2022 was examined, showing that Belgium's performance is slightly below Europe's. For changes in absolute values for value added and investment, the effect of inflation must be taken into account. For Belgium, cumulative inflation was 23% between 2013 and 2022. Hence the choice to compare the contribution of manufacturing with the whole economy.

Plotting manufacturing's share relative to the total economy shows that in Belgium the contribution of manufacturing declines slightly in terms of value added (−5%) and employment (−12%), which is less pronounced in Europe (+3% and −5%). For investment, the contribution remains relatively constant in both Belgium (+1%) and Europe (+2%). Compared with the United States, Europe shows a stronger evolution in additional value added and investment. This is lower than China in absolute values, but the share of Chinese manufacturing in the total economy falls more sharply. China is the only region in this period with a steep decline in employment (−29%), which is not the case in Europe (+5%), but is in Belgium (−12%).

Conclusion regarding the observed trends

Over the past decade, production in the (petro)chemicals, steel and refining sectors in Belgium has declined, which is also reflected in a shrinking share of manufacturing's gross value added, employment and investment. On these parameters, Belgium performs slightly worse to on a par with Europe.

Compared with the United States, Europe scores slightly lower on production parameters, but slightly better on socio-economic factors.

The main outlier is China, which over the past decade has taken a much larger share of production in refining, steel and chemicals. This has resulted in the strongest increases in investment and gross value added in its manufacturing sector. Employment in Chinese manufacturing, however, saw the largest decline compared with the other regions.

On emissions, Belgium achieves the best scores, with the lowest emissions in the industrial energy mix – due in part to the low emissions intensity of Belgian electricity and a rising electricity share in industrial consumption. On this front, China scores the lowest, with an industrial energy mix that in 2022 still emitted more than twice as much as Belgium.

[50] The data for the socio-economic factors was sourced from Eurostat, the U.S. Bureau of Economic Analysis and China's National Bureau of Statistics. For China's employment data, the "urban non-private units" category was used, as data for all manufacturing – including private and rural – was unavailable.

Table 2: Comparative analysis of the status of industrial competitiveness in Belgium vs Europe, the United States and China

Status of industrial competitiveness and transition	Score			Parameter	Value			
	BE vs EU	EU vs US	EU vs CH		BE	EU	US	CH
Production								
Production – refining	-	-	--	Change in world market share 2014–2023 (%)	-12% (0.8% -> 0.7%)	-8% (13% -> 12%)	-5% (20% -> 19%)	+39% (13% -> 18%)
				Change in production 2014–2023 (% / million barrels per day)	-6% (0.65 -> 0.61)	-2% (12.1 -> 11.9)	+1% (15.8 -> 16.0)	+49% (10.2 -> 15.1)
Production – steel	=	-	--	Change in world market share 2014–2023 (%)	-29% (0.4% -> 0.3%)	-29% (9.5% -> 6.7%)	-19% (5.3% -> 4.3%)	+9% (50% -> 54%)
				Change in production 2014–2023 (% / million tonnes crude steel per year)	-19% (7.3 -> 5.9)	-20% (157 -> 126)	-8% (88 -> 81)	+24% (823 -> 1019)
Production – chemicals	=	-	--	Change in world market share 2008–2023 (%)	-50% (1.5% -> 0.8%)	-46% (23% -> 13%)	-39% (18% -> 11%)	+126% (19% -> 43%)
				Change in sales 2008–2023 (% / € billion)	+28% (31 -> 40)	+39% (470 -> 665)	+57% (364 -> 572)	+482% (384 -> 2235)
Industrial energy use and associated CO_2 emissions								
Emissions relative to industrial energy use	+	+	++	Emissions per unit of industrial energy use 2022 (tCO_2/TJ)	69.0	84.1	93.5	146.2
				Change per unit of industrial energy use 2013–2022 (%)	-8% (75 -> 69)	-12% (96 -> 84)	-11% (105 -> 93)	-1% (148 -> 146)
Electricity emissions	++	+	++	Electricity emissions 2022 (gCO_2/kWh)	140	292	386	586
				Change in electricity emissions 2013–2022 (%)	-24% (184 -> 140)	-18% (357 -> 292)	-18% (502 -> 386)	-23% (717 -> 586)

Electricity use in industry	=	+	=	Share of electricity in industrial energy use 2022 (%)	34%	34%	26%	34%
				Change in share of electricity in industrial energy use 2013–2022 (%)	+11% (30% -> 34%)	+4% (33% -> 34%)	-6% (28% -> 26%)	+33% (26% -> 34%)
Socio-economic factors								
Gross value added	-	+	--	Change in manufacturing gross value added 2013–2022 (%)	+37%	+44%	+36%	+79%
				Change in share vs total economy 2013–2022 (%)	-5% (14% -> 13%)	+3% (16% -> 17%)	-12% (12% -> 10%)	-13% (31% -> 27%)
Employment	-	=	+	Change in manufacturing industry employment 2013–2022 (%)	-2%	+5%	+6%	-29%
				Change in share vs total economy 2013–2022 (%)	-12% (11% -> 10%)	-5% (15% -> 14%)	-4% (9% -> 8%)	-23% (29% -> 22%)
Investment	=	+	--	Change in manufacturing industry investment 2013–2022 (%)	+55%	+61%	+44%	+63%
				Change in share vs total economy 2013–2022 (%)	+1% (14% -> 14%)	+2% (15% -> 15%)	-15% (17% -> 15%)	-9% (34% -> 31%)

3.3.2. Analysis of underlying competitiveness factors

The competitiveness of energy-intensive sectors is determined by both price-forming production factors and other factors. Price-forming production factors include:

1. Energy and feedstock
2. Investment cost: inflation
3. Labour
4. Regulation or environmental protection
5. State aid or taxation
6. Logistics

Other factors include:

1. Innovation potential
2. Talent
3. Market demand
4. Permitting
5. Available infrastructure

Belgium's positioning on these underlying factors relative to Europe, the United States and China is explained further in the following sections.

Production price-forming competitiveness factors

Not all the factors below have an equally large impact on the production price. In a recent Cefic[51] competitiveness study for the European chemicals sector, weights were assigned to these factors to reflect their impact. The factors linked to the production of "upstream chemicals" – which are more capital- and energy-intensive (see Figure 24) – are applicable to the energy-intensive sectors within the scope of this study.

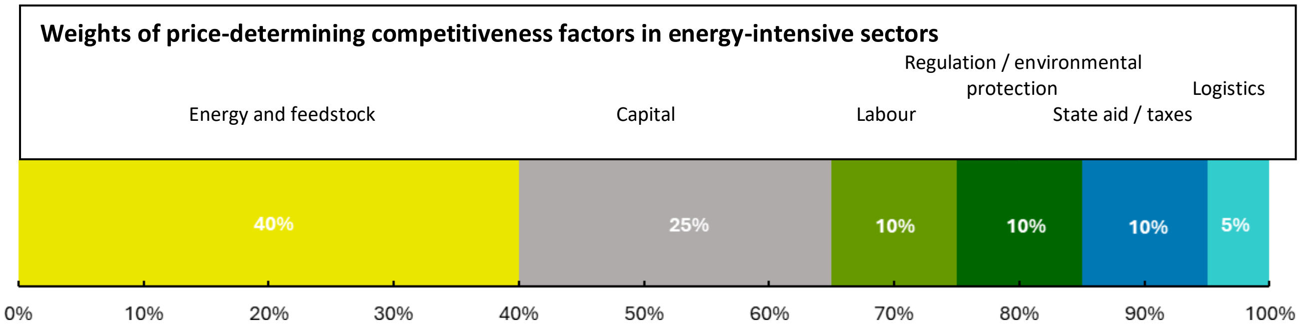

Figure 24: Weights of production price-forming competitiveness factors included in the Cefic/Advancy study for "upstream chemicals"

For refining, the cost of raw materials (crude oil) is the largest cost component (60–70% of total production costs). Non-feedstock energy costs account for 5–10% of production costs. The share of labour costs is 10–15%. The remaining percentage (around 10–25%) includes items such as maintenance, catalysts, chemicals, overheads and capital-related expenditures[52].

For steel production, feedstock and raw materials (e.g. iron ore, coal) again make up the largest share of production cost (up to 65%). The energy cost share is around 17%. Labour cost is around 7%. The remaining costs (e.g. capital, maintenance and CO_2 cost) account for roughly 15% of total production cost[53].

The most influential components of the production price for these sectors are therefore the costs related to energy and feedstock, followed by capital costs. Costs related to labour and logistics carry a lower weight for the energy-intensive sectors, but become increasingly important in more "downstream" value chains.

Belgium's scores relative to the other regions are set out in Table 3 and are explained further in the following sections.

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[51] Cefic, the competitiveness of the European chemical industry (link)

[52] CONCAWE (2012). *EU Refinery Energy Systems and Efficiency*. Available at: https://www.concawe.eu/wp-content/uploads/rpt_12-03- 2012-01520-01-e.pdf

[53] JRC, 2020, Production costs from iron and steel in the EU and third countries. Available at: https://www.eurofer.eu/assets/news/eu- technical-report-on-production-costs-from-the-iron-and-steel-industry-in-the-eu-and-third- countries/production_costs_from_the_iron_and_steel_industry_-_final_online.pdf

Table 3: Summary comparison between Belgium, Europe, the United States and China on production price-forming competitiveness factors

Production price-forming competitiveness factors	Score		
	BE vs EU	EU vs US	EU vs CH
Energy and feedstock	=	--	-
CAPEX (inflation)	=	-	--
Labour	-	+	--
Regulation or environmental protection	-	--	--
Corporation tax	-	=	+
State aid for the transition	-- (*)	(o)	N/A
Logistics (LPI)	+	++ (**)	++(**)

(*) vs neighbouring countries, (o) unclear to what extent major state aid under the Inflation Reduction Act will persist, (**) direct comparison with Belgium.

Energy and feedstock

Both electricity and gas prices rose sharply in Europe during the energy crisis (2021–2023). Prices have since fallen but remain noticeably higher than before 2021. Compared with the United States, both electricity and gas prices are much higher in Europe (×4 for gas and ×2 for electricity)[54]. Relative to China, electricity prices in particular are much higher (×2).

Countries with greater potential to supply themselves abundantly in future with locally produced, low-cost renewables can gain an additional price advantage, which will put further pressure on the competitiveness of Belgium's energy-intensive industry. This can reinforce the phenomenon of "green relocation"[55], whereby energy-intensive industrial raw materials are produced elsewhere and subsequently imported into Belgium.

[54] Cefic, 2025, The Competitiveness of the European Chemical Industry
[55] Impact of global heterogeneity of renewable energy supply on heavy industrial production and green value chains | Nature Energy

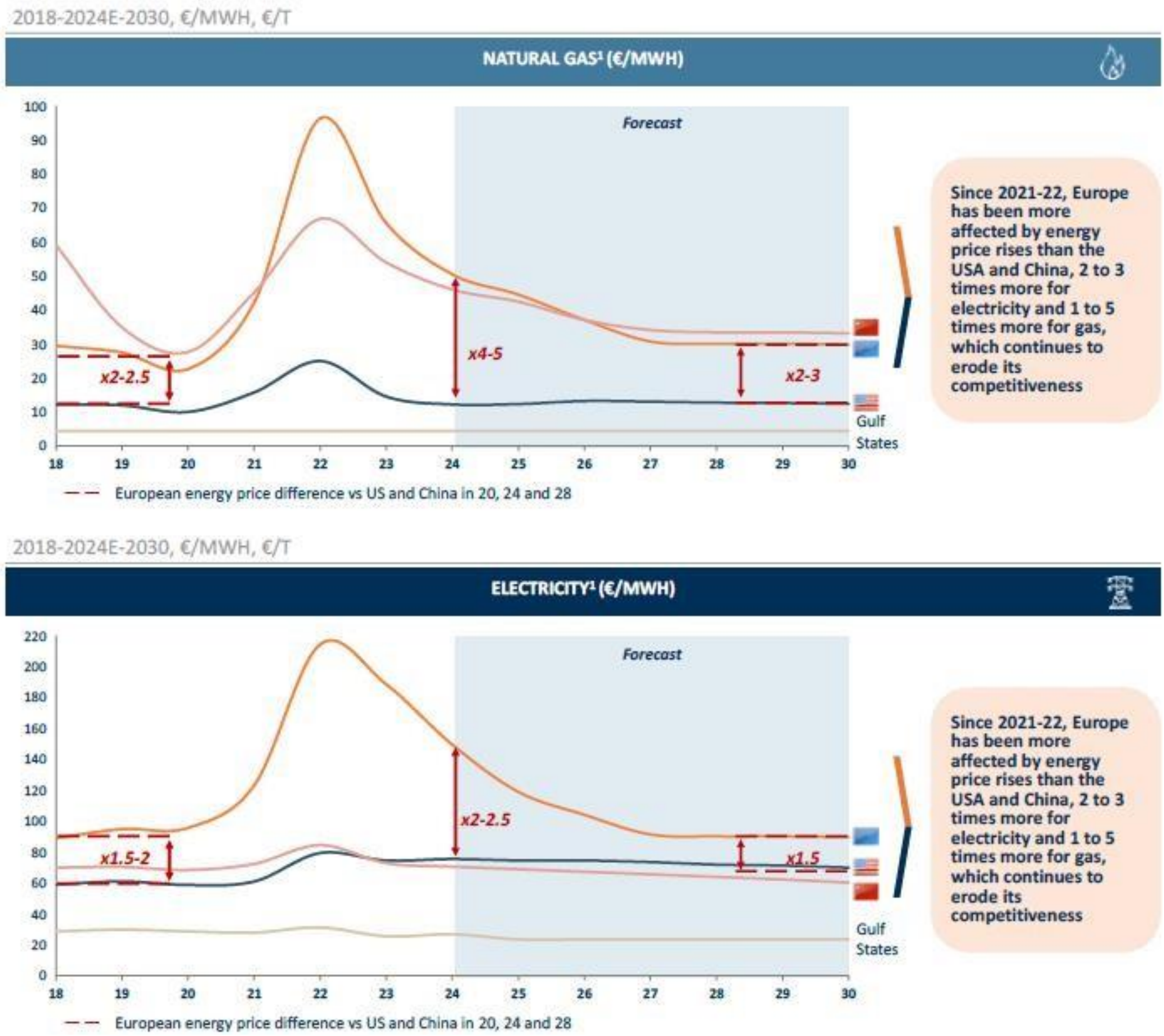


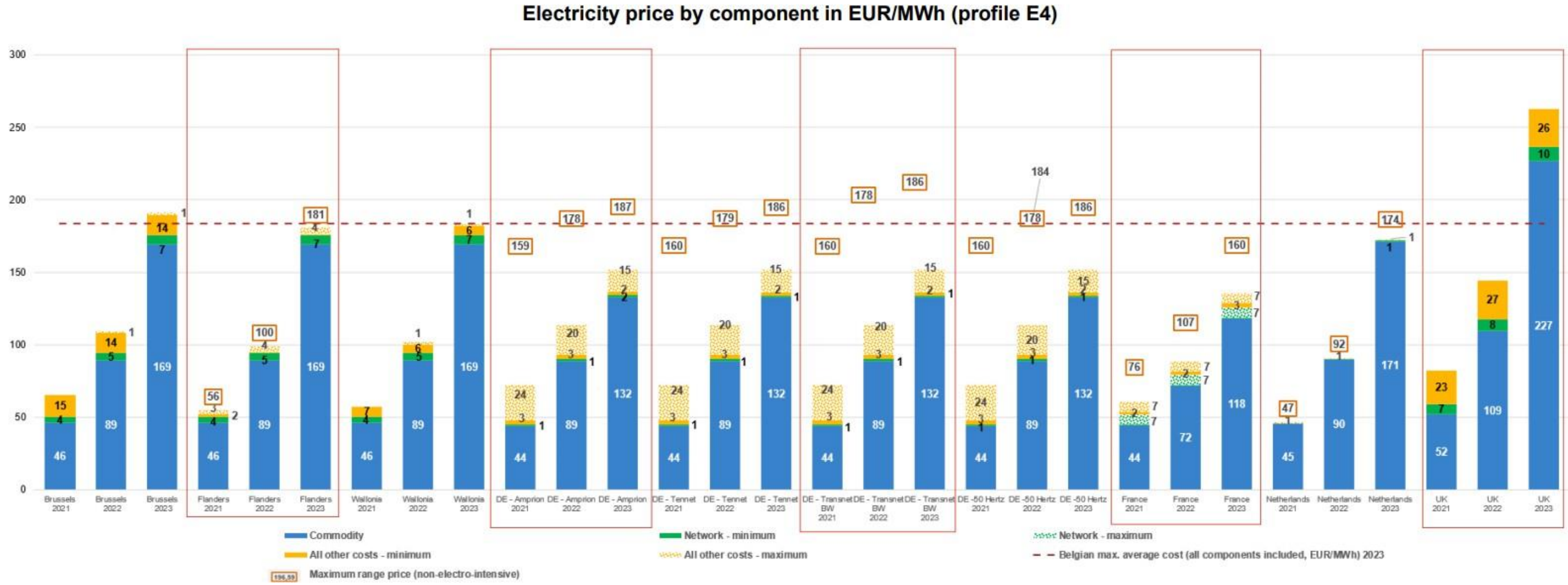
Figure 25: Comparative analysis of electricity (top) and gas prices (bottom) between Europe, the United States, China and the Gulf States, 2018–2030 (Cefic)

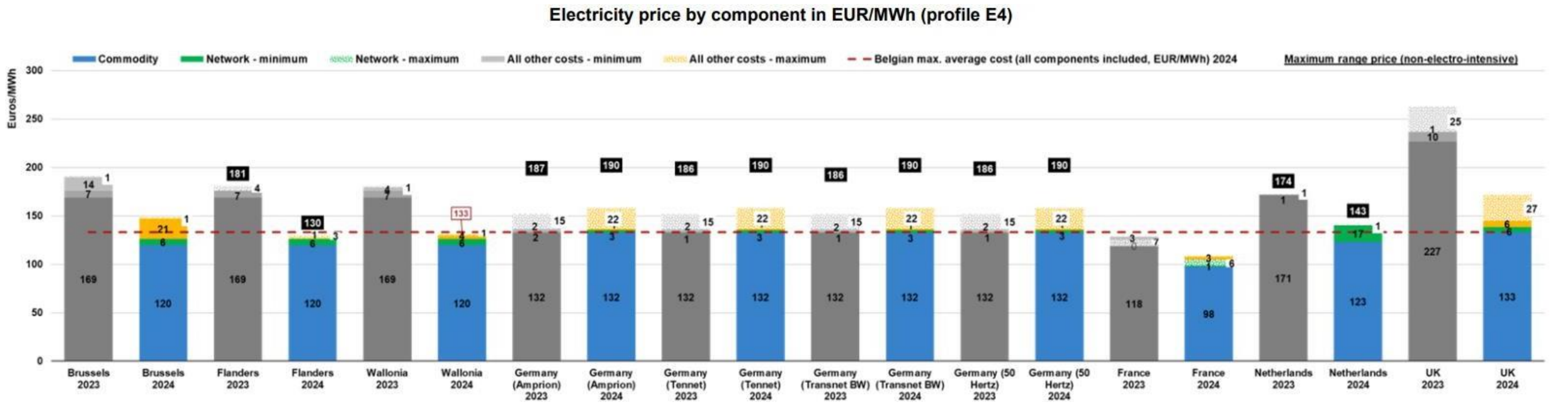
To compare with Europe, Flemish prices were set against those of immediate neighbours (Germany, France and the Netherlands) using the Forbeg studies[56] (see Figure 26). We looked at the largest energy consumers, namely E4 (>500,000 MWh) for electricity and G2 (>2,500,000 MWh) for gas.

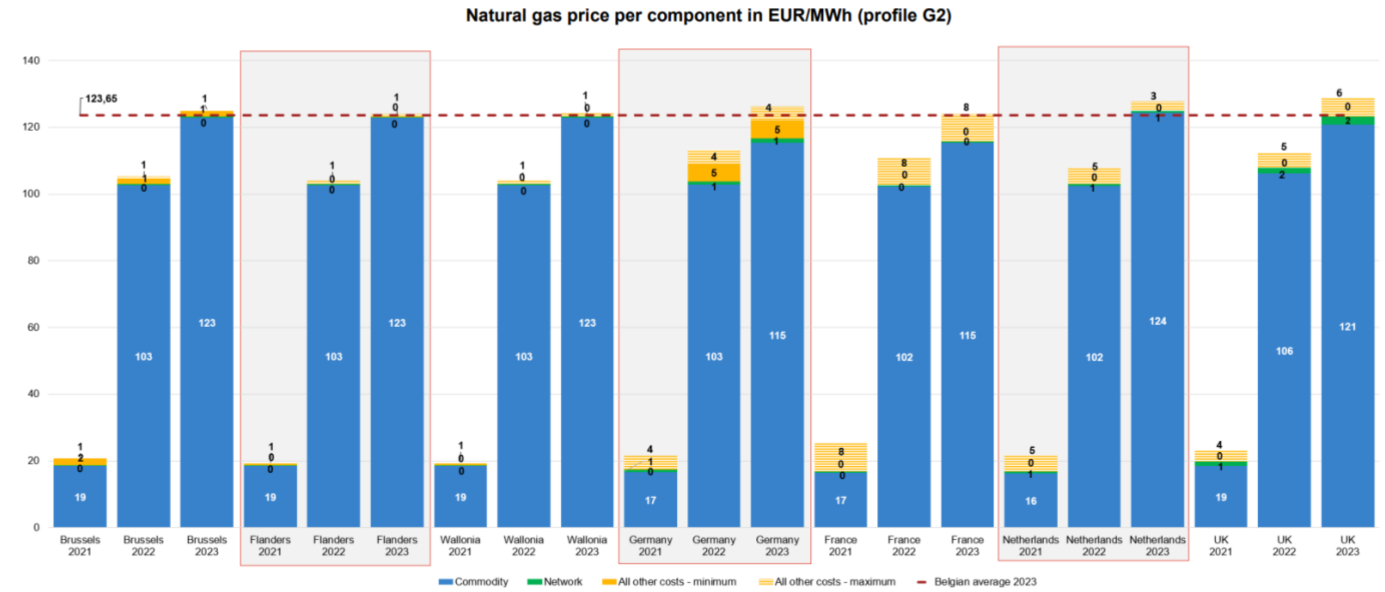
This analysis shows that electricity prices in 2023 were higher than in Germany, France and the Netherlands. In 2020, 2021 and 2024, electricity prices in Flanders were also at slightly higher or similar levels compared with Germany and the Netherlands, and significantly higher than in France[57]. Gas prices in Flanders were at a similar level to those in Germany, France and the Netherlands.

[56] A European comparison of electricity and natural gas prices for residential, small professional and large industrial consumers - 2024 | CREG: Commission for Electricity and Gas Regulation

[57] More recent figures were published in May 2025, which are not included in this analysis. The link is: F20250514EN.pdf


Electricity price by component in EUR/MWh (profile E4)
Commodity
Network - minimum
Network - maximum
All other costs - minimum
All other costs - maximum
Belgian max. average cost (all components included, EUR/MWh) 2023
Maximum range price (non-electro-intensive)
Brussels 2021
Brussels 2022
Brussels 2023
Flanders 2021
Flanders 2022
Flanders 2023
Wallonia 2021
Wallonia 2022
Wallonia 2023
DE - Amprion 2021
DE - Amprion 2022
DE - Amprion 2023
DE - Tennet 2021
DE - Tennet 2022
DE - Tennet 2023
DE - Transnet BW 2021
DE - Transnet BW 2022
DE - Transnet BW 2023
DE -50 Hertz 2021
DE -50 Hertz 2022
DE -50 Hertz 2023
France 2021
France 2022
France 2023
Netherlands 2021
Netherlands 2022
Netherlands 2023
UK 2021
UK 2022
UK 2023


Electricity price by component in EUR/MWh (profile E4)
Commodity
Network - minimum
Network - maximum
All other costs - minimum
All other costs - maximum
Belgian max. average cost (all components included, EUR/MWh) 2024
Maximum range price (non-electro-intensive)
Euros/MWh
Brussels 2023
Brussels 2024
Flanders 2023
Flanders 2024
Wallonia 2023
Wallonia 2024
Germany (Amprion) 2023
Germany (Amprion) 2024
Germany (Tennet) 2023
Germany (Tennet) 2024
Germany (Transnet BW) 2023
Germany (Transnet BW) 2024
Germany (50 Hertz) 2023
Germany (50 Hertz) 2024
France 2023
France 2024
Netherlands 2023
Netherlands 2024
UK 2023
UK 2024



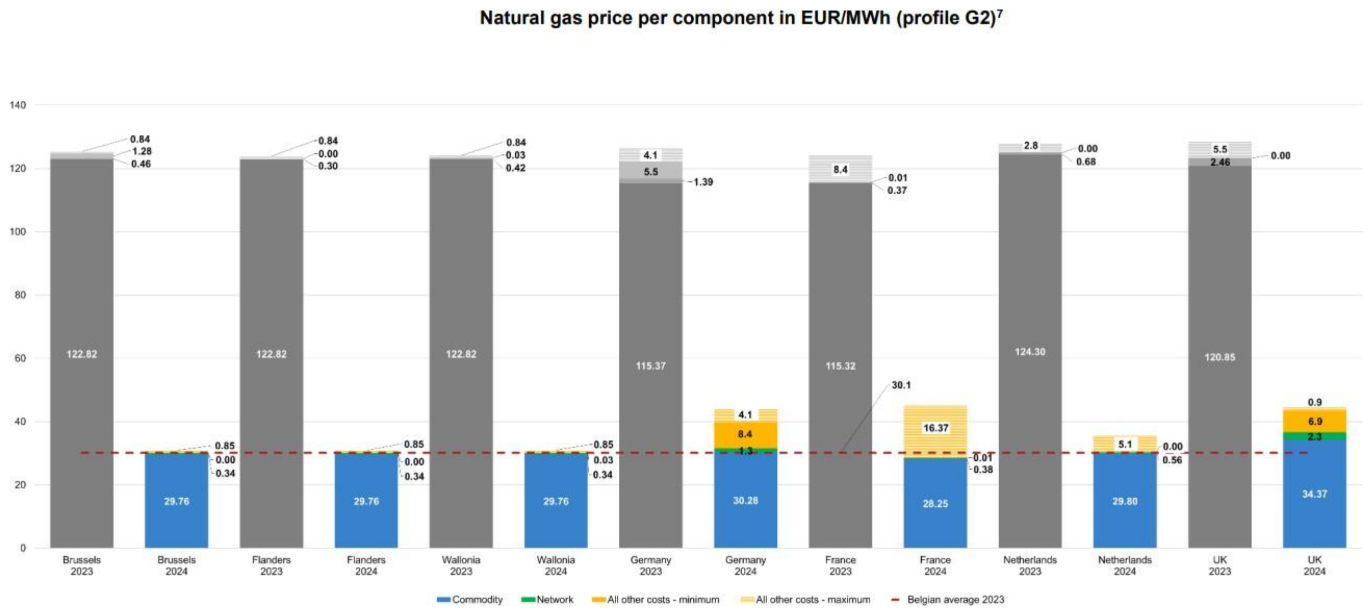


Figure 26: Comparative analysis of electricity and gas prices between Belgium, Germany, France and the Netherlands, 2021–2024 (Forbeg study).

For feedstock in the chemicals sector, sanctions on Russian exports created a (limited) competitive advantage in Asia for naphtha due to redirected exports. This is limited by several recent accidents at Russian refineries[58]. The expectation is that differences in naphtha prices between economic regions will remain limited (between €600 and €620 per tonne in 2030, with higher prices in Europe). For ethane, the United States retains a major competitive advantage due to large-scale local production[59].

The average price of coking coal for steel production, like gas and electricity, fell sharply from early 2023 (around $200 per tonne by the end of 2024 versus a peak around $325 per tonne in 2023). This relates to global overcapacity in steel production. Prices in Asia are lower due to surplus import possibilities from Australia and Russia, with regional prices below $200 per tonne[60]. Chinese import tariffs on US coking coal are likely to push down the price of this coal in Europe[61,62]. The price of iron ore in Europe is structurally lower than in China and the United States (but higher than in India)[63].

Crude oil prices, like gas, remain above pre-energy-crisis levels (e.g. around $70 per barrel in 2025 versus around $50–60 per barrel in 2016–2020)[64,65]. The United States and the Middle East have a structural competitive advantage here thanks to large-scale local production.

[58] https://www.argusmedia.com/en/news-and-insights/latest-market-news/2544301-naphtha-east-west-economics-becoming-unworkable
[59] Cefic, 2025, The Competitiveness of the European Chemical Industry
[60] https://gmk.center/en/news/asian-coking-coal-prices-accelerated-their-decline/
[61] https://www.spglobal.com/commodity-insights/en/news-research/latest-news/metals/020625-us-china-tariff-war-may-create-glut-of-us- coking-coal-cargoes-in-asia
[62] Based on an assessment in February 2025. Given the volatility of import tariffs worldwide – and in the United States in particular – this context may change.
[63] https://businessanalytiq.com/procurementanalytics/index/iron-ore-price-index/
[64] https://tradingeconomics.com/commodity/crude-oil
[65] The current economic context makes it difficult to provide reliable forecasts for oil prices.

Investment cost: inflation

The increased investment cost (CAPEX) due to inflation is one of the important factors[66] behind the absence or delay of final investment decisions for industrial climate projects (e.g. blue hydrogen).

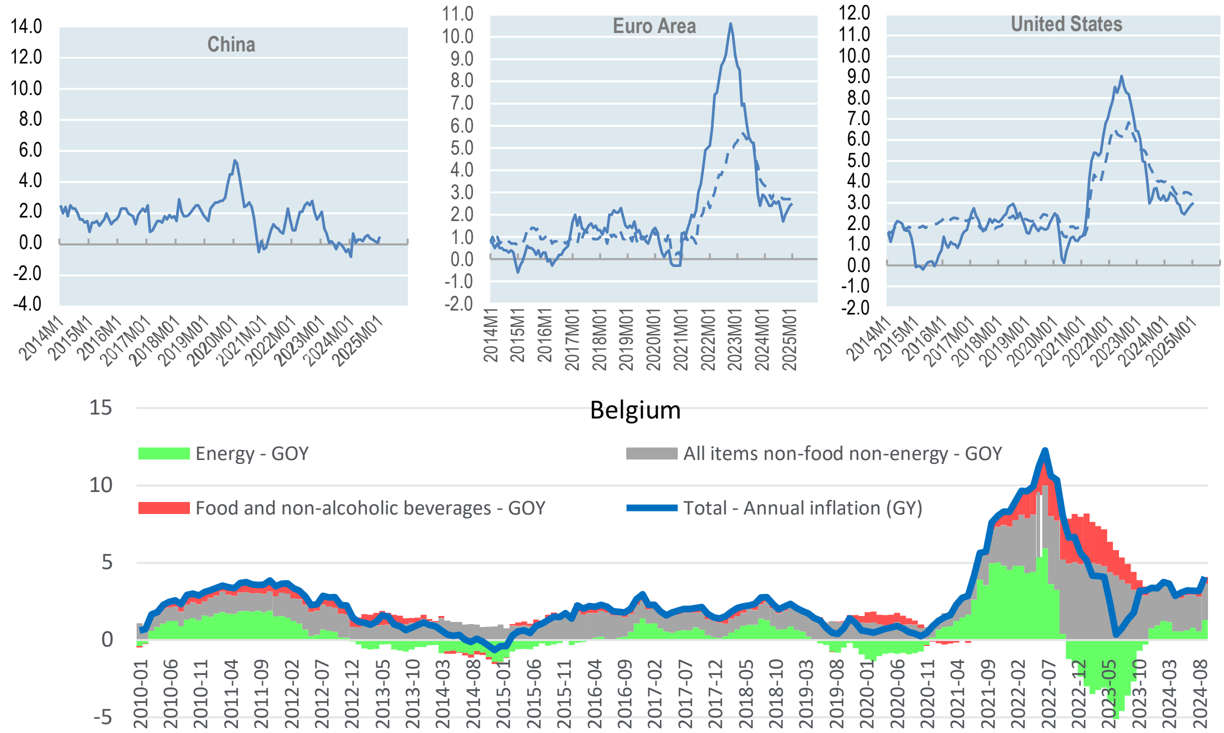


Figure 27: Comparison of the evolution of inflation in China, the EU, the United States and Belgium (All items and All items less food less energy, (CIP/HICP))

Inflation in the United States and the EU moved roughly in step. Inflation in China remained very low. Belgian inflation is in line with the European trend. A major driver of inflation between 2021 and 2023 was the rise in energy prices.

Labour

Labour costs in Belgium are clearly higher than the European average, but broadly in line with neighbouring countries. The gap with neighbouring countries has also narrowed in recent years[67]. The European average is lower than that of the United States. China has the lowest labour costs[68]. Productivity in the chemical industry is higher in Europe than in the United States[69].

As noted earlier, labour costs account for only a small share (around 10%) of production costs in the (petro)chemicals, steel and refining sectors. The impact of higher labour costs in these sectors is therefore limited.

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[66] Other factors relate to regulation, production costs and the resulting negative investment climate in industry due to lower demand and output in the EU.

[67] Via Eurostat: "Labour cost levels by NACE2 lc_lci_lev"

[68] Cefic, 2025, The Competitiveness of the European Chemical Industry

[69] https://media.rabobank.com/m/64a395bc07befd63/original/Euro-area-and-US-economic-competitiveness-A-comparative-analysis-of- unit-labor-costs.pdf

Figure 28: Comparative analysis of labour costs (Eurostat)

Regulation and environmental protection

In Europe, up to 10% of production costs for companies active in the (petro)chemicals sector can be related to (environmental) regulation. Compared with other regions, European policy is more regulation-driven than incentive-driven[70]. Industrial policy in Europe often appears complex and difficult to predict. This is also because industrial policy is a shared European competence, with initiatives from both the Member States and the European Commission, partly due to the subsidiarity principle – under which Europe sets rules mainly for the larger installations. In Flanders, environmental regulation is based on the BAT principle (Best Available Techniques) for all installations (both those regulated at European level and local ones), which the OECD has described as "best practice"[71].

A weakening of (environmental) regulation under the new US administration could further widen the cost gap with Europe[72]. The Carbon Border Adjustment Mechanism (CBAM) should partly address the level playing field issue on CO_2 costs (stemming from the EU ETS) for the sectors it covers (e.g. steel, fertilisers, hydrogen, etc.). CBAM, however, applies only to imports of these goods and does not make European products more competitive on the world market. There is also a risk of loopholes via imports of semi-finished and finished products or via "resource shuffling" – a shift of exports of lower-emission goods to Europe (and higher-emission goods to non-EU markets) without improving overall CO_2 intensity[73].

In Flanders (and the Netherlands) there is additional regulatory pressure regarding nitrogen and ammonia emissions and deposition. This creates significant uncertainty around the so-called "licence to operate". It can even negatively affect new investments that would emit far less CO_2. Other EU Member States are (for now) less affected by this issue. In Flanders, the problem stems in part from the fact that many nature areas have long been under sustained nitrogen pressure[74].

Corporation tax and state aid

The corporation tax rate in Belgium is 25%. This is above the European average (21.2%) and the average in the United States (21%), but the same as China (25%)[75].

Compared with neighbouring countries, Flanders currently lacks a large-scale transition instrument to support investments in climate-friendly industrial technologies. The European Commission has recently approved state aid

[70] Cefic, 2025, The Competitiveness of the European Chemical Industry
[71] Best Available Techniques (BAT) for Preventing and Controlling Industrial Pollution - Activity 1: Policies on BAT or similar concepts Across the World | OECD
[72] The announced trade tariffs will also have an impact, but this is hard to gauge because in some cases they will increase production costs in the US (e.g. more expensive imported materials).
[73] https://www.eurofer.eu/press-releases/clean-industrial-deal-right-diagnosis-but-more-radical-change-is-urgently-needed-to-turn-the- tide-says-eurofer
[74] What is the problem with nitrogen? | Vlaanderen.be
[75] https://tradingeconomics.com/belgium/corporate-tax-rate#

schemes of this kind in France (€4 billion), Germany (€5 billion) and the Netherlands (€750 million)[76]. Germany is likely to allocate a substantial additional amount as part of its newly approved national investment plan[77]. The above mechanisms are separate from any other project-specific support.

On the other hand, Flanders performs well in terms of the share of support obtained under the EU ETS Innovation Fund.

Logistics

The concentration of (petro)chemical, steel and refining activities in seaports confers a competitive advantage – especially over industries without such access. In the World Bank's 2023 Logistics Performance Index (LPI)[78], a benchmarking report on countries' logistics efficiency (especially in international trade and transport), Belgium ranks 7th – below Germany and the Netherlands, but above France and well above the United States and China.

Other competitiveness factors

For the other competitiveness factors, insights from the comparative analysis with other regions are summarised in Table 4; detailed discussion follows in subsequent sections.

Table 4: Summary comparison between Belgium, Europe, the United States and China on other competitiveness factors

Other competitiveness factors	Score		
	BE vs EU	EU vs US	EU vs CH
Innovation potential	++	--	--
Talent	=	-	--
Market demand	=	--	-
Permitting	++	=	=
Available infrastructure	++	Depends on location	Depends on location

[76] See: https://ec.europa.eu/commission/presscorner/detail/en/ip_24_2785, https://ec.europa.eu/commission/presscorner/detail/en/ip_25_846, https://ec.europa.eu/commission/presscorner/detail/en/ip_24_3962

[77] This investment package earmarks €100 billion for climate-related investments, including beyond the industrial sector.

[78] https://lpi.worldbank.org/sites/default/files/2023-04/LPI_2023_report.pdf

Innovation potential

Although public R&D expenditure in Europe as a share of GDP is comparable to – or even slightly higher than – that of the United States and China, total R&D expenditure lags significantly, mainly due to much lower business investment[79].

Flanders is far above the European average in both public and private R&D spending and is labelled an innovation leader in Europe[80]. Flemish R&D expenditure relative to GDP is among the highest in Europe, and private-sector R&D expenditure is the highest in Europe. Belgium also performs very well relative to the European average and, in terms of public R&D investment, trails only Germany. Chemicals and especially life sciences account for two thirds of industrial R&D investment in Belgium[81].

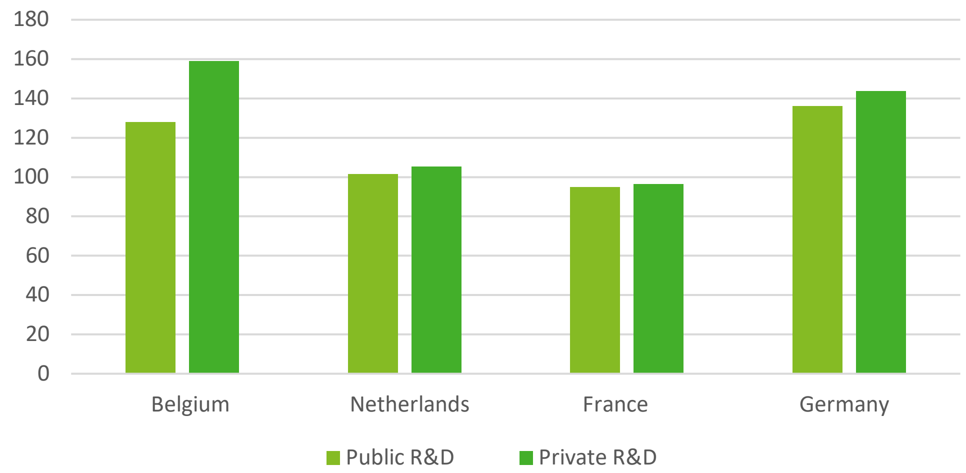

Figure 29: Relative scores vs the EU average for public and private R&D investment (EU Innovation Scoreboards 2024)[82]

Talent

Attracting skilled personnel into industry remains a challenge. The 2025 list of shortage occupations for Flanders shows, among other things, a shortage of maintenance mechanics and technicians for industrial installations – two indispensable profiles in industrial production[83].

As for future workers in industry, it is worrying that both PISA scores (mathematics and science) and interest in STEM programmes in Flanders are declining[84,85]. If these trends continue, they will harm the industry's competitiveness over time. Compared with neighbouring countries and the United States, current PISA scores are still at a similar level.

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79 Draghi M., 2025. "The future of European competitiveness – A competitiveness strategy for Europe"
80 https://ec.europa.eu/assets/rtd/ris/2023/ec_rtd_ris-regional-profiles-belgium.pdf
81 Amounting to €6.3 billion in 2023. https://www.essenscia.be/chemie-en-life-sciences/kerncijfers/
82 See: https://research-and-innovation.ec.europa.eu/statistics/performance-indicators/european-innovation-scoreboard_en
83 https://www.besox.be/vlaamse-knelpuntberoepen/
84 https://www.vrt.be/vrtnws/nl/2023/12/05/onderwijs-pisa-resultaten-wiskunde-lezen-wetenschappen/
85 https://www.tijd.be/politiek-economie/belgie/vlaanderen/populariteit-stem-richtingen-neemt-af-bedrijven-kijken-naar-het-buitenland-ze- vinden-bij-ons-het-talent-niet-meer/10459751.html

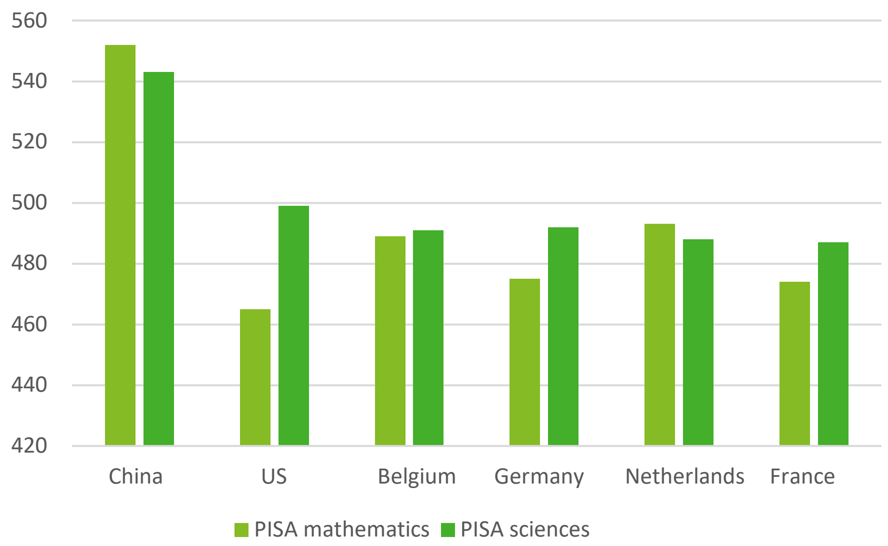

Figure 30: PISA 2022 scores for mathematics and science[86]

Market demand

Beyond higher energy costs in Europe, the drop in market demand from key sectors such as construction and automotive is one of the main reasons for declining production in Europe's chemicals and steel sectors[87]. China has also seen a notable stagnation in domestic demand; however, this is being offset by stimulating production for export[88]. The United States has experienced strong economic growth in recent years, including in industrial sectors. Explanations include greater immunity to high energy prices (due to domestic oil and gas production) and a large stimulus programme (Inflation Reduction Act). For Belgium relative to Europe, we see – as stated above – that the reduction in production (chemicals and steel) is neither better nor worse than the broader European trend.

Stimulating downstream demand, along with improving cost-reducing factors and using (European) defence instruments against unfair trade, will be the key tools to restore the health of Europe's basic industry. In that context, the recently announced German investment programme (€500 billion) will very likely have a significant spillover effect on the rest of European industry, particularly in neighbouring countries.

Further greening of products can be an additional driver to invest in low-CO_2 production processes. For example, as part of its Clean Industrial Deal, the European Commission announced greener public procurement along with the introduction of (voluntary) labels for climate-friendly products (e.g. green steel).

Permitting

BusinessEurope conducted a survey of about 240 companies from March to December 2023[89]. The permitting period in Europe averages between one and six years, involving multiple competent authorities. Around 53% of companies consider this a "serious problem" when making an investment decision, and 83% see it as an obstacle. The study highlights issues in obtaining permits such as response times, understaffing in the authorities involved, complexity between national and European legislation, lack of coordination among different authorities and the fact that multiple authorities are involved. According to the survey, obtaining a permit takes about 4.5 years in the United States and on average between two and five years in China[90].

[86] https://worldpopulationreview.com/country-rankings/pisa-scores-by-country#title
[87] https://www.icis.com/chemicals-and-the-economy/2025/01/europes-chemical-industry-and-its-economy-face-an-existential-challenge/
[88] https://carnegieendowment.org/posts/2024/07/why-is-it-so-hard-for-china-to-boost-domestic-demand?lang=en
[89] https://www.businesseurope.eu/wp-content/uploads/2025/02/2024-02-13_businesseurope_permitting_swot_analysis_-_final_report-ca3-_1.pdf
[90] Cefic, 2025, The Competitiveness of the European Chemical Industry

In Flanders, the period for obtaining an environmental permit is a maximum of 135–150 days, extendable by 60 days[91]. As mentioned earlier, insufficiently aligned EU regulations make this process in Flanders more complex – e.g. the nitrogen issue in the Habitats Directive combined with rules for water, air, soil, waste, energy and climate. Taken together, these elements can create uncertainty regarding the licence to operate. In addition, appeals during or after the permitting process can have a major impact on the eventual time required to obtain a permit. On the other hand, authorities in Belgium make significant efforts to provide legal certainty for large investment projects within the permitting framework.

Available infrastructure

Thanks to its location and the presence of seaports, Flanders is a hub of infrastructure for industrial supplies (electricity, gas, oil, etc.). Flanders also already has one of the largest hydrogen networks in the world. There is therefore great potential to develop additional infrastructure for CO_2, hydrogen (e.g. pipelines) and electricity interconnections.

Closures in the (petro)chemicals, steel and refining sectors

In recent years, Europe has seen major closures due to the energy and demand crisis, particularly in the (petro)chemicals sector. While Flanders has indeed seen major company closures (e.g. Ontex, Van Hool, etc.), the (petro)chemicals sector has fared better than neighbouring countries, although there have also been some closures, restructurings and redundancies[92]. The same applies to steel production[93] and refining. Naturally, all these sectors have been running at a lower throttle, with under-utilisation of capacity.

There is no single definitive explanation for the absence – so far – of large-scale closures in Flanders. Contributing factors include the strategic location in seaports and the interlinkage of refining and chemical value chains, which provides implicit robustness. Stand-alone installations are more vulnerable.

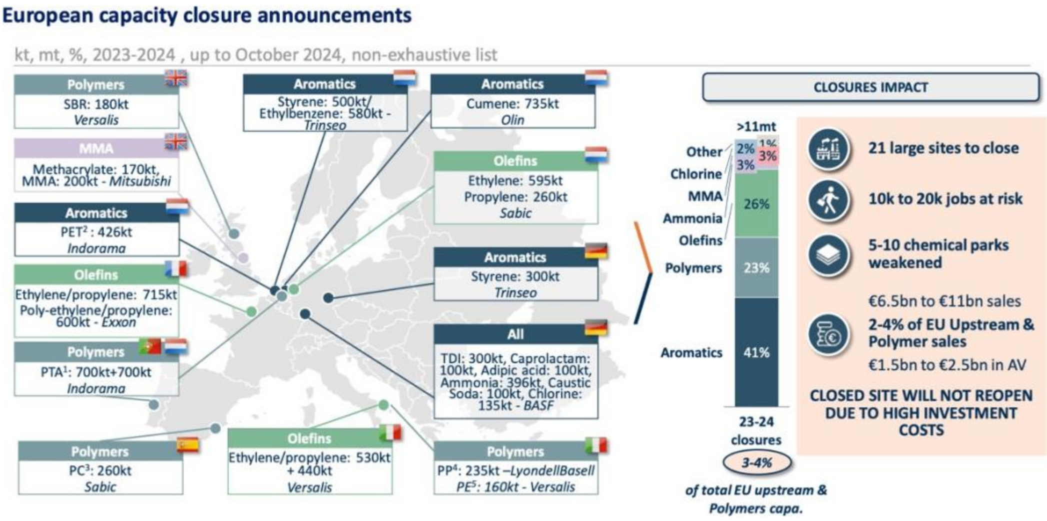

Figure 31: Announced closures in European chemicals (Cefic[94])

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[91] https://www.vlaio.be/nl/begeleiding-advies/bedrijfslocatie/bouwen-en-uitbreiden/de-omgevingsvergunning#:~:text=105%20dagen%2C%20tenzij%20er%20advies,een%20omgevingsvergunnings%2Dcommissie%20vereist%20is

[92] In April 2025, TotalEnergies Antwerp announced the closure of an (older) naphtha steam cracker due to the loss of a long-term ethylene offtake contract. There were also closures at Arlanxeo, Celanese, etc.

[93] In April 2025, ArcelorMittal announced the redundancy of several hundred administrative staff.

[94] Cefic, 2025, The Competitiveness of the European Chemical Industry

3.3.3. Conclusions

In general (with some exceptions), it can be stated that the competitive position of Flanders and Belgium relative to the rest of Europe is not negative. Flanders and Belgium, like other EU Member States, are exposed to negative competitive factors relative to the United States and China.

Belgium, like the rest of Europe, is experiencing a decline in production volumes compared with the United States and especially China. Nevertheless, Belgium has so far managed to hold its own relative to other European countries and neighbours, mainly by avoiding closures of production capacity. The reduction in production volumes also helps explain the recent decline in industrial emissions in Flanders. Emissions from Belgium's industrial energy mix are significantly lower than the EU average, as well as lower than those of the United States and China. Set against this, European and Belgian industry do face higher costs relating to regulation, including CO_2 pricing.

Electricity prices for large consumers in Belgium are more than double those in the United States and China. Large consumers in Belgium also pay significantly more for natural gas than in the United States (×4). Compared with neighbouring countries (with the exception of France), electricity and gas prices are at similar levels.

Labour costs in Belgian industry are comparable with those in neighbouring countries and account for only about 10% of the total production price in the energy-intensive sectors. Energy and raw material costs are by far the largest expenditure items for sectors such as steel, chemicals and refining. Belgium's corporation tax is also slightly higher than the European average and that of the United States, but equal to China's.

Flanders lags behind in terms of state aid for climate-friendly investments, which creates a competitive disadvantage relative to neighbouring countries that have developed large transition instruments[95]. On the other hand, Flanders has successfully obtained substantial funds from the EU ETS Innovation Fund. The increased capital cost for investments due to inflation is a significant barrier to implementing planned investments. Here, Europe has a (limited) disadvantage vs the United States and a larger disadvantage vs China. Belgium broadly follows the European trend.

On innovation, Flanders scores well within Europe, with strong public and private investment in research and development, with the chemicals and especially life sciences sectors contributing the largest share. There are concerns about shortage occupations in industry and declining PISA scores and interest in STEM studies, which could affect Flanders' future competitive position[96].

The (official) permitting period in Flanders (for environmental permits) is among the better ones in Europe and compares favourably with average timelines in the United States and China. There is concern about the licence to operate due to insufficiently aligned EU regulations which, together with the nitrogen issue affecting both Flanders and the Netherlands, can even be problematic for investments that have a positive impact on greenhouse gas reductions.

Finally, thanks to its location, seaports and existing (petro)chemicals clusters, Flanders has strong assets in (energy and feedstock) infrastructure, including for future investments such as CO_2 capture, hydrogen and electrification. The World Bank's LPI benchmark shows that Belgium performs well compared with the United States and China.

[95] Support for climate-friendly projects in industry can help to realise investments that may face, for example, high OPEX and/or lower than expected CO_2 prices.

[96] Flanders is following the European trend here, albeit in a somewhat more pronounced way.

3.4. Status of technological options and evaluation of the 2020 roadmap technology choices

3.4.1. Introduction

The technology analysis in this report seeks to answer two research questions:

- Are the technological options discussed in the 2020 context analysis still complete and up to date (focusing on the (petro)chemicals, steel and refining sectors)?
- Is the 2020 roadmap study – which assigns weights to technology options towards 2050 – still aligned with the latest technological insights and the evolution of investment activity?

The first analysis checks whether the technological options considered in 2020 remain relevant and whether additional options have emerged. To do this, it draws on other technology and R&D databases (Moonshot programme, ETS Innovation Fund and IEA)[97] and scientific literature. This analysis enables refinement of research focus and support where needed.

The second assessment reviews the weights assigned to technology options in the roadmap scenarios (in particular the MIX scenario). In other words: are the pathways proposed in 2020 still current, or must they be adjusted in terms of timing and technology choice? This uses analyses in more recent roadmaps with a similar scope (geographically and/or by sector), interviews with stakeholders (technology implementation) and literature analysis to better explain the context (e.g. competitiveness, changes in costs and other barriers to implementation).

On that basis, the associated infrastructure needs for the adjusted technology pathways are also evaluated. This analysis makes an important contribution to the qualitative update of the roadmap pathways set out in 2020, which follows in Chapter 4.

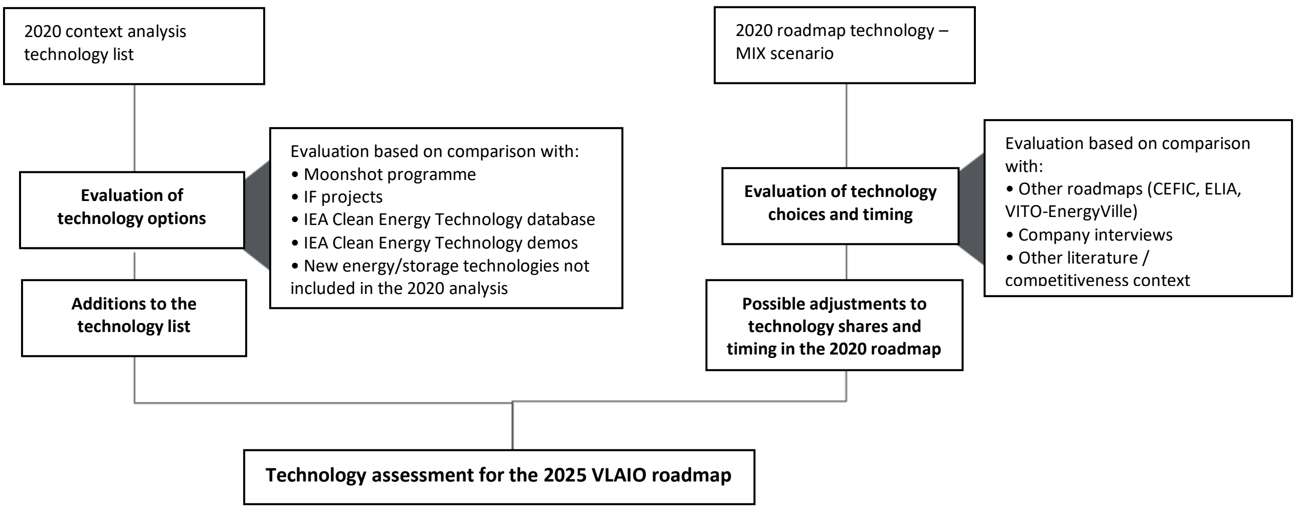

Figure 32: Method for technological evaluation

3.4.2. Evaluation of the 2020 context analysis technology list

Approach in the 2020 context analysis

In the 2020 context analysis and roadmap study, a broad list of technologies was examined that could help industry become climate-neutral. This list was compiled on the basis of an extensive literature review supplemented with information from interviews with companies in Flanders' energy-intensive sectors.

[97] The development of technological options goes beyond the databases studied here, so the analysis should not be seen as exhaustive, but rather as a thorough and targeted exploration.

An initial broad list of technologies was further filtered using the following criteria:

- The technology must be available at TRL 9 by 2040 at the latest
- The technology must (in theory) have an application in the Flemish basic industry
- Boundary conditions such as impact on electricity, hydrogen and biomass demand

The technologies were then classified and grouped under five transition pathways: electrification, CCUS, hydrogen, biomass and circularity. In total, the 2020 context analysis considered around 100 technologies for chemicals, steel, refining and industrial heat production. A subset of these was retained and used in the scenarios for the 2020 roadmap study.

Comparison with recent databases

To verify whether this list of technologies is still up to date, it was compared with[98]:

- The IEA Clean Energy Technology Guide (database) with an industry focus
- A global IEA database of pilot and demonstration projects in industry
- Approved (industrial) projects under the EU ETS Innovation Fund
- Approved projects under the Flemish Moonshot programme

All technologies included in the 2020 context analysis were checked against the options appearing in the four databases above, focusing on the chemicals, steel and refining sectors (see Table 5). On the left are the technologies appearing in the context analysis and the other databases. The green cells indicate whether the technology is mentioned in the 2020 context analysis (first green column), the 2020 roadmap (second column), the IEA Clean Energy Technology Guide (third), the IEA Clean Energy Demonstrations database (fourth), the EU ETS Innovation Fund (fifth), projects in Flanders (sixth) and Moonshot projects (seventh).

This overview shows that the technological options cited in the 2020 context analysis proved very complete, as the left-hand column is almost entirely green. Light-green cells indicate the technology was mentioned but not discussed in detail.

The IEA Clean Energy Technology Guide is a comprehensive interactive database of almost 600 clean energy technologies that contribute to reaching net zero emissions. Specifically, we looked at technologies for the (petro)chemicals sector (30 options), steelmaking (23 options), refining (3 options) and general industrial heat supply (25 options). In the (petro)chemicals sector these include, among others, ammonia production via biomass or electrolytic hydrogen, chemical recycling of polymers and methanol production with carbon capture. For the steel sector, technologies include hydrogen- or biomass-based direct reduction, partial coal substitution in blast furnaces and various CCUS applications. For industrial heat, the emphasis is on biomass, electrification (e.g. large heat pumps, induction and plasma furnaces) and combustion of ammonia and hydrogen.

We also used the IEA Clean Energy Demonstrations Database, which inventories major demonstration projects worldwide. Approximately 200 projects were identified within the chemicals, steel and refining sectors. Most are in the feasibility or construction phase; operational projects are a minority. There is a strong focus on electrolytic hydrogen production: globally more than 2,000 projects are known (around 630 operational and 930 under construction or planned), with total expected electrolysis capacity of about 23 GW by 2030. In addition, 114 projects were identified for hydrogen production with CCS, of which 22 are currently operational or in demonstration, with an expected output of roughly 4 Mt of hydrogen per year by 2030. CCUS technologies (30+ projects) and innovative recycling techniques (around 10 projects) also feature prominently.

For the EU ETS Innovation Fund – targeting large-scale low-carbon projects in Europe – about 90 industrial projects were selected from over 200 approved initiatives, with strong representation of CCUS (29 projects), electrolytic hydrogen production and applications (35 projects), circularity and chemical recycling (12 projects), biomass use (15 projects) and process electrification (6 projects). Belgium has been relatively successful within this fund, with 13 approved projects (8 in Flanders), amounting to nearly €1.3 billion in financing.

[98] The development of technological options goes beyond the databases studied here, so the analysis should not be seen as exhaustive, but rather as a thorough and targeted exploration.

In addition, Flanders supports roughly 60 research projects through the Moonshot innovation programme, mainly focused on CCUS technologies (20 projects), chemical recycling (16 projects), biomass applications (9 projects) and electrification (4 projects)[99]. Although these Flemish research projects are largely still in early development phases, later-stage innovation projects have significant potential for industrial application if successfully scaled to commercial level. Further valorisation of research results proceeds via other support instruments (e.g. through VLAIO, federal and European schemes)[100].

A detailed discussion of the various databases is provided in Annex 1: Analysis of different technology and project databases.

[99] These are linked to the Moonshot research pathways: bio-based chemistry (path 1), circularity of carbon in materials (path 2), electrification and radical process transformation (path 3) and energy innovation (path 4). https://www.moonshotflanders.be/en/moonshot-research- paths

[100] The Flemish government (VLAIO) supports innovation projects of the Catalisti chemistry cluster and R&D projects by companies that fall within the scope of Klimaatsprong. In addition, VLAIO supports investment projects, including through STRES and GREEN support. Flanders has allocated a significant share of RRF funds to projects in hydrogen technology. Further support is also possible for (large) investments in industrial decarbonisation in Flanders.

Table 5: Overview of technologies in the 2020 context analysis and roadmap study, IEA databases, ETS Innovation Fund, Moonshot projects and announced projects in Flanders

Sector	Output	Type	Technology Name	Roadmap 2020 - omgevingsanalyse ((x) = not discussed in detail)	Technology applied in Roadmap 2020 scenarios	IEA clean tech database ((x)= assumed to be covered)	Global pilot-demo projects database (IEA)	ETS Innovation Fund pilot-demo projects ((x) = assumed to be covered)	Pilot-Demo Projects in Flanders ((x) = announced, no FID)	MOT projects ((x)=related project/technology)
Chemicals	Ammonia	Biobased	Ammonia via biomass gasification	x		x				
Chemicals	Ethanol -> HVC	Biobased	Bio-ethanol production from sugar and starch rich biom	x	x	(x)	x			
Chemicals	Ethanol -> HVC	Biobased	Bio-ethanol production from lignocellulosic biomass	x	x	(x)	x			
Chemicals	H2	Biobased	Photolytic biomass for hydrogen production	x						
Chemicals	HVC	Biobased	Bio-Ethanol to ethylene	x		x				
Chemicals	HVC	Biobased	Lignin to aromatics via thermochemical routes	x	x	x	x	(x)	x	
Chemicals	HVC	Biobased	Lignin to aromatics via catalytic depolymerisation	x		x			x	
Chemicals	HVC	Biobased	Aromatics from cellulosic derived C5 sugars via the Diel	x						
Chemicals	HVC	Biobased	Lignocellulosic (poly) lactic acid production (PLA as PE	x	x					
Chemicals	HVC	Biobased	Fermentation of biomass derived sugars to C4, ...						x	x
Chemicals	HVC	Biobased	Concept lignocellulosic bio-refinery to HVCs (Lignine+c	x	x		x	(x)		x
Chemicals	Methanol -> HVC	Biobased	Bio-methanol production from biomass	x	x	x	x	x		
Chemicals	Naphtha -> HVC	Biobased	Bio-naphtha production from lignocellulosic biomass	x		x	x	x		
Chemicals	Syngas	Biobased	Biomass gasification	x		x				
Chemicals	Syngas	Biobased	Reforming of biomass with supercritical water	x						
Chemicals	Various (solid, fu	Biobased	Biomass pyrolysis	x		x				
Chemicals	H2	CC	Membrane reformer of methane	x						
Chemicals	H2 or electricity	CC	Gas Switching Reformer (GSR)	x						
Chemicals	HVC	CC	Naphtha Steam Cracking + carbon capture	x	x	(x)				
Chemicals	HVC	CC	Ethane Cracking + carbon capture	x	x	(x)				
Chemicals	Methanol -> HVC	CC	Methanol synthesis + carbon capture	x	x	x				
Chemicals	Syngas	CC	Sorption enhanced water gas shift (SMR/ATR)	x						
Chemicals	Syngas	CC	Steam Methane Reforming (SMR) with carbon capture	x	x	(x)				
Chemicals	Syngas	CC	Autothermal Reforming of methane (ATR) with carbon c	x	x	(x)	x	x	(x)	
Chemicals	Syngas	CC	Gas Switching Reforming (GSR) and combined cycle (C	x						
Chemicals	Syngas	CC	Sorption enhanced water gas shift (SMR/ATR)	x						
Chemicals	Syngas	CC	Gas Switching Reformer (GSR)	x						
Chemicals	CO -> HVC	CCU	CO2 to CO conversion (catalytic/dry reforming)							x
Chemicals	Ethanol -> HVC	CCU	Via fermentation of Blast Furnace gas steel production	x	x	x	x			
Chemicals	HVC	CCU	Methanol to olefins (MTO)	x	x	x	x		(x)	
Chemicals	HVC	CCU	Methanol to aromatics (MTA)	x	x	x	x			
Chemicals	HVC	CCU	Ethylene via CO2 and H2	x						
Chemicals	HVC	CCU	CCU-Ethanol to ethylene	x	x	x				x
Chemicals	Methanol -> HVC	CCU	Methanol via CO2 and H2	x	x	x	x	x	(x)	
Chemicals	Syngas	CCU	Dry reforming of methane to olefins	x	x					x
Chemicals	Syngas	CCU	Dry reforming of methane (CH4+CO2)	x						x
Chemicals	HVC	Circular	Chemolysis/Solvolysis plastic waste (PET/PS/PU)	x	x	x	x	x	x	x
Chemicals	MMA monomer	Circular	Chemical recycling (PMMA to MMA monomer) via molten metals				x	x		
Chemicals	Naphtha -> HVC	Circular	Pyrolysis plastic waste	x	x	x	x	x	x	x
Chemicals	Naphtha -> HVC	Circular	Catalytic Cracking (CC) plastic waste	x	x					x
Chemicals	Naphtha -> HVC	Circular	Hydrocracking plastic waste	x		x				x
Chemicals	Syngas -> HVC	Circular	Gasification plastic waste	x	x					
Chemicals	H2 (+carbon)	Electrification	Methane pyrolysis	x	x	x				
Chemicals	HVC	Electrification	Electrification of naphtha steam cracking (direct+ indir	x	x	x	x			
Chemicals	HVC	Electrification	Electrification of naphtha steam cracking - rotor/shockw	x	x	x				x
Chemicals	HVC	Electrification	Electrification of ethane steam cracking (direct + indire	x	x					
Chemicals	HVC	Electrification	Electrification of ethane steam cracking - rotor/shockw	x						(x)
Chemicals	HVC	Electrification	Plasma assisted methane to ethylene (non-oxidative co	x						
Chemicals	HVC	Electrification	Electrification of non-oxidative coupling of methane to H2 en C2)							x
Chemicals	Ammonia	Electrochem	Ammonia via aqueous electrolyte	x						
Chemicals	Ammonia	Electrochem	Ammonia via molten salt or molten oxide electrolyte	x						
Chemicals	H2	Electrochem	Alkaline electrolysis	x	x	x	x	x	x	
Chemicals	H2	Electrochem	Proton Exchange Membrane (PEM) electrolyser	x	x	x	x	x		x
Chemicals	H2	Electrochem	Solid Oxide Electrolyser (SOE)	x	x	x				
Chemicals	H2	Electrochem	Photo-electro(cata)lytic (PEC) hydrogen production	x		x	x	x		x
Chemicals	HVC	Electrochem	Electrochemical conversion of ethane to ethylene	x						
Chemicals	HVC	Electrochem	Ethane to ethylene fuel cell (PC-EFC)	x						
Chemicals	HVC	Electrochem	Methane to ethane to ethylene fuel cell	x						
Chemicals	Syngas	Electrochem	Solid Oxide electrolyser cell (SOEc) using CO2 and H2O	x		x				x
Chemicals	HVC	CCU - electrochem	Other electrochem HVC production	(x)						x
Chemicals	HVC	CCU - electrochem	Electrochemical acrcylic acid with CO2							x
Chemicals	H2	CC - electrochem	Methane based Solid Oxide Fuel Cell with carbon captu	x						
Chemicals	HVC	Process Intensificati	Catalytic cracking of light olefins	x		x				
Chemicals	HVC	Process Intensificati	Ethane oxidative dehydrogenation (ODH)	x	x					
Chemicals	HVC	Process Intensificati	Chemical looping (CL) ODH process	x						(x)
Chemicals	HVC	Process Intensificati	Oxidative coupling of methane (OCM)	x	x					x
Chemicals	HVC	Process Intensificati	Propane oxydehydrogenation (ODH)	x						
Chemicals	HVC	Process Intensificati	Propane oxydehydrogenation with CO2 (ODH + CO2/C(	x						
Chemicals	Ammonia	Use of blue H2 (CC vi	Blue Ammonia (various CO2 capture)	x	x	x	x	x	x	
Chemicals	Ammonia	Use of electrolytic H:	Green Ammonia (via eletrolytic H2)	x	x	x	x	x		
Chemicals	H2	Storage - H2	(green) Ammonia cracking to H2						(x)	
Chemicals	Polymers	Circular	Advanced sorting/treatment post consumer waste	(x)		x	x	x	x	x
General	Heat	Biobased	Biobased methane as fuel	(x)	x	x	x	x		
General	Methane	Biobased	Biomethane from organic matter via fermentation	x		x	x	x		
General	Methane	Biobased - electroch	Biomass gasification with syngas reforming	x		x	x	x		
General	CO2	CC	Post-combustion carbon capture (absorption/adsorptic	x	x	x	x	x		
General	CO2	CC	Pre-combustion carbon capture (MEA)	x	x	x	x	x		
General	CO2	CC	Oxyfuel combustion catbon capture	x		x	x	x		
General	CO2	CC	Direct air capture (DAC)	(x)		x				
General	CO2	CC	Enzymatic carbon capture				x	x		
General	CO2	CC	Advanced post combustion CO2 separation (membrane	(x)		x				x
General	CO2	CC	Cryogenic Separation of CO2	(x)		x	x	x	(x)	
General	Electricity, CO2	CC	Power production via Allam-cycle CCS	(x)		x	x	x		
General	CO2	CCS Liquefaction	CO2 liquefaction infrastructure	(x)		(x)	x	x	x	
General	CO2	CCS Storage	CO2 transport storage infrastructure	(x)		(x)	x	x		
General	Methane	CCU	E-methane production via the Sabatier reaction (CO2 +	x	x		x	x		
General	Synfuel (RFNBO	CCU	Other than ethanol and methanol	(x)	x	x	x	x	x	
General	Heat	Electrification	Electrification of boilers	(x)	x	x			x	x
General	Heat	Electrification	Chemical heat pump (Q-pinch)	x					x	
General	Heat	Electrification	Large Scale Heat pump	(x)		x				
General	Heat	Electrification	Microwave heating	(x)		x				
General	Heat	Electrification	Infrared heating	(x)		x				
General	Heat	Electrification	Induction heating	(x)		x				x
General	Heat	Electrification	plasma heating	(x)		x				x
General	Heat	Electrification	Radio-frequency heating	(x)		x				
General	Energy storage	Storage - Electrocher	Molten salt batteries	(x)		x				
General	Heat	ammonia as fuel (gre	Ammonia as fuel			x	x	x		
General	Energy storage	Storage - energy	Thermally regenerative batteries (TRBs)	(x)		x				
General	Energy storage	Storage-Electrificati	(Cryogenic Liquid) air energy storage (LAES)	(x)		x	x			
General	Energy storage	Storage-Electrificati	Power to heat storage in high thermal capacity materials				x	x		
General	Energy storage	Storage-Electrochem	Flow-batteries	(x)		x	x	x		
General	Energy storage	System integration	Flexible demand and batteries			x	x	x		
General	Heat	System integration	waste heat recovery and upgrading (partially covered w	(x)		x				x
General	Heat	System integration	(e-boiler) Steam network in industrial cluster			x				
General	Biofuel 2nd gen (	Biobased	Fuels other than bio-naphtha (e.g. kerosine)	(x)	x	x	x	x	x	
General	CO2	CCS (Storage)	CO2 storage via mineralisation				x	x		
Steel	Steel	Alternative feedstock	Direct Reduced Iron (DRI) with Electric Arc Furnace (EAF) using ammonia			x				
Steel	Steel	Alternative feedstock	Use of bio-coal (Torrero project)	x	x					
Steel	Steel	CC	BF-BOF steel production + CC	x	x	(x)	x	x		
Steel	Steel	CC	Direct Reduced Iron (DRI) with Electric Arc Furnace (E/	x		x	x	x		
Steel	Ethanol -> HVC	CCU	Utilisation of steel waste gas (CO2/CO) to chemicals (e	x	x	x	x	x	(x)	
Steel	Steel	CCU	Carbon recycling through thermochemical coupling (IEA)			x				
Steel	Steel	Circular	Advanced sorting/treatment post consumer waste	(x)		x				
Steel	Steel	Alternative feedstock	Use of plastic waste and CO2 (IGAR project) via plasma	x	x				x	
Steel	Steel	Electrochem	Iron Ore Electrolysis (low T)	(x)		x			(x)	
Steel	Steel	Electrochem	Iron Ore Electrolysis (High T) - Molten Oxide Electrolysis	(x)		x				
Steel	Steel	Electrochem	Reduction via alkali metal looping (IEA)			x				
Steel	Steel	Alternative feedstock	Hydrogen injection in Blast Furnace (replacing coal)	x	x	x	x		(x)	
Steel	Steel	Alternative feedstock	Direct Reduced Iron (DRI) with Electric Arc Furnace (E/	x		x	x	x	x	
Steel	Steel	Process intensificati	Fast smelting with CC (Hisarna type)	(x)		x			x	

Evaluation of technology options by value chain

Based on the comparison with the various databases and insights from interviews (see Annex 4: Overview of stakeholders consulted in the interviews), an evaluation by value chain at the level of technology options follows below.

Chemicals

The 2020 context analysis remains a current and comprehensive assessment for the chemicals sector, with a focus on high value chemicals (HVC). The IEA Clean Energy Technology Guide contains far fewer technology options for the (petro)chemicals sector than the 2020 context analysis. In terms of industrial pilots and demonstrations (in Europe and globally), there is major attention for ammonia and methanol production (green via hydrogen electrolysis, blue via CCS and turquoise via methane pyrolysis) as well as chemical recycling. Electrification and biomass as feedstock feature somewhat less.

Process electrification

The 2020 context analysis identified electric cracking of naphtha or LPG as an important option once the technology reaches TRL 9 around 2035. Since 2020, there has been major further development, with pilot and demo units in the Netherlands[101] and Germany[102], and the expectation remains that large-scale deployment will be possible around 2035. Similar process electrification options for broader applications are part of several Moonshot projects[103].

Most other new electrochemical processes (such as co-electrolysis of hydrogen and CO_2 and the electrification of non-oxidative methane coupling)[104] are under further study but remain at lower TRL levels, with large-scale deployment expected only after 2040.

Circular

In the 2020 context analysis, circular polymers represented an important share of new feedstock in a future climate-neutral chemicals sector. The main technologies cited were solvolysis, pyrolysis and gasification of plastics to the basic building blocks of the (petro)chemicals sector (e.g. monomers, naphtha, CO, hydrogen, etc.). In the 2020 roadmap study, mechanical recycling was also indirectly included because it extends product lifetimes and is a key route to recycle plastics. This study places the emphasis on chemical recycling and its technologies.

Based on comparison with projects under development and interviews with companies and experts, pyrolysis[105] of plastic waste is the technology most commonly applied – or expected to be – for plastics where solvolysis[106] cannot be used. Gasification will most likely remain an option for plastic residual streams that, due to contamination, cannot be used for pyrolysis. In the 2020 context analysis, the potential to use pyrolysis oil or naphtha (from plastic pyrolysis processes) in conventional naphtha steam crackers was seen as limited (e.g. 10% of feedstock). In theory, this figure can be revised upwards and depends entirely on the purity and quality of the plastic waste used. Developing a logistics chain that can cost-effectively supply large volumes of selected plastic waste of the right quality for pyrolysis (yielding a consistently high-quality end product suitable for steam cracking) remains a major bottleneck to large-scale application.

Moonshot projects on chemical recycling of plastics[107] focus mainly on specific challenges – for example specific polymers (e.g. containing nitrogen), thermosets, mixed waste streams – as well as on more advanced separation processes in post-consumer waste.

CCUS

The 2020 context analysis devoted substantial attention to the capture, use and storage of CO_2. Methanol (via CO_2 and hydrogen) and, to a lesser extent, ethanol were identified as potential new platform molecules for building other high

[101] https://coolbrook.com/news/coolbrook-starts-work-on-worlds-first-sustainable-naphtha-cracker/
[102] https://www.basf.com/global/en/media/news-releases/2024/04/p-24-177
[103] For example, the P2O (power-to-olefins) Moonshot project.
[104] For example, the ELCO2SYN and CAMELEON Moonshot projects.
[105] The high-temperature heating of plastic waste that converts it into an oil-like product which can be used as feedstock in a naphtha steam cracker.
[106] Returning polymers to monomers or base constituents by means of a solvent (solvolysis).
[107] For example, the CHRONICLE Moonshot project, which focuses on chemical recycling of plastics containing nitrogen.

value chemicals and polymers. The development of many international demonstration projects in this direction confirms this choice. For example, the EU ETS Innovation Fund lists 29 projects in the CCUS value chain, including eight focused on methanol production; the IEA global demo database identified 40 such projects.

It seems unlikely that CCU-based (green) methanol will be produced on a large scale in Flanders due to the high electricity demand associated with the required hydrogen production[108]. Methanol production based on natural gas with carbon capture or from biomass would be possible. Methanol is one of the hydrogen-carrying molecules that can be transported relatively cheaply over long distances. For CCU-based ethanol, Flanders saw major progress with the commissioning of the Steelanol demonstration unit at ArcelorMittal Ghent.

Moonshot projects focus on electrochemical processes and other new processes that use CO_2 (often with hydrogen) to make new molecules important to chemistry. Beyond the classic base molecules such as ethylene, Moonshot projects also explore the synthesis of other molecules with more specific applications[109].

Cost-effective separation of CO_2 from process streams and (more difficult) flue gas emissions remains a key concern. At the level of fundamental research, not only are newer processes being investigated, but also their integration with electrification. An important new technology that is very likely to be applied on a large scale in Flanders in the near future is cryogenic CO_2 separation. Its advantage is achieving the high purities needed for CO_2 transport and storage. In most cases, the technology is used alongside existing separation processes (such as pressure swing adsorption or amine-based absorption), sometimes improving process plant efficiency (e.g. higher hydrogen yield in steam methane reforming (SMR)). This technology will likely play a crucial role for process emissions with high and mid-high (+15%) CO_2 concentrations – think of applications such as SMR (with hydrogen production for ammonia), ethylene oxide, steel, cement and certain refining processes. These cover most of the processes identified for CCUS in the 2020 context analysis.

By contrast, (cost-effective) capture and separation from combustion processes with low CO_2 concentrations remains the main challenge. Given the high additional energy demand, there is also interest here in the useful deployment of low-temperature waste heat.

With Kairos@C, H2BE and related CO_2 infrastructure projects, once final investment decisions are taken, Flanders can take a crucial step in CCUS development with the possibility of becoming a northwest European hub.

Bio-based applications

The 2020 context analysis focused primarily on bio-based applications of woody biomass towards high value chemicals and plastics. In practice, we see this confirmed by projects using lignin and lignocellulose to produce high value chemicals for the (petro)chemicals sector.

Moonshot projects continue to build on lignin- and lignocellulose-based products[110].

In addition, the importance of deploying biomass or waste residues as a high-temperature heat source continues to grow (e.g. Ecluse III[111]).

Hydrogen and ammonia

The 2020 context analysis identified three main routes for hydrogen production: electrochemical (e.g. via alkaline, PEM or solid oxide electrolysis), via steam methane reforming (SMR) or autothermal reforming (ATR) with carbon capture and via methane pyrolysis. Alkaline- and PEM-based hydrogen are already at TRL 9; solid-oxide is slightly lower on the TRL scale but progressing. Blue hydrogen production (using amines for CO_2 separation) is also already at TRL 9.

Methane pyrolysis has advanced internationally and is now close to TRL 8–9. Deployment of this technology is therefore possible in Flanders under the right economic conditions, in particular where the solid carbon produced can be valorised. Large-scale application is still expected to be feasible after 2030.

[108] See, for example, https://www.nature.com/articles/s41560-025-01752-6/
[109] For example, acrylic acid production using CO_2 (the ECAP project) or electrochemical production of methanol with CO_2 (the EDL2CO₂ project).
[110] For example, the AC2GEN project.
[111] Ecluse: News

Steel

The 2020 context analysis highlighted a broad spectrum of technologies for reducing emissions in steelmaking: from using hydrogen in existing blast furnaces, through its application in direct reduction of iron ore (DRI), to the reuse of CO and CO_2 to produce ethanol and other hydrocarbons, the use of biomass and other wastes in the blast furnace and large-scale CO_2 capture. Electrochemical routes such as molten oxide electrolysis of iron ore were excluded at the time because they were at an early stage and there were no plans to develop them further in Flanders. The 2020 roadmap itself did not include hydrogen DRI.

Since 2020, major steps have been taken towards climate-neutral steel. Hydrogen DRI is now close to TRL 9, with (planned) large-scale demonstrations in Sweden and possible investment decisions elsewhere in Europe and worldwide. International demonstrations in steel focus on replacing coal with other feedstocks such as hydrogen and biomass, and on using CO and CO_2 from the blast furnace to produce hydrocarbons[112].

For newer, lower-TRL technologies such as electrochemical processes, no large-scale deployment in Flanders is expected before 2040.

Refining

Only a limited number of technologies were considered for refining in the 2020 context analysis: hydrogen production, electrification of heat and CCS. The 2020 roadmap anticipated that the bulk of refinery emissions from crude oil processing would be avoided via CCS.

These options remain relevant in 2025, though there is significant uncertainty about the absolute volume of refined products that will still be produced in Flanders by 2050, given the projected sharp decline in demand for transport and heating fuels in Europe.

Innovation in refining is focused on developing alternative fuels for aviation and maritime transport, in particular Sustainable Aviation Fuel (SAF) with bio-based inputs and RFNBOs (renewable fuels of non-biological origin). Because EU-level targets for these fuels are binding, this sector will invest in electrolytic hydrogen production; costs can be passed on to end users.

Industrial heat

On energy applications (heat), the 2020 context analysis remained fairly general (e.g. electrification). Since then, a broader range of applications has been examined, notably in the similar Flemish context analysis for non-ETS companies[113].

This chiefly concerns industrial heat pumps for lower-temperature heat[114], now being built at ever larger scales so they will also become available to heavy industry in the (relatively) near term. For high-temperature electric heat there are promising developments in the ceramics and glass industries.

In the (petro)chemicals sector, primary steelmaking and refining, electrification of heat remains limited for now. There are plans to install e-boilers, but initially these will mainly serve to balance heat demand. The principal barrier to wider electrification of heat is the relatively high electricity price compared with natural gas.

Consistently with this, both the EU Innovation Fund and the IEA's international demonstrations database contain only a limited number of (direct) electrification projects in (petro)chemicals, steel and refining.

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[112] The BluePlasma project in Flanders is also a good example here, in which CO_2 is converted into CO: BluePlasma | Catalisti.
[113] Technopolis and VITO, 2022, "Economic potential study on greening heat demand (energy-related emissions) in the non-ETS industry in Flanders". https://www.vlaio.be/nl/nieuws/studie-hoe-vergroenen-we-de-niet-energie-intensieve-industrie-vlaanderen
[114] See also the UpHeat-INES-2 Moonshot project, which targets output temperatures up to 200°C: UpHeat-INES-2 | Moonshot Flanders.

Beyond electrification, thermal energy storage has progressed since 2020, with large-scale demonstrations using materials with high thermal capacity. This allows electricity to be converted into heat at relatively low CAPEX and OPEX when prices are low or even negative, and the heat to be used later (weeks afterwards).

Biogas or waste-to-energy with carbon capture can also play an increasing role in supplying industrial heat. Flanders plans, among other things, to phase down cogeneration (CHP) certificates, which is likely to increase interest in using the steam produced as an industrial heat source in future (e.g. the Ecluse II project).

Table 6: Assessment of the most impactful technologies from the 2020 context analysis and roadmap study

Technology	Technology progress	Implementation challenges
Electric cracking	• Advancing towards TRL 7–8. Market-ready around 2030. • Demonstrations at BASF (Germany) and SABIC (Netherlands)	• High electricity prices render production (for now) uncompetitive • Grid congestion in the short to medium term • Major impact on electricity demand in Flanders • CCS may be an alternative option
Chemical recycling of plastics	• High interest, but few large projects • The 2020 limit of 10% on naphtha substitution can be exceeded provided the feedstock is very pure	• High cost of recyclate vs low cost of virgin material • Underdeveloped value chain – consistent, clean feedstock is essential
Blue hydrogen	• Positive trend Planned investments in Flanders exceed 2020 expectations • Cryogenic capture boosts hydrogen production efficiency and achieves the purity needed for transport and storage	• Higher CAPEX than in 2020; limited support in Flanders • Uncertainty around RED III rules for low-carbon hydrogen in industry
Green hydrogen	• EU and Flemish ambitions for green H_2 were overestimated. • Use of hydrogen as an energy carrier is becoming more limited • Investments are delayed due to electrolyser costs (inflation) and market uncertainty • Many projects worldwide focus on hydrogen derivatives such as ammonia and methanol	• Lower CAPEX and OPEX (electricity price) • The potential for green hydrogen in Flanders is very limited • Smart investment in international logistics and value chains for importing derivatives is necessary
Steel: hydrogen-DRI	• Positive trend – international development • Hydrogen-DRI moving towards TRL 8	• OPEX (cost of green/blue hydrogen/natural gas) • Poor investment climate for steel
Methanol-to-olefins	• Technology largely mature	• CAPEX/OPEX • Reliable (international) value chains required
Electrification of heat	• Positive trend – industrial heat pumps now available for lower-temperature uses (<200°C) • High-temperature electrification is developing but not yet at TRL 9 • Large-scale high-temperature heat storage is possible	• High electricity price vs natural gas • Grid congestion in the short to medium term • Electrification should be coupled with efficiency gains or positive symbiosis with variable green power
Carbon capture at low CO_2 concentrations	• Remains a technological challenge to keep OPEX low • Focus area in Moonshot projects	• Trade-offs with electrification, biomethane/H_2 and carbon capture, depending on costs
Steel CCU	• Positive trend – Steelanol is up and running	• Sector coupling to chemicals (e.g. ethanol to ethylene) • Hydrogen price (green vs blue, in the context of RFNBO requirements)

3.4.3. Evaluation and adjustment of the 2020 roadmap technology choices

Approach

To determine whether the trajectories set out in the 2020 roadmap study (as part of the context analysis) need to be adjusted, this section:

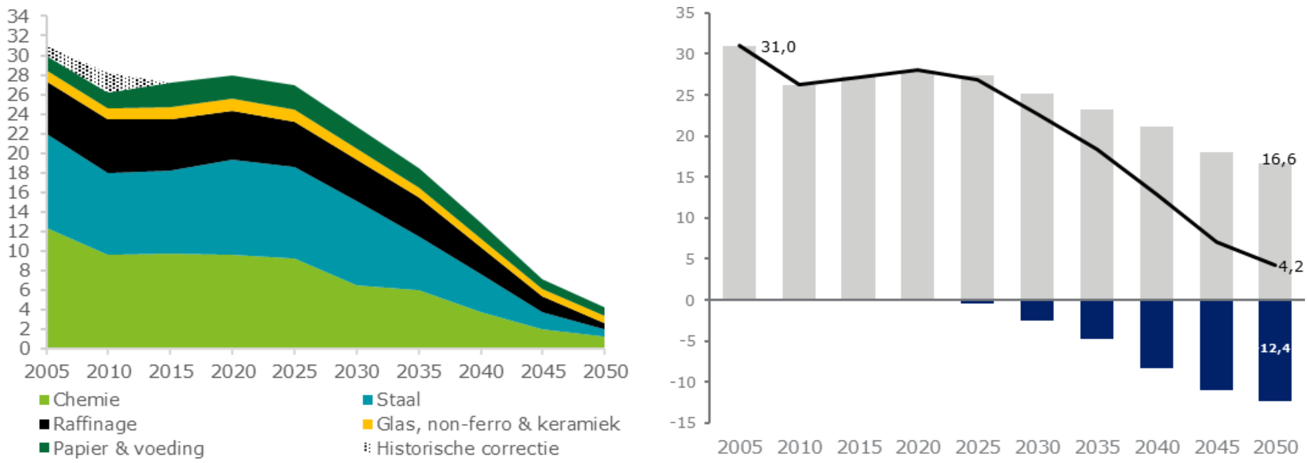
- briefly restates the central exploratory scenario from the 2020 roadmap;
- compares that "MIX" scenario with other (recent) roadmaps with a similar sectoral/geographic scope; and
- maps the state of investment in climate-friendly technologies in Flanders to verify whether the investments envisaged for 2020–2030 are materialising.

Together with insights from interviews, these analyses are then used to judge whether the 2020 trajectories are still accurate and, if not, where adjustments are needed.

Roadmap 2020 assumptions

This study uses the above-mentioned central exploratory scenario ("MIX") from the
2020 roadmap study, as that was also the basis for the roadmap and policy recommendations.

In general, the MIX scenario projected that emissions in the Flemish basic industries would fall by about 80% by 2050 compared with the base year 2005. To achieve this, the roadmap study assumed CO_2 capture and storage amounting to 12.4 Mt in 2050. The MIX scenario also covered other sectors, but (petro)chemicals, refining and steel accounted for the bulk (87%) of 2005 emissions. The present evaluation focuses only on these sectors.

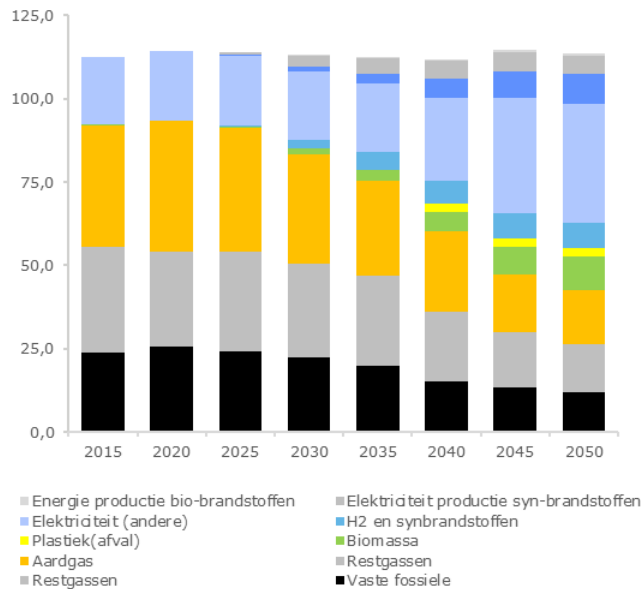


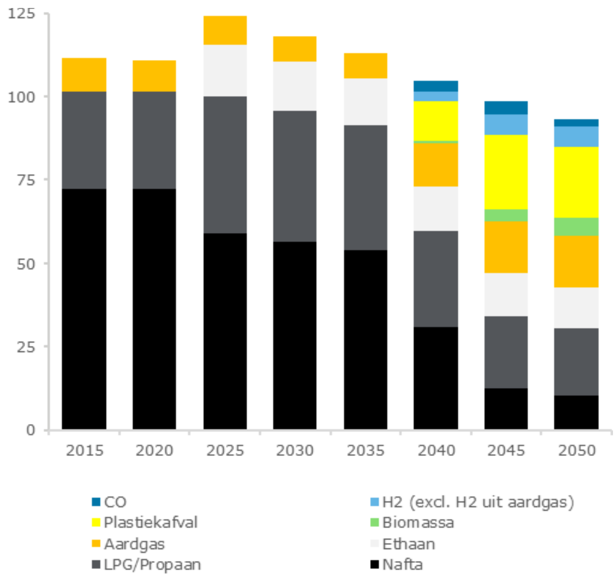
Chemicals | Steel
Refining | Glass, non-ferrous & ceramic
Paper & food | Historical correction

Figure 2.4.2: Projected evolution of greenhouse gas emissions in the 2020 roadmap under the MIX scenario (left) and the contribution of CO_2 capture assumed for Flemish basic industry in the 2020 roadmap (right). Figures are expressed in Mt CO_2.

Besides CO_2 capture, process transformations in both energy use and feedstock deliver the remaining emission reductions (see figure below). In terms of energy use, the MIX scenario does not fully phase out fossil fuels; it does, however, foresee clear growth in electricity consumption alongside the introduction of biomass, plastic waste and synthetic hydrocarbons.

For chemical feedstocks, the MIX scenario anticipates a significant decline in fossil inputs, offset by a major increase in plastic waste (chemical recycling), together with biomass, low-carbon H_2 and synthetic hydrocarbons.





Energy production – bio-fuels	Electricity production – synthetic fuels	CO	H_2 (excl. H_2 from natural gas)
Electricity (other)	H_2 and synthetic fuels	Plastic waste	Biomass
Plastic (waste)	Biomass	Natural gas	Ethane
Natural gas	Residual gases	LPG/propane	Naphtha
Residual gases	Solid fossil		

Figure 33: Projected evolution of energy use in the 2020 roadmap under the MIX scenario (left) and feedstock use in the chemicals sector (right). Figures are expressed in TWh.

A fuller description and summary of the MIX scenario are provided in Annex 2: Extended summary of the MIX scenario in the 2020 roadmap study.

Comparison with other roadmap studies

To assess the MIX scenario against the latest insights, we compared it with recently published roadmap studies that overlap geographically or sector-wise. The roadmap studies considered are:

- ELIA – Powering Industry Towards Net Zero (2022)
- Fluxys: North Sea Integration Model (2024)
- VITO-EnergyVille Paths 2050 Coalition (2025)
- Cefic – The Carbon Managers (2024)
- Plastics Europe – The plastics transition (2023)

A summary description of these roadmap studies is provided in Annex 3: Summary descriptions of the various roadmap studies analysed to evaluate the 2020 roadmap study. The table below compares the weights assigned to the different transition pathways with those in the 2020 roadmap study.

Table 7: Comparative analysis of recently published roadmap studies that each have overlaps in geographical or sectoral scope with the 2020 roadmap study

	Elia – Powering Industry Towards Net Zero	Fluxys – North Sea Integration Model	VITO-EnergyVille Paths 2050 coalition	Cefic – The Carbon Managers	Plastics Europe – The plastics transition
Scope	Net zero roadmap for industry in Belgium and parts of Germany (the 50Hertz area)	Net zero energy system analysis to 2050 for 10 countries around the North Sea	Net zero roadmap for Belgium	Net zero analysis for the European chemicals sector	Climate roadmap to 2050 for plastics production in Europe
Comparability with the 2020 roadmap study	Good comparability; develops three scenarios to 2050 (CCUS, ELEC and MOL)[115], with separate data for Belgium.	Aims more at optimising national energy supply than transforming industrial processes.	Good comparability; models all sectors, including industry.	Focuses only on chemicals and on the EU as a whole, so findings are not directly transferable to Flanders.	Well comparable as regards the weighting of transition pathways for HVC (especially towards polymers).
Differences in transition pathways					
Biomass	The use of biomass is mentioned in the study but is not mapped in detail.	The model mainly looks at meeting energy demand in terms of electricity, natural gas and hydrogen, not at alternative production processes based on recycling and biomass.	Biomethane and biomass (29–43 TWh together by 2050) are used in maritime transport, industry and for electricity/ heat production. By combining biomass with CCS in industry, negative emissions can be achieved.	The analysis assumes a major use of biomass both for energy needs and as feedstock. In the crackers, the analysis assumes approx. 35% bio-naphtha by 2050. In the MIX scenario of the 2020 roadmap study this was only 6%. For energy use too, the Cefic study assumes almost a 50% contribution from biomass (mainly agricultural residues and biogas), versus 13% in the roadmap study.	Plastics from biomass would account for 18% (11.4 Mt) of EU production by 2050.

[115] The ELEC scenario focuses on electrification and the MOL scenario emphasises imports of hydrogen and hydrogen-derived products.

	Elia – Powering Industry Towards Net Zero	Fluxys – North Sea Integration Model	VITO-EnergyVille Paths 2050 coalition	Cefic – The Carbon Managers	Plastics Europe – The plastics transition
Circular	The use of recycling is mentioned in the study but is not mapped in detail.	N/A	Not explicitly mentioned in the industry scenarios, except for a higher share of secondary steel.	The study assumes both mechanical and chemical recycling for plastics production. The use of chemical recycling in crackers is approx. 26% vs 23% in the roadmap study, i.e. broadly in line.	Substitution of fossil plastics could reach 65% in 2050. This means that an estimated 65% of plastics consumed by converters in Europe would be circular. This 65% circular plastics mix is expected to consist of: Mechanically recycled plastics: 15.3 Mt (24%) Chemically recycled plastics: 12.4 Mt (19%)
Electrification	In the various scenarios, electricity demand in the (petro)chemicals and steel sectors rises by 100% to 175%, compared with 100% in the MIX scenario of the roadmap study. All three scenarios include the deployment of industrial heat pumps and electric boilers, as well as a partial contribution from electric crackers.	The model takes into account total estimated electricity consumption from ENTSO's Ten Year Network Development Plan (TYNDP) scenario. This amounts to approx. 200 TWh for Belgium. The model assumes roughly half from wind and solar and the other half from imports. In addition, there remains a need for gas-fired generation, mainly in winter.	Electricity use is expected to more than double in all scenarios, from 80 TWh in 2025 to 155–170 TWh in 2050. Electrification is identified as a no-regret measure, particularly for building heating and road transport. A large increase in industrial electrification is also expected (about double the current demand).	Electricity demand doubles towards 2050 for the (petro)chemicals sector. This is in line with the assumptions in the MIX scenario of the 2020 roadmap study. The increase in electricity use is mainly due to electrification for heat generation and a partial switch to electric crackers.	The roadmap assumes the application of electric naphtha steam crackers after 2035. No specific figures.

	Elia – Powering Industry Towards Net Zero	Fluxys – North Sea Integration Model	VITO-EnergyVille Paths 2050 coalition	Cefic – The Carbon Managers	Plastics Europe – The plastics transition
Hydrogen	Hydrogen demand rises to 35–60 TWh in the various scenarios. In the MIX scenario of the roadmap study this was 26 TWh. All scenarios assume hydrogen use in new DRI-EAF installations for steel production.	Total estimated hydrogen demand is considered, not just for industry. This amounts to 143 TWh in 2050. The model indicates that in 2050 hydrogen demand in Belgium will scarcely be met by local electrolysis (2%). The model prefers blue hydrogen (17%) and imports (80%) from the North Sea (offshore wind + electrolysis) and neighbouring countries.	Domestic production of green hydrogen via electrolysers coupled to renewable energy sources is expected to be negligible, with some exceptions such as production enabled by nuclear Small Modular Reactors (SMRs) or as industrial by-products. Green molecules (hydrogen, e-methane, ammonia, etc.) gain importance, driven mainly by EU legislation for international transport (aviation, maritime). Their role in total final energy demand is limited by cost compared with electrification. International transport alone will account for at least 57 TWh in all scenarios.	The Cefic study assumes a modest increase in hydrogen use (+30%) by 2050 for the chemicals sector. In the 2020 roadmap study the increase was more than 200%. Furthermore, the Cefic study assumes hydrogen production only from natural gas (mainly pyrolysis and partly via CO_2 capture). The 2020 roadmap study did still envisage the use of green hydrogen (35%).	The production of methanol using captured CO_2 and low-carbon hydrogen is an important route for CCU-based plastics. The estimated methanol requirement for this in 2050 is 8.7 Mt, requiring around 2 Mt of hydrogen (or roughly 67 TWh).

	Elia – Powering Industry Towards Net Zero	Fluxys – North Sea Integration Model	VITO-EnergyVille Paths 2050 coalition	Cefic – The Carbon Managers	Plastics Europe – The plastics transition
CCUS	Carbon storage volumes range between 8 and 16 Mt CO_2 in the various scenarios versus 12.4 Mt CO_2 in the MIX scenario of the 2020 roadmap.	Carbon storage volumes in the model amount to approx. 7 Mt CO_2.	Carbon capture and storage (CCS) will play a crucial role in reducing hard-to-decarbonise CO_2 process emissions. The model assumes CCS scales to 20 million tonnes per year from 2030. A future without CCS is feasible but more expensive and requires significantly higher imports of green molecules.	Emission reductions linked to carbon capture for the chemicals sector amount to approx. 23% in 2050 versus 2019 in the Cefic study, compared with 44% versus 2005 in the roadmap study. For the EU average, the Cefic study thus assumes a lower deployment of carbon capture.	Production of plastics from captured CO_2 is expected to reach 3.2 Mt (or 5% of production in 2050) by 2050. This depends on CCS scaling up to supply the captured carbon.

Conclusions

Compared with the 2020 context analysis, the Cefic Carbon Managers roadmap assigns much more weight to biomass (both as feedstock and energy) in the chemicals sector. One reason is that the optimisation model chooses to actually reach net zero emissions in 2050 by neutralising remaining fossil emissions through biogenic CO_2 capture and storage and by storing (biogenic) CO_2 in materials. Nevertheless, the roadmap in general relies less on capturing fossil CO_2 and more on the use of biomass. There are doubts as to whether the large amount of biomass needed to realise this scenario is also applicable in Flanders.

Overall, the transition pathways in Elia's industry roadmap align well with the 2020 roadmap study. Elia's roadmap has a stronger focus on electrification and the use of hydrogen. The roadmap assumes, among other things, hydrogen-based steel production (via H_2-DRI) for Belgium.

The Fluxys model is mainly an optimisation model for meeting energy demand for Belgium as a whole; it does not itself model the transformation of industrial processes. This model indicates that production of hydrogen or derivatives in Belgium will be limited. It does foresee large production of these molecules nearby (North Sea) and relies on transport by ship and pipelines for both hydrogen and CO_2.

The Plastics Europe roadmap follows the same transition pathways as the 2020 context analysis. The level of ambition is also comparable.

The VITO-EnergyVille Paths 2050 coalition is, broadly speaking, in line with the 2020 roadmap study. It has a similar estimate for CCS. The expected future electricity demand in industry is also more or less the same. Production of green hydrogen in Flanders is seen as negligible. Offsetting this (after 2040) is an expected large demand for green molecules (e.g. for aviation and shipping), depending on future EU-level targets.

Across all the roadmap studies analysed, it can be concluded that the transition pathways are comparable to those in the 2020 context and roadmap study. They all focus on electrification, CCUS, hydrogen as feedstock, biomass and (a high degree of) circularity. The weights of these options sometimes differ markedly from those in the 2020 context analysis, for example through greater deployment of electrification and biomass and lower deployment of CC(U)S. In general, for Belgium and Flanders it can also be stated that local hydrogen production will be limited and that green molecules will more likely be imported. A point to note for the comparison is the possible difference in zeitgeist and context in which the various studies were drawn up. That context may differ from the current study at the time of execution. No criticism is expressed of the methodologies used within the studies compared. The comparison serves as an additional reflection within the overall scope of the current assignment.

Projects in Flanders

To gain insight into the current status of the industrial transition in Flanders, projects in or related to industry in Flanders were reviewed.

The table below gives an overview of projects in Flanders at various stages of development (from concept to operational) that relate to the climate transition of the chemicals, refining and steel sectors. It should be emphasised that this list is very likely incomplete, as it was derived from announcements in the media and discussions with a limited number of companies (see Annex 4: Overview of stakeholders consulted in the interviews).

A total of 41 projects were identified so far, including:

- 8 CCUS projects (incl. 2 blue hydrogen projects and 1 project that was cancelled)
- 5 biobased projects, including Sustainable Aviation Fuel production
- 9 circular plastics projects (incl. food waste recycling)
- 3 electrification projects, two of which are at an early concept stage
- 13 hydrogen projects (incl. 2 with CCUS – blue hydrogen)

In general, the focus of the projects is in line with the assumptions from the 2020 context analysis. A significant share of these projects (which at that time were often still at concept, permitting or construction stage) was (implicitly) included in that analysis. The projects cover the main options from the 2020 context analysis (e.g. CCUS, circularity, electrification and biomass).

More progress had been hoped for on CCS, for example via the Antwerp@C project. The Kairos@C project was approved by the ETS Innovation Fund in the 2020 call, but its implementation was delayed by sharply increased inflation, additional investment costs and regulation. Kairos@C is in the short term the first and largest user of Antwerp@C, which is why Antwerp@C has also been delayed. A final investment decision for Kairos@C is expected in the first quarter of 2026. In terms of circularity and biomass, the Next-Gen hub in Port of Antwerp-Bruges also plays an important role in providing a home for investments in demos or first-of-a-kind installations for circular plastics and biomass valorisation. However, to realise the large-scale recycling hub role that Flanders should play by 2050, larger investments had been expected according to the 2020 context analysis. For steel production, investment in a DRI is now an (uncertain) option because of reduced competitiveness of steel production in the EU. The DRI technology was not included in the central scenario of the 2020 roadmap.

An important finding and concern is that more than half of these projects have not yet reached a final investment decision, so there is significant uncertainty about their eventual realisation. The absence or cancellation of such decisions will affect the achievement of the interim and, in all likelihood, the long-term targets in the 2020 roadmap[116].

In addition to the projects below that are aimed at investment, industrial research projects are also supported in Flanders. For example, in 2024 VLAIO provided support for 30 research projects in industry (incl. feasibility studies, strategic basic research and development projects). Owing to the confidential nature of some research projects, no detailed overview of these projects can be included.

[116] In particular for interdependent projects such as the Zesta project, H2BE and the Fluxys CO_2 backbone.

Table 8: Overview of climate projects in Flanders for the chemicals, steel and refining sectors (green = operational or under construction; orange = planned but not yet implemented, FID still to be taken; grey = cancelled)

Project Name	Type	Status	Company/Partners	Technology/Description	Location
bioSAF – refining	Bio	Start-up in summer 2025	Total	SAF	Antwerp
BioHy	Bio	FID tbd	OMV/Borealis	Valorisation of (bio) waste oil into SAF	Antwerp
Torero	Bio	Operational	ArcelorMittal	Bio-based feedstock	Ghent
Bio-refinery pilot	Bio	Operational	Bio-base Europe	Pilot plant to test biobased processes. Capacity 300 kt p.a.	Ghent
Ecluse II	Bio/waste	Under way	Indaver, SLECO, FINEG, Maatschappij Linkerscheldeoever, Port of Antwerp-Bruges, Water-Link	Steam network for transporting heat from waste incineration companies	Antwerp
Steelanol	CCUS	Operational	ArcelorMittal	Ethanol production based on blast furnace gas (CO) (LanzaTech)	Ghent
Vioneo MTO Plant	CCUS	Announcement	Vioneo/Honeywell UOP	Methanol-to-olefins technology	Antwerp
Kairos@C	CCUS	FID tbd	Air Liquide/BASF	CCS (ETS Innovation Fund project)	Antwerp
Antwerp@C	CCUS	FID tbd (dependent on Kairos@C)	Air Liquide, BASF, Borealis, ExxonMobil, Ineos, Fluxys, TotalEnergies	CCS export hub	Antwerp
FLUXYS C-grid	CCUS	FID tbd	FLUXYS, PoAB, Socof	CO_2 transport infrastructure (linked with Kairos@C)	Belgium
Arcade	CCUS	FID tbd	Refining	Carbon capture and deNOx in refining	Antwerp
Power to Methanol	CCUS	Cancelled	Engie/Fluxys/Indaver /PoAB	E-methanol production	Antwerp
VTTI-Pyrum	Circular	Announced	VTTI-Pyrum	Tyre recycling	Antwerp
Advanced recycling plant	Circular	Announced	ExxonMobil	Chemical recycling of plastics	Antwerp
Purecycle	Circular	Announced	Purecycle, PoAB NG-district	Chemical recycling of polypropylene	Antwerp
Triple Helix Pure Sure	Circular	FID – constructio n later in 2025	Triple Helix, PoAB NG-district	Circular economy technology provider (Material as a Service (MaaS)) – PU recycling	Antwerp
Bolder	Circular	FID – construction 2026–2027	Bolder, PoAB NG-district	Tyre recycling	Antwerp
Synpet	Circular/Bio	Announced	Synpet, Kolmar	Chemical recycling of plastic waste (180 kt/year)	Antwerp
Triple W	Circular	Operational	Triple W, PoAB NG-district	Demo – lactic acid from food waste	Antwerp
Borealis Beringen	Circular	Under way	Borealis	Mechanical plastics recycling (Borcycle M technology)	Beringen
P2C (Plastic to Chemicals)	Circular	Operational	Indaver	PS to PS and pOF to naphtha conversion	Antwerp
BASF E-BOILER	Electrification	Planning	BASF	Electric boiler installation	Antwerp
Steam-backbone	Electrification	Concept	Port of Antwerp-Bruges (PoAB)	Double-sided open-access steam backbone (incl. electrification of heat)	Antwerp
Q-pinch	Electrification	Operational	Borealis/Qpinch	Chemical heat pump	Antwerp
BASF Antwerp Green PPA	Green PPA	Operational	BASF	Green PPA / co-owner in offshore NL	NL-Antwerp
ENHANCE NH3 cracking	H_2	FID tbd	Air Liquide	Pilot plant to crack green ammonia into hydrogen	Antwerp
H2Backbone	H_2	Planning	Fluxys	Construction of pipeline network for hydrogen transport	Belgium
Hyoffwind	H_2	Under way	Virya Energy	Green hydrogen production via offshore wind energy with the aim of injection into the natural gas network (25 MWe)	Zeebrugge
North C Hydrogen	H_2	Not yet started	Engie/Flanders	Production of green hydrogen for methanol production	North Sea Port (Ghent)

RecHycle	H_2	R&D first deployment	ArcelorMittal/Fluxys	Research project (recycling residual hydrogen and using green hydrogen in the steel production process to reduce carbon emissions)	North Sea Port (Ghent)
Terranova	H_2	Under way	Terranova Hydrogen/DEME/De Nul/Aertssen/Luminus /Nippon Gas	Multiple-to-multiple: combining hydrogen from various renewable sources with multiple applications; 2.5 MW electrolyser	North Sea Port (Ghent)
Air Liquide	H_2	FID tbd	Air Liquide	Ammonia cracker	Antwerp
Advario-Fluxys	H_2	FID tbd – opening 2028	Advario, Fluxys	Ammonia terminal (and cracker)	Antwerp
Amplifhy	H_2	Announced	VTTI	Ammonia cracker and terminal	Antwerp
Plug Power	H_2	FID tbd – start-up shifted to 2027	Plug Power, PoAB (NG-district), Vleemo, Luminus	H2 production (12.5 Kt per year)	Antwerp
Hope	H_2	Planning	Lhyfe	Offshore wind hydrogen production. Demo 10 MWe electrolyser. 2026	Ostend
H2BE Project	H_2-CCUS	FID tbd	Engie/Equinor	ATR hydrogen production + CCS (ETS Innovation Fund)	Ghent
RFNBO – refining	H_2/CCUS/Green e PPA	Operational end of 2027	Total	Hydrogen production in NL for use in refining in Flanders	NL-Antwerp
INEOS Project ONE	New process	Under construction	INEOS	Ethane cracker	Antwerp
BASF Superabsorbent Polymer	Other	Operational	BASF	Superabsorbent polymers with zero carbon footprint	Antwerp
ZESTA Project	Steel DRI EAF	FID tbd	ArcelorMittal	EAF + DRI + CCS (ETS Innovation Fund)	Ghent

Evaluation of technological options in the MIX scenario of the 2020 roadmap study

Based on the comparison with the various roadmap studies, the announced projects and the insights gained from the interviews, an evaluation is set out below for each value chain at the level of the transition pathways included in the MIX scenario of the 2020 roadmap study. For each value chain, the insights are also summarised in a schematic overview. These tables provide an overview of the main technology pathways from the roadmap study and how recent insights affect the weight of these pathways towards 2050.

Chemicals

CCS at a tipping point

Although the ambition level from the 2020 roadmap has been pushed back in time due to delays in the implementation of Antwerp@C, the (petro)chemicals sector is close to major investments that could capture and store up to 1.5 Mt CO_2 by 2030[117] through, among other things, European support (via the Innovation Fund) for the Kairos@C project.

However, no final investment decisions have yet been taken for this project. The cause lies in the high inflation of recent years, which has greatly increased the estimated CAPEX, as well as a lower CO_2 price that makes these projects (relatively) less profitable. In addition, there remains some uncertainty about the transposition of the European REDIII directive and the recognition of blue hydrogen in industry.

These investments are not only crucial to reduce a significant share of emissions in the (petro)chemicals sector; by investing in the necessary infrastructure for CO_2 capture and transport, they also make it possible for other companies in the Port of Antwerp and beyond to make use of it.

Green hydrogen losing importance; blue hydrogen becoming more important

Large-scale green hydrogen production will most likely not take place (in the short and medium term) in Flanders[118]. The main stumbling blocks are the (higher) cost of electricity, the availability of sufficient low-carbon power and EU regulation (including the additionality principle). Green hydrogen will be used where there is a market for derivatives (e.g. RFNBO deployment in transport fuels) that allows a higher price to be passed through, whether or not indirectly via the “refinery route”. Using green hydrogen as a fuel seems unlikely where the option of electrification or biomass exists and these alternatives prove more economical. The same conclusion can be drawn for the use of synthetic fuels in industry, except where quotas are imposed by Europe, as with Sustainable Aviation Fuels.

In addition to applying carbon capture to existing hydrogen production (via Kairos@C), a new investment in blue hydrogen is also in the pipeline (the H2BEe project). This investment would increase hydrogen production in Flanders by about 210 kt per year (6.9 TWh). It could therefore partly replace the projected demand for green hydrogen in 2050 (8.7 TWh) in the 2020 roadmap (because of higher demand from steel production). This investment is currently facing uncertainty regarding volumes and the sales price due to the as yet uncertain status of blue hydrogen in the REDIII regulation[119].

More electrification possible but little visible for now

The 2020 roadmap underestimated the potential for electrification after 2030. For low-, medium- and high-temperature heat, several technological options are now available.

In practice, however, options for electrification (e.g. e-boilers) are hardly being deployed yet in the (petro)chemicals sector. The main reason remains the large cost difference between electricity and natural gas, as well as possible problems in obtaining a (reinforced) grid connection in time. Small-scale investments in e-boilers may take place that can be used flexibly depending on, for example, the wholesale power price. It must be emphasised for this and other analyses in this report that this is a snapshot from early 2025; it is therefore possible that by 2030 more investments in electric boilers will be made.

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[117] This is a substantial emission reduction, since emissions from Flemish industry under the EU ETS were close to 21 Mt in 2024.

[118] See, for example, the Fluxys roadmap (North Sea Integration Model) and the recent Paths 2050 coalition model, discussed earlier in this report.

[119] More clarity is expected in the “low-carbon hydrogen” delegated act that the European Commission is due to publish shortly.

For electrification, the technology that brings a large efficiency gain will be chosen. In that respect, the recent investment in a large-scale industrial heat pump (50 MWh)[120] is encouraging. This should (using waste heat) be three times more efficient than a steam boiler fired by natural gas. In practice, it would therefore become profitable if the difference between electricity and gas prices were kept below a factor of three. This should be possible.

Another way to achieve efficiency gains is to use economies of scale, for example by using steam networks (based on electricity) that can supply multiple industrial sites. Finally, better use can also be made of the variability in the electricity price (for example in times of plentiful renewable generation) by deploying electric heat storage. Here too, important progress has recently been made through new installations that can store large amounts of heat (for longer periods and at high temperature) in materials on a larger scale and release it later without significant energy loss.

In the 2020 roadmap, the electrification of naphtha steam crackers was put forward as an important option (after 2035). In the meantime, this technology has made great strides, driven by two industrial consortia that have each successfully further developed a type of technology. This electrification is now close to TRL 7–8. Large-scale deployment is still expected around 2035. Two major stumbling blocks remain for its application in Flanders: first, as stated earlier, the need for a (very) large amount of cheap carbon-free electricity; second, a solution for the use of off-gases from the cracking processes that are currently used as an energy source in the same process. Ultimately, some form of reforming will have to be applied to convert them into hydrogen and CO and CO_2, with eventual capture of this CO_2.

The alternative to electrifying cracking processes remains CO_2 capture. Here too, it is a great challenge to reduce the cost of low-concentration CO_2 emissions (from combustion). The trade-off between CO_2 capture and electrification will therefore mainly depend on the relative costs and the availability of the necessary infrastructure. If the planned investments around Kairos@C and Antwerp@C go ahead, the choice may therefore tend towards CO_2 capture, provided CO_2 separation is cost-effective.

Alternative feedstock for olefins

The 2020 roadmap also anticipated investments after 2030 in units that use alternative feedstock for the production of olefins, in particular the conversion of methanol via Methanol-to-Olefins (MTO) and Methanol-to-Aromatics (MTA) processes and the conversion of ethanol (from CCU via steel production) to ethylene. These options are still retained for the time being, taking into account the relatively large number of new investments elsewhere in the world for the production of (green) methanol. Local production of methanol via CO_2 capture and hydrogen will depend on the availability of (cheap) imported hydrogen. Alternatives can be the production of methanol via gasification of hard-to-process residual waste streams, provided carbon capture is applied, or production from biomass.

Large-scale chemical recycling remains a must

The 2020 roadmap assigned (chemical) recycling a very important role, in addition to mechanical recycling, as feedstock for the production of high-value chemicals, with the aim of creating a chemical recycling hub for Europe in Flanders. This level of ambition should be maintained, not only for climate targets but also because of the increasingly ambitious targets for plastics recycling.

In practice, the expected large-scale investments in these technologies remain below expectations. The two most important reasons are the cost of recycled plastic versus virgin plastic and the underdeveloped value chain for sufficient plastic waste with specifications suitable for chemical recycling. The use of recycled material as feedstock in plastics production will also be determined by whether binding targets are adopted and by smart investments in developing a downstream recycling value chain.

Reduced outlook for synthetic fuels in industry

Using synthetic fuels as a fuel in industry is less cost-effective than direct electrification and carbon capture, which gives them less potential – except where quotas are imposed by Europe, as with Sustainable Aviation Fuels. The roadmap should be adjusted in this respect towards higher electrification or (where that is not possible) CO_2 capture or biomass use. For refining, the production of synthetic fuels could, however, gain in importance if further ambitious European targets are introduced in future.

[120] https://www.gigkarasek.com/news/large-scale-heat-pump-basf

Question marks over large-scale use of biomass as feedstock/energy carrier

The 2020 roadmap assumed a limited share of biomass as feedstock and energy carrier in the chemicals (and other) sector. This contrasts with, for example, the Cefic Carbon Managers roadmap, which counts on biomass as one of the key elements to make the (petro)chemicals sector climate-neutral. The 2020 roadmap recommended a thorough study of the availability of (sustainable) biomass for the industrial transition. To reduce uncertainty in this area, this recommendation is repeated here.

Table 9: Overview of the main technology pathways for Chemicals from the roadmap study and the weight of these pathways towards 2050

Production			
Production volumes	**Evolution 2015–2050 MIX scenario**	**Adjustment: 2050 evolution**	**Discussion**
High value chemicals	+30%	→	Growth sustained through new investments (ethane cracker, PDH)
Ammonia	+0%	→	Transition to CCS-based (blue) ammonia, also due to uncertainty over future imports of green/blue ammonia
Chlorine	+10%	→	No change expected
Other	+0%	→	Follows general economic development
Feedstock			
Feedstock	**2050 weight MIX scenario**	**Adjustment: 2050 weight**	**Discussion**
Fossil feedstocks	62%	↗	Increase due to higher production of blue hydrogen (new investment)
Biomass	6%	→	Keep constant; uncertainty about large-scale use of biomass in Flanders
Plastic waste	23%	→	Already ambitious; maintain level of ambition
Renewable H_2	6%	↘	Lower level of ambition due to high cost and availability of carbon-free electricity; reduced in favour of blue hydrogen (but greater certainty of recognition under REDIII is needed)
CCU	3%	↘	Linked to (higher-cost) green hydrogen; Lower domestic production via CCU; possible export of CO_2 to a region in Europe with inexpensive hydrogen production[121]

[121] See https://www.nature.com/articles/s41560-025-01752-6/figures/4

Energy use			
Energy source	**2050 weight MIX scenario**	**Adjustment: 2050 weight**	**Discussion**
Fossil energy sources	30%	→↘	Possibly less use of fossil fuels in favour of higher electrification compared with the 2020 roadmap
Electricity	50%	↗→	Possibly more electrification, especially for low- and medium-temperature heat; uncertainty over electric cracking of naphtha (can be electric but also via CCS)
Biomass	13%	→	Uncertainty about the use of biomass
Synthetic fuel	7%	↘	Lower due to high cost
Carbon capture and storage			
Technology	**2050 weight of emission reduction, MIX scenario**	**Adjustment: 2050 weight**	**Discussion**
CCS	–44% vs 2005	↗→	Could be higher if electrification is relatively too expensive or carbon-free power is not sufficiently available; choice between electric cracking of naphtha or CCS (provided capture cost is low enough)

→ status quo compared with the 2020 roadmap study; ↗ rising share or importance; ↘ falling share or importance; ↗→ possibly rising importance or share but conditional on the evolution of another energy carrier or technology route; **(→↘), (↗)** arrow in brackets indicates (greater) uncertainty about the future evolution of production or demand.

Refining

The transition in refining – aside from the uncertainty about future demand for fossil fuels – currently depends on other investments in the Port of Antwerp, in particular CO_2 infrastructure.

Future (more ambitious) European targets for the use of sustainable fuels in, among other sectors, shipping and aviation will also play an important role in new investments for producing these fuels.

Table 10: Overview of the main technology pathways for Refining from the roadmap study and the weight of these pathways towards 2050

Production			
Production volumes	**Evolution 2015–2050, MIX scenario**	**Adjustment: 2050 evolution**	**Discussion**
Refining	-15%	**(→)**	Uncertainty about future production; keep stable for now but monitor
Energy use			
Energy source	**2050 weight, MIX scenario**	**Adjustment: 2050 weight**	**Discussion**
Fossil energy sources	66%	**(→)**	Depends on production volumes, as a large share is refinery off-gases; natural gas firing could be lower with higher electrification
Electricity	29%	**↗**	Higher uptake possible; most processes are low- or medium-temperature
H_2 and CCU	5%	**(↗)**	Dependent on demand for RFNBOs via EU regulation
Carbon capture and storage			
Technology	**2050 weight of emissions reduction, MIX scenario**	**Adjustment: 2050 weight**	**Discussion**
CCS	–52% vs 2005	**↘**	Lower if electrification increases

→ status quo compared with the 2020 roadmap study; **↗** rising share or importance; **↘** falling share or importance; **↗→** possibly rising importance or share but conditional on the evolution of another energy carrier or technology route; **(→↘), (↗)** arrow in brackets indicates (greater) uncertainty about the future evolution of production or demand.

Steel

The 2020 roadmap assumed a combination of measures (e.g. CCU, hydrogen, biomass and use of plastic waste) to cut emissions from conventional blast furnaces, supplemented with CCS. At the time, the option of deploying hydrogen DRI was not retained because of the very large demand for (green) hydrogen it would create.

The current plans of the largest steel producer in Flanders partly deviate from those assumptions. The adjusted roadmap would, in time, replace one blast furnace with a hydrogen-fed DRI together with one or two electric arc furnaces. For the other blast furnace, the applications proposed in 2020 remain valid. The DRI would use blue hydrogen (via the H2BE project mentioned above). Additional investments in electric arc furnaces could also raise the share of recycled steel in Flanders.

Given the current economic context, there is significant uncertainty as to whether and when these major investments in the Flemish steel sector will take place. It should be emphasised that this investment, together with the H2BE project (and Kairos@C), are key investments for the climate transition of Flanders' base industry and therefore merit policy priority.

Table 11: Overview of the main technology pathways for Steel from the roadmap study and the weight of these pathways towards 2050

Production			
Production volumes	**Evolution 2015–2050, MIX scenario**	**Adjustment: 2050 evolution**	**Discussion**
Steel	+9%	→	Maintain production level; higher EAF+DRI share vs BF-BOF
Energy use			
Feedstock	**2050 weight, MIX scenario**	**Adjustment: 2050 weight**	**Discussion**
Fossil feedstocks	45%	↘	Increased deployment of DRI and EAF using H_2 (derived from methane)
Electricity	21%	↗	Due to additional EAF capacity
Biomass	11%	→	Stable (Torero project)
Plastic waste	11%	→	Stable
Green H_2	11%	↘	Lower in favour of blue hydrogen
Carbon capture and storage			
Technology	**2050 weight of emissions reduction, MIX scenario**	**Adjustment: 2050 weight**	**Discussion**
CCS	–49% vs 2005	↘	Lower within the scope of steel production; higher for production of the blue H_2 used by the steel sector

→ status quo compared with the 2020 roadmap study; ↗ rising share or importance; ↘ falling share or importance; ↗→ possibly rising importance or share but conditional on the evolution of another energy carrier or technology route; **(→↘), (↗)** arrow in brackets indicates (greater) uncertainty about the future evolution of production or demand.

Conclusion

The extensive evaluation of the 2020 roadmap study, supplemented by recent interviews, presents a nuanced picture of the transition to a more sustainable industry in Flanders. Technological innovations such as CCS, the shift towards blue hydrogen, emerging electrification technologies and sustainable circular processes offer significant potential. At the same time, there remain substantial challenges around investment costs, regulatory uncertainties (e.g. implementation of RED III) and the availability of reliable, affordable carbon-free energy.

3.4.4. Assessment of infrastructure needs

The 2020 roadmap study showed that timely development of new infrastructure is essential for industry to meet future climate targets. It identified the following large-scale infrastructure needs:

- Reinforcement of electricity generation and the electricity grid
- Development of infrastructure for CO_2 liquefaction and transport (in industrial clusters and via a west–east CO_2 backbone)
- Expansion of hydrogen infrastructure with a view to importing hydrogen carriers
- Logistics chains for large-scale recycling of plastic waste and for biomass

The 2020 roadmap also indicated timing: it is important to have a large part of these investments in place by 2030 so that new process units (that use electricity, plastic waste, hydrogen (and derivatives), etc.) or modifications for CO_2 capture in industry can proceed after 2030.

Most of the above elements also recur in other, more recent roadmap studies with a similar scope (e.g. Elia's "Powering Industry towards Net Zero", Fluxys' "North Sea Integration Model" and VITO-EnergyVille's "Paths 2050 Coalition"), as discussed earlier in this study.

Electricity grid infrastructure

A major expansion of Belgium's electricity grid is needed to meet rising industrial electricity demand, which could double by 2050[122]. This requires integrating substantial renewable energy sources, such as offshore wind, and creating additional interconnections. Key projects such as Ventilus and the Boucle du Hainaut are crucial to connect offshore renewables to the mainland[123]. A proactive approach is essential to spur timely grid investments that can support industry's electrification ambitions. Regional reinforcements and upgrades to higher voltage levels are also necessary to accommodate future needs[124].

Infrastructure for low-carbon molecules

Low-carbon molecules – especially hydrogen and its derivatives – are essential for sectors where full electrification is not feasible[125]. By 2050, demand for these molecules in Belgium could reach 30–60 TWh[126]. Given the limited domestic potential for renewables, a large share will have to be imported. Investments in import facilities and pipelines to industrial clusters are therefore prudent, underlining the importance of developing infrastructure for green molecules alongside improvements to the electricity grid[127].

Carbon capture and storage (CCS)

As indicated in this study, CCS is indispensable for reducing emissions from industrial processes that are hard to decarbonise. The infrastructure for carbon capture, transport and storage must be put in place within the current decade[128]. Access to CO_2 storage via the Belgian seaports offers advantages; developing CO_2 pipelines and liquefaction facilities is crucial. A forward-looking approach, similar to that for electricity grids, is recommended to ensure CCS infrastructure is ready in time.

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[122] Elia, VITO-EnergyVille
[123] Elia, Fluxys
[124] VITO-EnergyVille
[125] Fluxy, Elia, VITO-EnergyVille
[126] Elia, VITO-EnergyVille
[127] Ibid.
[128] VITO-EnergyVille, Fluxys

Challenges and strategic approaches according to the roadmaps

Timely delivery of these infrastructure projects faces challenges such as lengthy permitting procedures, resource availability and investment needs. Streamlining permitting and strengthening the public interest status of grid projects in legislation are necessary steps[129]. In addition, it is important to increase the number of skilled workers and to ensure a stable supply chain for materials and equipment. Flexible regulation is needed to stimulate industrial flexibility and support innovation[130].

In short, to achieve net zero emissions by 2050, a strategic combination is needed of expanding electricity grid capacity, deploying CCS infrastructure and developing logistics networks for low-carbon molecules, plastics and biomass. Cooperation between industrial stakeholders, policymakers and system operators is essential to address these challenges effectively and to ensure the infrastructure is ready on time for the transition to a carbon-neutral future in Belgium.

The recommendations of the roadmaps analysed therefore largely align with those of the 2020 roadmap study. One element not addressed in the 2020 roadmap is collective electrification of heat. Initiatives in that area within industrial clusters can, thanks to scale and flexibility, potentially limit the costs (notably OPEX) of electrification for end users.

Since 2020, the geopolitical context and the associated security framework have changed profoundly. This means these aspects will also have to be taken into account in the further development (and optimisation) of infrastructure (for example in terms of security of supply, cyber security, sabotage and kinetic warfare).

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[129] Elia. Powering industry towards Net Zero

[130] Elia. Powering industry towards Net Zero, VITO-EnergyVille, Paths 2050 coalition

4. Adjusted roadmap for a climate transition with attention to a competitive economy

On the basis of the analyses in Chapter 3, the 2020 roadmap has been re-examined. First, the various technologies or technological options and how they evolved between 2020 and 2025 were reviewed, using the 2030 milestones in the original roadmap as a benchmark. The impact of this evaluation is then extrapolated towards 2040.

Next, for the (petro)chemicals, refining and steel sectors, new milestones for 2030, for 2030–2040 and for 2040–2050 are proposed on the basis of the foregoing analyses and interviews with stakeholders.

This covers the weight that can be assigned to the various technologies in the roadmap as well as feedback from the stakeholder interviews.

The aim is to determine where and how the 2020 roadmap needs to be adjusted – first for the short term up to 2030, then towards 2040, while (as in the 2020 roadmap) assuming that after 2040 the focus will mainly be on extending application of technologies already in place by then.

This final analysis also takes account of the tightened targets for industry under the EU ETS since 2020 (e.g. Fit for 55), which now stands at −62% in 2030 and is expected to be significantly stricter by 2040. This means large-scale deployment of technologies such as electrification and carbon capture and storage must be brought forward compared with the original roadmap.

4.1. Evaluation of the 2020 roadmap and technological pathways, taking industrial competitiveness into account

In the tables below, the five technology routes (biomass, circular, electrification, hydrogen and CCUS) from the 2020 roadmap are assessed to see whether achievements since 2020 are in line with the stated 2030 goals. A traffic light code is used (red: major deviation; amber: limited deviation; green: on track). Arrows indicate whether (policy) adjustments are needed. A negative deviation from the trajectory envisaged in 2020 does not necessarily mean an adjustment is required – for example if the future potential of a given technology has been revised down in this report.

The table also considers possible impacts on the assumptions set for 2030–2040 in the 2020 roadmap. A delay in achieving 2030 goals can affect the following decade.

4.1.1. Biomass

Table 12: Biomass – Achievements since 2020 versus the stated goals for 2030 and implications for 2030–2040

Evaluation of 2020 roadmap			
2020–2030 assumptions	**Evaluation**	**Discussion**	**Adjustment**
Demonstration of bio-based HVC (and/or new aromatics)	(orange)	• Pilot lignin conversion already started, but large-scale demo biorefinery is missing • There are some foreign demos (e.g. NL)	↘
Demonstration of use of bio- and synthetic fuels (low-, medium- and high-temperature heat)	(red)	• Synfuels used only to a very limited extent (in industry) due to high cost • Biogas application limited (and location-dependent)[131]	↘
Evaluation of techno-economic potential of large-scale bio-based refining	(orange)	• Targeted study not known • Sector study available by Energia (2023)	↗
Demonstration of synthesis of bio-coal for steel production	(green)	• Torero project at ArcelorMittal launched	→
2030–2040 assumptions	**Risk**	**Discussion**	**Adjustment**
100 kt BTX plant per year from biomass	(orange)	• Uncertainty about the potential for large-scale biomass HVC production in Flanders • Greater potential in Scandinavia	↘
300 kt bio-based feedstock (e.g. ethanol/methanol) for chemicals	(orange)	• Uncertainty about large-scale biomass HVC production in Flanders, but possible investment in green methanol to MTO • Greater potential in Scandinavia	→
Refining reorientation towards biofuels for aviation and shipping	(green)	• Dependent on EU regulation that may or may not drive demand • Downstream market stimulation is very important	→

Table continues on the next page

[131] See https://assets.vlaanderen.be/image/upload/v1665401654/Potentieel_biomassa_2030_yusqbq.pdf

Introduction of new targets			
Target	**Period**	**Discussion**	**Weight**
Repeat: study of biomass potential in Flanders for industry	2025–2030	Study of the scale of biomass application for Flanders' base industry via local production and import	↗

red: major deviation from the 2020 roadmap trajectory towards 2030; **amber**: limited deviation; **green:** on track.

4.1.2. Circular[132]

Table 13: Circular – Achievements since 2020 versus the stated goals for 2030 and implications for 2030–2040

Evaluation of 2020 roadmap			
2020–2030 assumptions	**Evaluation**	**Discussion**	**Adjustment**
Build a large-scale hub for chemical recycling Ensure logistics chains; remove regulatory carbon barriers	red	• No concrete plans yet, but exploratory studies ("Plastic Recycling Hub") • Bottlenecks in feedstock, cost, permitting, space provisioning, etc.	↗
Build chemical recycling capacity of 10–100 kt per year, including demonstration of (plastic) waste as feedstock for production	green	• Various demonstrations: Indaver P2C (65 kt by 2028), Renasci P2C (20 kt as a target) • Various announcements (e.g. Freepoint, PureCycle)	↗
2030–2040 assumptions	**Risk**	**Discussion**	**Adjustment**
Further scale-up and optimisation of chemical recycling within the chemical value chain (for HVC production) 1 Mt plastic recycling (80% towards feedstock or monomer chemistry)	amber	• Scaling plastics-to-HVC is possible and desirable. Bottlenecks remain logistics chains and cost.	↗
Introduction of new targets			
Target	**Period**	**Discussion**	**Weight**
Develop logistics for circular plastics	2025–2040	• More focus on building the upstream value chain for circular plastics	↗
Assess potential for gasification of bio- and plastic waste	2025–2040	• Examine whether gasification of hard-to-process bio- and plastic waste can be applied at large scale (instead of conventional incineration)	↗
Greater use of scrap in steel production	2025–2040	• Via a new electric arc furnace (EAF)	↗

red: major deviation from the 2020 roadmap trajectory towards 2030; **amber**: limited deviation; **green:** on track.

[132] This mainly concerns the recycling of plastic waste and steel (scrap).

4.1.3. Electrification

Table 14: Electrification – Achievements since 2020 versus the stated goals for 2030 and implications for 2030–2040

Evaluation of 2020 roadmap			
2020–2030 assumptions	**Evaluation**	**Discussion**	**Adjustment**
Demonstration of HVC production via electric (steam) cracking (10–100 kt per year)		• No demonstration in Flanders, but in Germany and the Netherlands	→
Electrification via low-temperature boilers – hybrid systems		• Small-scale plans for hybrid e-boilers in Flanders that respond to variable renewable output and periods of lower electricity prices	↗
Demonstration of high-temperature electrification		• No demonstration in Flanders	↗
(Grid) infrastructure prepared for electrification of industrial processes (research)		• Infrastructure could come under pressure if electrification accelerates in the coming years	→
2030–2040 assumptions	**Risk**	**Discussion**	**Adjustment**
Scaling electric cracking from 100 kt to 500 kt HVC per year (electric catalytic cracking subject to conditions)		• Scale-up possible after 2030. Bottlenecks remain the electricity price and availability of low-CO_2 power.	→
Electrification of boilers < 1 MW and high-temperature electrification applications		• Electrification needs to be scaled up from 2030, but depends on the cost of electricity versus gas.	↗
Introduction of new targets			
Target	**Period**	**Discussion**	**Weight**
Steel production via EAF	2030–2040	• Possibly two additional EAF installations in Flanders	↗
Use of industrial heat pumps and heat storage	2025–2040	• Facilitate the roll-out of these technologies in Flanders Necessary to reduce (OPEX) costs and highly compatible with renewable energy	↗

red: major deviation from the 2020 roadmap trajectory towards 2030; amber: limited deviation; **green:** on track.

4.1.4. Hydrogen

Table 15: Hydrogen – Achievements since 2020 versus the stated goals for 2030 and implications for 2030–2040

Evaluation of 2020 roadmap			
2020–2030 assumptions	**Evaluation**	**Discussion**	**Adjustment**
Investments in blue hydrogen		• Kairos@C (awaiting FID) • H2Be (ATR)	→
Investments in green hydrogen		• A few small-scale projects • No large-scale H_2 via electrolysis – delays	↘
Demonstration of hydrogen production via methane pyrolysis		• No demonstrations in Flanders, but international ones exist	→
(Building) H_2 infrastructure (pipelines, compression, terminals for liquid hydrogen)		• Exact timing and planning of H_2 infrastructure unclear	→
2030–2040 assumptions	**Risk**	**Discussion**	**Adjustment**
Limited growth of blue hydrogen production in Flanders		• Path dependency with Kairos@C; limited growth after 2030 • Scale-up possible if electrolysis/imported H_2 fails to materialise	→
Scaling H_2 production in Flanders via electrolysis		• No significant potential for electrolytic H_2 in Flanders	↘
Scaling H_2 production in Flanders via methane pyrolysis		• Possible in Flanders after 2030, but the business model must work (valorisation of carbon)	→
Further build-out of H_2 infrastructure as H_2 use grows and to support, among other things, CCU routes		• Development of infrastructure is required for importing H_2 and derivatives	↗

Table continues on the next page

Introduction of new targets			
Target	**Period**	**Discussion**	**Weight**
Adjusting the balance between blue, green and imported hydrogen	2030–2050	• Due to new projects in steelmaking and blue hydrogen, the overall expected balance between supply and demand towards 2040–2050 needs to be mapped.	n/a

red: major deviation from the 2020 roadmap trajectory towards 2030; **amber**: limited deviation; **green:** on track.

4.1.5. Carbon capture, utilisation and storage (CCUS)

Table 16: CCUS – Achievements since 2020 versus the stated goals for 2030 and implications for 2030–2040

Evaluation of 2020 roadmap			
2020–2030 assumptions	**Evaluation**	**Discussion**	**Adjustment**
Demonstration of Antwerp@C for CO_2 capture (2.5 Mt in 2030)	(orange)	• Kairos@C at 1.5 Mt (awaiting FID)	→
Research into CO_2 capture at sources with low CO_2 concentrations (compatibility of HVC installations with CCU/S)	(red)	• No demonstrations • Low-concentration CO_2 is still expensive to capture	↗
Demonstration of HVC production via CCU and carbon–carbon coupling (1–10 kt/year)	(orange)	• Announcement of an MTO project in Antwerp (bio-based but can use any form of methanol)	↗
Demonstration of CCU in steelmaking (Steelanol) (10 kt per year)	(green)	• Started	→
Building CO_2 network infrastructure (for both storage and use)	(orange)	• CO_2 infrastructure moving towards FID	↗
2030–2040 assumptions	**Risk**	**Discussion**	**Adjustment**
Expansion of CCS capacity in Flanders to approx. 10 Mt by 2040	(orange)	• Expansion of CCS in Flanders after 2030 depends on infrastructure, cost and especially capture of low-concentration CO_2	↗
Large-scale CCS for sources with medium and low CO_2 concentrations by 2040	(orange)	• Expansion of CCS in Flanders after 2030 depends on infrastructure, cost and especially capture of low-concentration CO_2	→
Scaling up CCU and carbon–carbon coupling for HVC production	(orange)	• Expansion after 2030 depends on the availability of green ethanol and methanol (imports)	↗
Scaling up CCU in steelmaking (Steelanol)	(green)	• Possible expansion of Steelanol	→

Table continues on the next page

Introduction of new targets			
Target	**Period**	**Discussion**	**Weight**
Adjust domestic CCU products in favour of imports	2030–2050	• The high (RFNBO) hydrogen cost will limit domestic CCU	n/a

red: major deviation from the 2020 roadmap trajectory towards 2030; **amber**: limited deviation; **green:** on track.

4.2. Adjusted roadmap based on the new technology mix

4.2.1. Chemicals and Refining

Transition pathway in chemicals and refining	2020–2030	2030–2040	2040–2050
Biomass	• Need for better analysis of large-scale deployment of bio-based chemistry in Flanders • Growing demand for Sustainable Aviation Fuel in refining	• Uncertainty about large-scale deployment • Build integrated biorefineries for HVC (5% of total production) • Growth in the use of (sustainable) biomass in refining depends on new and more ambitious EU targets. Strong focus on 2nd-generation biofuels. • Import biomass-derived products as feedstock (e.g. methanol, ethanol, bio-naphtha) • Limited use of biogas for heat	• Target remains unchanged (5% HVC production) Domestic HVC production and/or use of imported biomass-derived feedstock • Biofuel production via refining follows EU targets • Limited use of biogas (where possible) for high-temperature heat that is not electrified
Circular	• Start building the value chain for circular plastics • First demo(s) of plastic waste pyrolysis and/or solvolysis	• Downstream value chain can supply up to 1 Mt/year of purified feedstock • By 2040, 1 Mt of HVC production via plastic waste • Start gasification of hard-to-recycle waste to syngas (+ carbon capture) – can be coupled to local blue methanol production	• Build out an international plastics waste value chain • By 2050, at least 2 Mt of HVC production via plastic waste

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Electrification	• Initial electrification of boilers: hybrid • Investment plans by grid operators + government (priorities) to avoid congestion in 2030–2050 • Prepare large-scale investments in heat pumps, e-steam networks and heat storage	• Network reinforcement investments completed by 2035 at the latest • Electrification of naphtha steam cracking after 2035 (OR carbon capture). Large-scale roll-out before 2040 to meet ETS targets • By 2040, a large share (70%) of low- and medium-temperature heat in clusters is electric via heat pumps, flexible e-boilers and e-steam networks • Demo for high-temperature heat electrification	• Electric naphtha cracking fully deployed by 2050 (OR via carbon capture, or a mix). • Higher low- and medium-temperature electrification by 2045–2050 • High-temperature heat partially electric (or biogas, or carbon capture)
H_2	• Apply carbon capture to SMR chemistry by 2030 (blue hydrogen) • New ATR + carbon capture around 2030 (blue hydrogen) • Import/produce green hydrogen in refining for RFNBO targets (accounting)	• Growth in green hydrogen driven by RFNBO targets to 2040 • Carbon capture on all SMR units • New ATR + carbon capture operational • Import hydrogen carriers (methanol, ammonia)	• Pipelines for green H_2 imports delivered (e.g. north–south and/or towards offshore wind) • Green hydrogen to refining for RFNBO and derivatives (e.g. ammonia and methanol) for shipping • Hydrogen production via methane pyrolysis • Methanol value chain in place

Table continues on the next page

CCS/U	• Blue hydrogen and ammonia production by 2030 (Kairos@C), with possible expansion via the H2BE project • Ethylene oxide (process emissions) fully captured (Kairos@C) • CO_2 logistics in an advanced phase (shipping + North Sea pipeline) • CCU or derivative demo (e.g. Methanol-to-Olefins)	• Decision by 2035 on carbon capture for naphtha/ethane cracking (and/or electrification) • Deploy (CCU/bio) ethanol dehydrogenation for HVC • Start building MTO/MTA capacity by 2035 • Expand Kairos@C to hydrogen production in refining • Start other carbon capture projects in refining and chemicals (if more cost-effective than electrification) • National CO_2 logistics completed by 2035–2040 (max capacity)	• Apply carbon capture to high-T heat if cost-effective versus electrification or biogas • MTO/MTA via green (CCU), blue or bio-methanol and ethanol dehydrogenation (via CCU or bio-ethanol) reach 15% of total production • International CO_2 connections completed (2045). Ports of Antwerp-Bruges and Ghent become an international CO_2 hub • Keep the total carbon capture estimate for chemicals from 2020 (around 5 Mt in 2050) owing to more blue hydrogen (more capture) and more electrification (less capture) • For refining, carbon capture will be slightly lower than 3 Mt in 2050 (higher electrification and possibly lower output)

4.2.2. Steel

Transition pathways for the steel sector	2020–2030	2030–2040	2040–2050
Biomass	• Torero project running (bio-coal)	• Possible limited expansion of biomass in steel	• Status quo
Circular	• Use of plastic waste (demo) as feedstock • FID for electric arc furnace (EAF)	• Apply plastic waste in blast furnace • Two EAFs operational → 50% of steel via scrap	• Status quo
Electrification	• FID for EAF	• Two EAFs operational	• Status quo
H_2 and DRI	• Deliver the blue hydrogen pathway before 2030, essential for steelmaking (H_2-DRI)	• New DRI on natural gas and switch to blue (or green) H_2 depending on the H2BE project; replaces older blast furnace (−65% emissions) • Blue hydrogen supplies H_2-DRI in Flanders • Green hydrogen possibly as a replacement feedstock in the existing blast furnace	• DRI on hydrogen (blue or green) • Maximum substitution of coal with green/blue H_2 in the blast furnace
CCS/U	• Steelanol project running (CCU-ethanol) • Test CO_2 capture on blast furnace	• Ethanol (via CCU) from steelmaking to chemicals (ethylene) • Possible expansion of Steelanol depending on the evolution of the rest of steelmaking and hydrogen availability • Start applying carbon capture on one blast furnace	• All (Steelanol) ethanol to chemicals (for ethylene production) • Site-wide carbon capture reaches 2 Mt captured per year (for storage; if blue hydrogen is used, higher capture elsewhere). This is much lower than the 5 Mt foreseen in the 2020 roadmap.

4.3. Conclusion

The 2025 update of the 2020 roadmap underscores the growing importance of electrification (for low-temperature heat) in the chemicals and refining sectors. New(er) technologies such as industrial heat pumps and large-scale heat storage will facilitate this transition. The average electricity price being much higher than that of natural gas still makes this transition difficult. In addition, there is a risk of grid congestion with rapid, large-scale electrification. On the other hand, the growing number of hours with low or even negative electricity prices (due to a surplus of renewable electricity) makes hybrid applications (i.e. a combination of electric and gas boilers) possible. Nevertheless, the effort to capture CO_2 remains, but this depends on available infrastructure and cost. This makes current CCS projects key projects.

On plastics circularity, the level of ambition must be maintained and translated into the development of upstream value chains for plastics recycling.

The 2020 roadmap assumed a large share for both blue and green hydrogen production. The share of blue hydrogen can be increased at the expense of green hydrogen and/or imports, but here too this depends on the realisation of projects that are in the development phase.

For steelmaking, the updated roadmap now assumes a combination of the current BF-BOF route (with a change of feedstock) and CCUS, together with production via a DRI (ultimately running on hydrogen) and two electric arc furnaces (EAF). The hydrogen for steelmaking is supplied via an ATR (methane) with CCS.

For all sectors, the 2050 ambition level has been partly brought forward towards 2040. This is to account for the existing and expected tightening of targets under the EU ETS towards 2040. The current ETS target is −62% versus 2005 in 2030. As a reminder, the 2020 roadmap arrived at roughly 80% emissions reductions in 2050.

In practice, this means that major investments in all process installations must take place before 2040. For the necessary infrastructure and logistics (e.g. CO_2 infrastructure, electrification, plastics waste value chain) this means that investments must be ready by 2035. There is therefore little time left to install and test demonstration projects. Investments in chemicals, steel and refining to meet future targets will therefore need to be first-of-a-kind or more mature technologies. The majority of these investments (including infrastructure) must therefore take place within a 15-year window, counting from 2025. This also means that (for large-scale investments) the investment decision must be taken around 2030.

In that respect, the next five years are crucial. At present, several investment decisions are in the balance whose implementation is essential to achieve later targets. This means that, from a policy perspective, the focus on delivering these or equivalent investments is important. This includes helping to de-risk investments, providing clarity on regulations that may affect investments, facilitating necessary infrastructure and keeping an eye on the overall competitive context in which industry in Flanders operates (especially energy costs). This policy support becomes even more important given the current volatile and uncertain investment climate (linked to the geopolitical and economic context).

5. Policy recommendations for the industrial transition to a carbon-circular and low-CO_2 basic industry in Flanders

The previous chapters provided a clear overview of the changes that have taken place over the past five years in the basic industry in terms of policy context, industrial activity, competitiveness and technological solutions. This chapter offers an overview of policy recommendations that, within this context, aim to facilitate the industrial transition and strengthen the competitiveness of the basic industry.

The comprehensive set of recommendations is based on insights from the data analysis and interactions with stakeholders, such as interviews and consultations with the Permanent Steering Group and the Sounding Board during this study. In addition, the action plan for the Flemish industry and the policy notes of the Flemish Government, previous Klimaatsprong evaluations and recommendations from the previous roadmap and other studies were included.

From these sources, more than 50 policy recommendations were identified and grouped into four dimensions: policy steering and regulation, financing the transition, infrastructure and availability of affordable energy, and innovation and talent. Within these dimensions, the proposed policy recommendations were further clustered into a number of sub-dimensions. This structure is shown in the figure below.

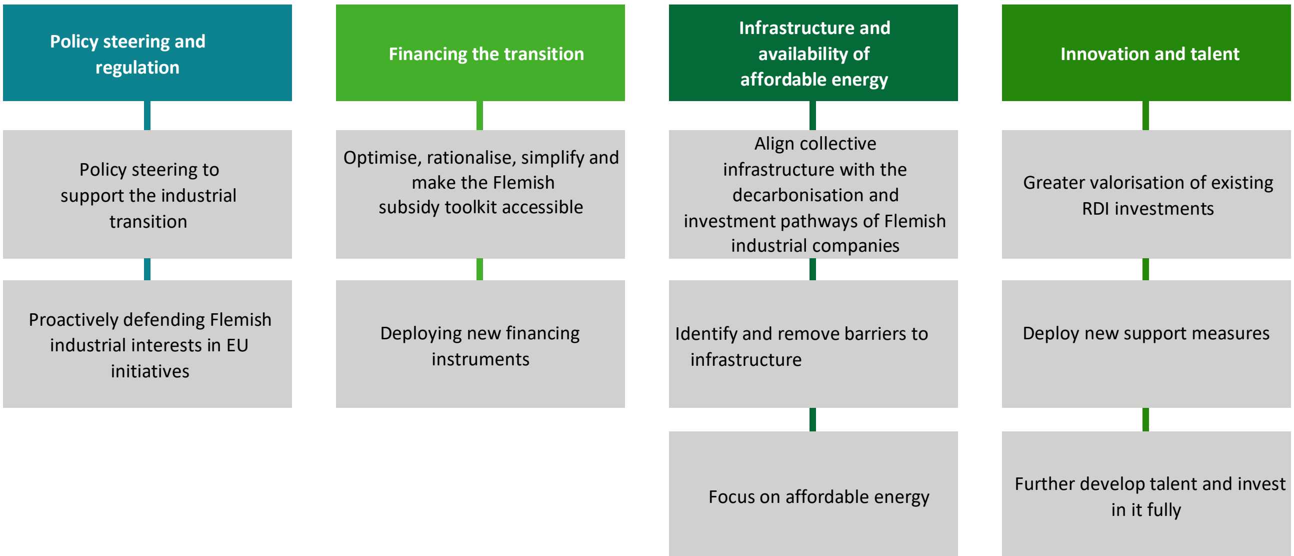

Figure 34: Overview of the dimensions of the proposed policy recommendations

The complete list of recommendations was presented to all Klimaatsprong stakeholders with the aim of completing the overview and indicating priorities to further concretise specific recommendations. During this consultation the overview was completed in interaction with those present. The current, comprehensive overview reflects the possible initiatives that contribute to the industrial transition and the competitiveness of the basic industry.

During the consultation it was not possible to quantify the relative importance of the various recommendations and to discuss their concrete design exhaustively with all the different stakeholders. In addition, the overview also includes recommendations whose implementation lies outside the mandate of Klimaatsprong. For some recommendations, trajectories have already been initiated by the competent authorities. The proposed recommendations require a follow-up process to arrive at a broadly supported and feasible policy vision in the new programme note for Klimaatsprong and to embed this in effective governance.

In the discussion that follows, the full overview of proposed policy recommendations is discussed, with reference each time to the possible role for Klimaatsprong. This makes it possible to include the insights in follow-up processes and as part of a rolling programme.

Thereafter, the assignments specifically allocated to Klimaatsprong as part of the Flemish Coalition Agreement are addressed. This more extensive elaboration was drawn up in support of the next programme note.

5.1. Detailed discussion of all proposed policy recommendations

5.1.1. Recommendations on policy steering and regulation

It is of paramount importance that Flanders, in consultation with the other Regions and the federal government, articulates a shared and feasible policy vision regarding the climate and energy transition and, with this, proactively defends its own interests in respect of European policy. In doing so, Flanders can provide the basic industry with the necessary legal certainty and breathing space for their investments. The policy framework should be clear and consistently multi-annual in terms of what government expects from companies.

Most objectives for the energy-intensive industry in Flanders stem from European decisions. Flanders aligns itself with these European objectives, but does not impose higher standards, goals or norms when transposing European or other international regulations into Flemish regulation, so as not to undermine the Flemish economy and competitive position (the “no gold-plating” principle as included in the Flemish Coalition Agreement 2024–2029).

It is therefore recommended that Flanders focus primarily on achieving the European objectives and remain alert to the reality and economic feasibility of the obligations imposed, so as not to create additional obstacles for industry. In addition, Flanders can further support industry in the transition by proactively assisting companies and coordinating cross-company projects.

The recommendations on policy steering and regulation are subdivided into two themes, further explained below:

- Policy steering to support the industrial transition; and
- Proactively defending Flemish industrial interests in EU initiatives.

Policy steering to support the industrial transition

Flanders already has a number of initiatives that safeguard policy steering of the industrial transition, namely Klimaatsprong and the Flemish Industry Forum. In addition, Flanders also has the EBO Commission, which encourages as many energy-intensive companies as possible to become and remain frontrunners in energy efficiency on a voluntary basis. Since the new EBO cycle of 2023–2026, companies are also required to draw up a climate roadmap by the end of 2024 and to map their heat demand and residual heat potential. Nevertheless, Flanders can further improve its policy steering. The following recommendations were identified in this respect:

- Monitoring the progress of the industrial transition
- Exploring the possibilities of setting up an organisational cluster approach for the follow-up and coordination of cross-company projects (e.g. infrastructure, CO_2 capture, interdependencies between FIDs, etc.)
- Supporting energy-intensive companies (via VLAIO) according to their needs on the path to decarbonisation
- Evaluating the extension of the Energy Policy Agreements (EBOs) and the possibilities for adjustment
- Studying market stimulation of low-carbon products, including through criteria in public procurement, based on developments in EU legislation
- Studying the techno-economic potential of large-scale deployment of sustainable biomass as a feedstock and energy source for the basic industry in Flanders (incl. valorisation of residual waste)

- Following up and adjusting policy measures to support circular production processes (e.g. evaluation of the raw materials declaration procedure)
- Simplifying administrative burdens by aligning reporting obligations (e.g. ETS, EBO, IMJV).

Monitoring the progress of the industrial transition

As the Flemish programme for the industrial climate transition, it is important that Klimaatsprong safeguards the overall progress of the industrial transition. Moreover, the decree on the organisation and financing of science and innovation policy requires Klimaatsprong to carry out an evaluation of the expiring Flemish programme note approved in the previous parliamentary legislature. It is therefore recommended to establish an evaluation framework within Klimaatsprong that can primarily monitor its own initiatives, while also framing this within the overall progress of the industrial transition. For monitoring overall progress, the emphasis will be on using existing reports and studies. Existing monitoring of emissions and energy use at VEKA can be used, among other sources. In addition, it is possible to look at reporting within the EBOs or the mandatory transformation plans from 2030 under the IED. The modalities for this will be developed in consultation with stakeholders.

This action has already been included in the Flemish Coalition Agreement 2024–2029 and can be further elaborated by Klimaatsprong. The proposed approach is explained in more detail later in Section 5.2.

Exploring the possibilities of setting up an organisational cluster approach for the follow-up and coordination of cross-company projects

The objective of exploring, via Klimaatsprong, the possibilities for developing a programmatic cluster approach was included in the Flemish Coalition Agreement 2024–2029 and the subsequent policy notes on Economy, Science, Innovation and Industry, and Energy and Climate.

The initiative underlines the importance of cluster operations for progress in the climate transition. Various projects are strongly interdependent, meaning the successful restart of one project can be influenced by the restart of another. A data-driven approach is needed to map existing cluster operations and collaborations, which may themselves be interdependent.

In addition to other information sources, it can be examined whether insights from the climate roadmaps (including boundary conditions and obstacles tied to the scenarios included) can be used to map the current situation. However, it is possible that this data is not available or not suitable for these purposes.

With a good understanding of current cluster operations, actions can be formulated to further stimulate these collaborations.

This action has already been included in the Flemish Coalition Agreement 2024–2029 and can be further elaborated by Klimaatsprong. The proposed approach is explained in more detail later in Section 5.2.

Supporting energy-intensive companies according to their needs on the path to decarbonisation

In addition to following up cross-company projects, it is also recommended to provide additional support to individual companies on their path to decarbonisation, via account managers. Flanders can adopt a proactive approach to provide companies with the latest knowledge about the existing financing instruments, technological options, infrastructure and the developed policy and permitting frameworks. This approach can also gather additional insight into what is happening within companies, which can be taken into account in further developing the policy framework and financing instruments.

This support will form part of VLAIO's operations and can be undertaken in collaboration with other departments, such as Environment for permitting. Klimaatsprong will be kept informed of the progress of this initiative, where possible and if desired by the stakeholders involved.

Evaluating the extension of the Energy Policy Agreements (EBOs) and the possibilities for adjustment

The current, third generation of voluntary agreements with energy-intensive companies, the EBO2, runs over the period 2023–2026. The Flemish Coalition Agreement 2024–2029 and subsequent policy notes already include a thorough evaluation of extending the EBOs after 2026. This evaluation has already started under the guidance of WEWIS and VEKA, with final delivery scheduled for December 2025, and will include both an ex-post and an ex-ante perspective. A survey of representatives from the basic industry in Flanders indicates a demand for extending the EBOs after 2026 and an evaluation focused on possibilities for adjustment to put additional emphasis on companies' transition. Regarding the ongoing evaluation, there is a request to be involved as an equal partner in the process. In doing so, account must be taken of maximally avoiding additional administrative burdens, as well as the continued sustainable anchoring of our Flemish industry.

Given Klimaatsprong's unique perspective on this theme, it is recommended to remain informed about the initiative's progress.

Studying market stimulation of low-carbon products, including through criteria in public procurement, based on developments in EU legislation

Market stimulation of low-carbon products can play an important role in the industrial transition. It is important to note that these are additional initiatives, while measures to support industry itself remain crucial (e.g. high energy costs, etc.). By stimulating demand for low-carbon products, companies can be given incentives to focus on innovation and investments in environmentally friendly technologies. This in turn leads to the development of new business models and production processes that are less dependent on fossil fuels. The Flemish Government could stimulate market demand by implementing policy and regulation that encourage the adoption of low-carbon technologies, including incorporating additional criteria in public procurement that prioritise the purchase of low-carbon products. The European Commission also plans to work on this under the Clean Industrial Deal. We therefore recommend following these developments closely and representing Flemish interests, then implementing the new regulations swiftly. Imposing more far-reaching goals than EU legislation in Flanders is discouraged because of the "no gold-plating" principle, which the Flemish Government also endorses.

Given Klimaatsprong's unique perspective on this theme, it would be worthwhile to draw up an advisory note or further elaborate the action in the form of a project. Within this trajectory, if supported by the various stakeholders, other forms of market stimulation can also be considered.

Studying the techno-economic potential of large-scale deployment of sustainable biomass as a feedstock and energy source for the basic industry in Flanders (incl. valorisation of residual waste)

In evaluating the transition pathways of the 2020 roadmap, uncertainty remains about the techno-economic potential of large-scale deployment of biomass as a feedstock and energy source for the basic industry in Flanders. It is recommended to carry out a study to map this more clearly and to incorporate this knowledge into policy steering. In Cefic's roadmap[133], biomass emerged as one of the most important transition pathways for the European chemicals sector. The question is whether this is also applicable in Flanders and what the additional potential is in the refining and steel sectors. This requires thorough research into the availability of (sustainable) biomass and residual waste in Flanders and the possible potential for imports.

Given Klimaatsprong's unique perspective on this theme, it would be worthwhile to draw up an advisory note or further elaborate the action in the form of a project. Collaboration with OVAM is possible for this project.

[133] Cefic – The Carbon Managers (2024)

Following up and adjusting policy measures to support circular production processes

Flanders, through Vlaanderen Circulair, aims to be a frontrunner in the circular economy. To accelerate developments along this transition pathway, the broader framework can be thoughtfully adjusted. There is a need to simplify and remove barriers for companies that implement circular processes. Clear and harmonised rules must provide unambiguous definitions and standards for secondary raw materials and end-of-waste criteria. A concrete example is identified in the integrated action plan for Flemish industry regarding the role of the raw materials declaration. OVAM is initiating consultations with industry federations with a view to optimising information provision and the procedure for a raw materials declaration to strengthen the circular economy in Flanders. Permitting policy must also pay attention to innovative recycling technologies. The Department of Environment is already working actively with the European Commission to develop “best practices” for permitting FOAK installations (e.g. the case of thermochemical recycling of plastics). The outcomes of this process are expected in autumn 2025. Future BREFs under the IED will also focus on circularity, with the output (the BAT conclusions) being binding for installations.

To achieve the objectives set out in the roadmap, a concrete plan is advocated for building a trans-regional circular hub from a cross-sector, cross-vector and cross-border perspective. Collaboration between Member States and economic actors in such hubs is likewise promoted by the European Commission in the “Clean Industrial Deal”. This plan must address all possible barriers (regulatory, logistical, etc.) that stand in the way of scaling up, for example the need for a well-designed logistics approach to supply sufficient high-quality plastic waste that can be used as feedstock, taking account of the complementarity between mechanical and chemical recycling.

At the European level, there is also a need for a single market for the circular economy, for waste and by-products as well as material flows that have attained end-of-waste status. Another important factor in the growth of chemical recycling is a “mass balance approach” to calculate the recycled content in plastic products and to integrate this into European targets for the use of recyclate. Commissioned by WEWIS, OVAM and VLAIO, work is being carried out under Vlaanderen Circulair and the Work Agenda for Chemicals and Plastics on a plastics recycling roadmap. This examines in detail the policy measures required. Given the importance of circularity within the industrial climate transition, there is a need to monitor developments in this area. Cooperation between the various initiatives should be central.

Given Klimaatsprong’s unique perspective on this theme, it would be useful to follow developments within Vlaanderen Circulair and, if necessary, to elaborate the action further within Klimaatsprong in the form of a project.

Simplifying administrative burdens by aligning reporting obligations

As indicated in this study, European companies – and by extension Flemish companies – already face very high administrative burdens regarding various reporting obligations. This is also an important focal point at European level, which the new Commission is seeking to give as much attention as possible. It is therefore advisable to monitor these developments closely and, once decisions are taken at European level, to implement them as quickly as possible. In addition, it can be examined whether existing reporting obligations for the energy-intensive industry can be bundled to further reduce administrative burdens – for example, by analysing obligations under ETS, EBO, IMJV, etc. Under the new Industrial Emissions Directive, companies will also have to draw up transformation plans by 2030, where parallels can be drawn with the climate roadmaps under the EBOs. Moreover, the IMJV is currently being redeveloped in light of the new IED. In many cases, confidentiality of company data is a challenge, which means that data supplied by companies often cannot be reused by multiple public bodies. This is also a known stumbling block from earlier attempts. The confidentiality of certain data limits the possibilities for simplification and alignment. In consultation with stakeholders, it could be explored, for example, whether a different level of confidentiality can be applied for certain information.

There are various ongoing trajectories that often extend beyond the target group within Klimaatsprong. Klimaatsprong should be kept informed when the initiative or other initiatives are worked out for themes directly relevant to the Flemish basic industry.

Proactively defending Flemish industrial interests in EU initiatives

New European regulation and policy steering has direct consequences for Flemish industry. It is therefore important to follow all developments closely and to form a joint vision at Flemish level that can then be communicated proactively. Based on existing regulation and emerging initiatives, the following recommendations have been identified:

- Advocate adequate recognition of low-carbon hydrogen in the context of REDIII RFNBO provisions for industrial hydrogen users.
- Contribute to the policy discussion on market stimulation of low-carbon products at European level, with rapid transposition of the Industrial Decarbonisation Accelerator Act.
- Proactively support the ETS revision that recognises industrial competitiveness with adjustment measures (e.g. 2040 target, ETS(1) cap, phase-out of free allocation of emission allowances, etc.).
- Thoroughly scrutinise (new) state aid rules under the Clean Industrial Deal (level playing field).
- Advocate sufficient EU funds for research, development and innovation within the next Multiannual Financial Framework.
- Advocate an EU instrument such as contracts for difference for decarbonisation technologies in industry (monitor the Industrial Decarbonisation Bank) and advocate inclusion of technologies that fit the Flemish roadmap.
- Proactively support the CBAM revision with the aim of making the mechanism effective by finding a solution for the export share, addressing circumvention techniques and expanding the products within the value chain
- Advocate recognition of chemical recycling in EU targets (e.g. mass balance approach for recycled content targets under the PPWR).
- Advocate a well-considered revision of accounting rules under ETS with adjustments for CCU and biogenic CO_2.
- Proactively support development of the Affordable Energy Action Plan with proposals for concrete actions.

We recommend further strengthening administrative capacity, in line with the actions included in the Flemish Coalition Agreement 2024–2029, to ensure proactive follow-up of dossiers at European level. Klimaatsprong can then be kept informed of the progress of relevant initiatives at European level, if desired by the stakeholders involved. In addition, Klimaatsprong can serve as a sounding board to align the positions communicated with the various stakeholders. It may be useful to prepare a targeted advisory note for specific recommendations, in particular to support the ETS and CBAM revisions and the establishment of the EU CfD instrument, as well as the recognition of low-carbon H_2 in a potential REDIII revision.

5.1.2. Recommendations on financing the transition

The transition of the basic industry requires major investments by industry. Investment cycles in the (petro)chemicals, refining and steel sectors are also very long, making it important to create sufficient investment certainty so that final investment decisions are taken in time. As indicated in the evaluation of the technological options, many of the technologies needed in the transition are not yet cost-efficient. Additional support is therefore needed to introduce these technologies in time. The development of the necessary basic infrastructure will also require pre-financing, as this basic infrastructure only pays for itself over a period of several decades.

Companies in Flanders have already proved successful in obtaining European funds to finance demonstration projects (i.e. the EU Innovation Fund). Access, however, remains complex, which limits the number of companies in Flanders for whom it is worthwhile to apply for these European funds (see the action under the innovation theme: active support for participation by Flemish companies and research institutions in EU research programmes and EU support mechanisms). Moreover, it has become apparent that these projects, even after obtaining EU funds, still struggle to reach implementation due, among other things, to increased costs (CAPEX) and additional uncertainty about revenues and other costs (OPEX). Additional support is therefore necessary to achieve implementation. Besides European funds, the transition also requires additional resources to meet climate targets. Flanders has already taken the first steps here, within the framework of Klimaatsprong, by developing the test case "contracts for difference" instrument (i.e. transition contracts). However, the countries around us – such as the Netherlands and Germany – are deploying much larger resources for the implementation of CO_2-reducing technologies in industry (NL: SDE++ and NIKI; DE: Klimaschutzverträge and BIK). It is therefore important for Flanders to scale up the transition instrument, both in terms of resources and in terms of the number of different technologies supported.

The recommendations made are subdivided into two sub-domains, explained further below, namely:

- optimising, rationalising, simplifying and making the Flemish subsidy toolkit more accessible; and
- deploying new financing instruments.

Optimising, rationalising, simplifying and making the Flemish subsidy toolkit more accessible

The recommendations within this theme focus on evaluating existing support measures for their effect and adjusting them where appropriate from an overarching policy vision and system approach. The aim is to deploy Flemish resources in as targeted a manner as possible to support the industrial transition. The following recommendations were identified:

- evaluate existing instruments for sustainable technologies, aimed at further simplification, speed and transparency, and coordination with federal support measures (incl. budgets). Also consider possibilities within new state aid frameworks;
- align VLAIO and VEKA instruments (e.g. green heat in industry);
- further position the VLAIO support toolkit in the market and further develop VLAIO as the "central point of contact";
- potentially deploy strategic ecology support in a targeted way to support industrial hubs, with, for example, a focus on collective investments (heat, CCS, etc.);
- revise the use of ETS funds (Climate Fund), e.g. deploy ETS1 auction revenues as a priority to support the transition among energy-intensive industries; and
- maintain compensation for indirect emission costs, adjust after the EU evaluation and advocate a joint EU mechanism.

All these recommendations are linked to actions already included in the integrated action plan for Flemish industry and the Flemish Coalition Agreement 2024–2029. Working out these actions requires political decisions in the first instance. The initiative should therefore lie with the relevant ministerial offices and administrations of the Flemish government. It is advisable, when elaborating these initiatives, to consult the relevant stakeholder groups of Klimaatsprong to gain insights into the effectiveness of existing instruments and then to indicate which financing instruments are most suitable for additional emphasis.

Deploying new financing instruments

To actively accelerate the transition, government should additionally focus on (further) developing new financing instruments within the permitted possibilities of the European state aid frameworks. The following recommendations were identified:

- evaluate and scale up the "contracts for difference" instrument with clarity on resources (incl. follow-up of "auctions-as-a-service" in EU instruments);
- explore possibilities for public-private partnerships;
- guide major decarbonisation projects through a tailored approach with sufficient resources and transparency in spending; and
- develop a mechanism for avoiding (spreading) the "first mover" malus for new infrastructure investments.

Evaluating and scaling up the "contracts for difference" instrument

The "contracts for difference" (CfD) mechanism, for new investments, not only provides a fixed subsidy to support initial CAPEX, but also tracks operational costs (OPEX) and revenues over the life of the project and adjusts subsidies accordingly. Such instruments help reduce investors' risks and thus bring them to investment decisions more quickly.

The first Flemish CfD instrument to support industry in the transition was developed within Klimaatsprong and was launched in early July 2024, when companies could pre-register. The first tender procedure started in February 2025 and runs until 30 May 2025. This is a pilot call with a budget of €70 million, for large-scale electric boilers and heat pumps, which – besides CAPEX – also provides OPEX support over a period of 10 years. The aim of this pilot call is to test the new CfD mechanism so that it can be evaluated and then scaled up. In parallel with the first call, VLAIO is also conducting a benchmarking study, making a broad comparison with such support instruments in other European countries. The final report is expected by June 2025.

Scaling up should happen both in terms of available resources and in terms of the number of different technologies supported. The evaluation can consider how to deploy the instrument most efficiently to support the different types of technologies (electrification, CCS, circular, etc.). Attention must be paid to criteria that allow sufficient technological neutrality to be safeguarded.

In addition to setting up its own mechanisms, close attention should also be paid to which new instruments are launched at EU level. At present, there is already an "auctions-as-a-service" system under which Member States have the option to support additional hydrogen production projects in their own region. With the development of the decarbonisation bank under the Clean Industrial Deal, Member States may potentially also support other technologies through such mechanisms. In this case, it can be evaluated which instrument is the most effective for Flanders to deploy funds for supporting transition technologies.

Given the elaboration and follow-up of this theme during the start-up of Klimaatsprong, it is recommended to further develop this action in Klimaatsprong's next programme.

Exploring possibilities for public–private partnerships

In further developing the Flemish subsidy toolkit, active outreach can be made to investment companies with the aim of facilitating businesses as much as possible in financing their transition projects. Such public–private partnerships can both reduce the investment risk and provide the necessary capital requirements via the investment companies (e.g. "blended financing"). It is therefore recommended to work actively with investment companies to identify synergies that can accelerate the transition. Options can also include "off-balance" financing or participatory vehicles whereby public investment companies provide capital to enable transition investments (e.g. FINEG with Finarmit and Finmalt).

The Flemish industry plan already stipulates that PMV and VEB will examine the possibilities, opportunities, desirability and feasibility of public–private partnerships for financing climate, energy and decarbonisation projects. In the context of this initiative, Klimaatsprong can be kept informed.

Guiding major decarbonisation projects through a tailored approach

Alongside administering instruments with a predefined scope and mechanism, Flanders has consistently supported projects through a tailored approach. Within the transition, such an approach is also desirable where certain technologies are introduced only rarely and therefore do not fit well into an auction system or a predefined instrument. To provide such support, approval must always first be obtained from the European Commission.

By supporting the transition proactively from a systems perspective (including via the cluster approach), it is possible to assess in advance which technologies warrant a separate instrument and for which a tailored approach is preferable. This can be developed in parallel with scaling up the transition instrument. In this way, communication can be more transparent and the necessary budgets better estimated.

Work can start from the list of known investment projects for which no final investment decision has yet been taken. This action is therefore closely linked to the account management approach via VLAIO to provide additional support to individual companies on their decarbonisation pathway through account managers (see above under policy steering).

In the Flemish industry plan, the Flemish Government is developing a coherent support framework for industry to aid the transition. Further elaboration of tailored guidance will only be possible after this evaluation. In the context of this initiative, Klimaatsprong may be consulted.

<u>Developing a mechanism for avoiding (spreading) the “first mover” malus for new infrastructure investments</u>

When building new infrastructure networks, such as for CO_2 and H_2, initial investment costs will be high relative to the initial potential revenues because only the first users will be connected. As the network expands and more users connect, investment costs can be spread more effectively. To avoid first users having to pay a high contribution for the network upfront, a mechanism should be developed to absorb the initial costs. This action is extremely important because, for new investments, infrastructure-related costs can weigh significantly. In designing the mechanism, care must be taken to ensure that investments always go hand in hand with actual infrastructure needs.

The CO_2 network falls under Flemish competences, making it relevant to develop this mechanism actively within Klimaatsprong. Fluxys already has studies underway, but there is as yet no coordinated approach involving the various administrations and ministerial offices. Stakeholders include the ministerial offices (responsible for, among other things, economy, innovation, industry, energy, climate, environment, public works and ports), the administrations VLAIO and VEKA, infrastructure operators, industry and employers’ federations and the Flemish Utilities Regulator. The mechanism developed can also be further validated with the sounding board group. In developing the mechanism, one can, among other things, look at the financing of district heating networks, where similar challenges arise.

A similar mechanism is important for the start-up of the hydrogen network. This must be worked out together with the federal level. Based on the insights gained in developing the mechanism for the CO_2 network, Flanders can initiate targeted dialogues with federal policymakers for the hydrogen network.

Given Klimaatsprong’s unique perspective on this theme, it would be worthwhile to draw up an advisory note or further elaborate the action in the form of a project. In addition, Klimaatsprong can be kept informed of the initiative’s progress, if desired by the stakeholders involved.

5.1.3. Recommendations on infrastructure and the availability of affordable energy

The transition to a low-carbon future is one of the greatest challenges for Flemish industry. Crucial to the success of this transition are robust infrastructure and affordable energy. Without these fundamentals, the ambitious objectives for decarbonisation and industrial growth cannot be achieved. Strategic policy recommendations that support the development of collective infrastructure and access to affordable energy are therefore essential.

This section discusses policy recommendations aimed at aligning collective infrastructure with the decarbonisation and investment pathways of Flemish industrial companies, identifying and removing barriers to infrastructure development and ensuring affordable energy for industry. These actions are necessary to accelerate the transition and strengthen Flanders’ competitiveness in an ever-changing global market.

The importance of these actions cannot be overstated. Well-planned and efficient infrastructure – future-proof and openly accessible – forms the backbone of industrial activities and of the climate transition, while affordable energy is a crucial factor in maintaining economic competitiveness. Proactive implementation of these policy recommendations will ensure that Flemish industry meets current requirements and is prepared for future challenges and opportunities. Government intervention will be crucial to realise the necessary infrastructure quickly enough. The infrastructure discussion must be conducted from a cross-border, cross-vector and cross-sector perspective to maximise synergies. Within Belgium (cross-regional), it should also be examined how to connect value chains optimally.

Aligning collective infrastructure with the decarbonisation and investment pathways of Flemish industrial companies

A crucial component of this transition is the availability of collective infrastructure that supports the decarbonisation and investment pathways of the basic industry. Given the complexity and long lead times of infrastructure projects, a considered approach is essential. This calls for broad collaboration across sectors, regions and even national borders. To emphasise these elements, several policy recommendations have been formulated:

- System approach for infrastructure projects that anticipates future investments (e.g. the MIEK programme in the Netherlands, link with EnergieGrip).
- Proactively reserve sufficient space for pipeline corridors (based on the existing position statement).
- Develop a tool to project energy needs and mix (e.g. energy study model).
- Work with the federal government to align investment plans and guarantee security of supply.
- Develop an international port policy.
- Initiate international cooperation around collective infrastructure for CO_2, H_2 and other molecules or hydrogen derivatives, and for electricity.

System approach for infrastructure projects anticipating future investments

It is essential to align infrastructure projects with the long-term needs of the basic industry and with one another so that synergies are optimally exploited. This requires a genuine system approach. A clear, stable long-term vision is necessary. In the Netherlands this is organised via the Multi-Year Programme for Energy and Climate Infrastructure (the “MIEK programme”). Such a vision helps companies align their plans and clearly communicate their long-term needs. In this way, large infrastructure projects can be matched to those needs and the necessary capacity provided in time. This system approach should be supported by insights from the investment plans of the various companies. To map this, inspiration can be drawn from the EnergieGrip initiative.

This recommendation is closely connected to the assignment for Klimaatsprong in the Flemish Coalition Agreement, namely launching a participatory process to determine infrastructure needs. Section 5.2 explains this assignment in more detail.

Proactively reserving sufficient space for pipeline corridors

The update of the roadmap study highlights the importance of connections within Flanders and with neighbouring countries. Pipelines will be necessary for the efficient and effective transport of, among other things, hydrogen (or hydrogen carriers), CO_2 and other molecules. Underground pipelines can, for example, connect the chemical clusters in the Port of Antwerp with those in the Netherlands and Germany. In the previous period a position was drawn up on pipeline corridors. This position can be revised in light of the insights from this study and submitted to the Flemish Government. As part of the 2024–2029 Coalition Agreement, the Flemish Government already refers to initiating consultations with the Netherlands on cross-border networks and reserving space for pipeline zones needed to make the economy more sustainable.

In the previous period the stakeholders within Klimaatsprong prepared an advisory note. Given Klimaatsprong’s unique perspective on this theme, it is useful to update the advisory note with recent insights and submit it to the Flemish Government. In addition, Klimaatsprong can be kept informed of the initiative’s progress, if desired by the stakeholders involved.

Developing a tool for projecting energy demand, supply and infrastructure

Any discussion of infrastructure requires insight into the capacity needed. This discussion becomes highly complex when it concerns different energy carriers across different sectors and time periods. The tool will provide insight into the infrastructure and energy sources needed to support the transition. This requires a rigorous methodology and a calculation model that can support the various discussions with projections of the industry’s future energy needs and mix. An important condition is that this should not be a one-off analysis or study. Given the complexity, baseline assumptions are likely to change over time. Energy carrier prices can also fluctuate and thereby influence decisions.

Various calculation models are available to support such projections. A concrete example is the model developed as part of the Energiestudie 2050+, an initiative in the previous legislative period that sought to understand how to provide Flemish society with climate-friendly energy in a realistic and cost-efficient manner. It does so using a cutting-edge, open-source energy model (the PyPSA-Eur model) that optimises the future energy system from a techno-economic and European perspective. This model is one possible option for projecting the industry's future energy needs and mix.

The federal government will establish a High Council for Security of Energy Supply. One of this High Council's tasks is to collect annually the current and projected evolution of consumption, capacity and production of all energy vectors in light of the most recent data and the progress of projects. It is important that the choice of a projection tool be aligned with the federal initiative. In the context of infrastructure for the climate transition it is also important to devote sufficient attention to the use of energy sources as feedstock in the basic industry.

This recommendation is closely connected to the assignment for Klimaatsprong to launch a participatory process to determine infrastructure needs. Section 5.2 explains this in more detail. In the context of the assignment to launch a participatory process to determine infrastructure needs, there is a need for a dynamic tool that makes it possible to quantify shifts or changes in the underlying assumptions.

Cooperating with the federal government to align investment plans and guarantee security of supply

A coordinated approach between the Flemish and federal governments is necessary to align investment plans and ensure security of supply (including via the inter-federal energy pact[134]). The other regional governments must also be involved in this cooperation. Developing a joint vision that takes account of the needs of different sectors and energy carriers can form the basis for international cooperation. As an interim step, a clear vision for Flanders can be drawn up. The basis for these discussions can be found in the development of the Flemish Energy and Climate Plan. In this way the infrastructure debate is conducted from the shared ambition to realise the climate transition and strengthen the competitiveness of the basic industry in Flanders.

The federal government will work with the Regions on a long-term vision and strategy based on the figures produced by the High Council for Security of Energy Supply. Klimaatsprong brings together a wide variety of stakeholders and can therefore make a unique contribution to these discussions by highlighting unique insights.

Klimaatsprong could be consulted as part of the High Council's work, specifically in drawing up the long-term vision and strategy. In addition, Klimaatsprong can be kept informed of the progress of this initiative, if desired by the stakeholders involved.

Developing an international port policy

Flanders has strategic seaports that play a crucial role in industrial infrastructure. In every transition pathway, the seaports are pivotal for both energy and feedstock infrastructure. Their role in the climate transition is unmistakable and deserves targeted support. They also bring a unique perspective thanks to in-depth knowledge and experience with the complexity of basic industry value chains. Developing an international port policy can strengthen Flanders' position as a true hub. Sufficient attention must be paid to each transition pathway and to their interactions.

This study also shows the importance of developing pilot projects in port clusters such as Antwerp and Ghent. These regions are ideal thanks to their industrial concentrations and the presence of current initiatives such as Kairos@C, the NH_3 Antwerp Terminal, H2BE and ZESTA.

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[134] Energy Pact

The Flemish industry plan acknowledges the crucial role of the seaports. The Flemish Government will support the port companies as industrial centres and involve them as key partners in rolling out an industrial policy. In addition, an international port policy will be developed in consultation with the Flemish ports and the relevant departments and agencies.

Given the potential impact of such a policy on the climate transition, it is important that Klimaatsprong be kept informed of progress and outcomes insofar as they are relevant to the basic industry's transition.

Initiating international cooperation around collective infrastructure for CO_2, H_2 and other molecules or hydrogen derivatives, and electricity

The updated roadmap study underlines the importance of transporting CO_2, H_2 and other molecules or hydrogen derivatives, and electricity, with an emphasis – particularly for hydrogen carriers – on enabling effective and efficient import. Collective infrastructure for CO_2, H_2 and other molecules or hydrogen derivatives, and electricity should not only be tackled cross-sector and inter-regionally, but will also benefit from economies of scale through international cooperation. Belgium can take a strategic position as a corridor to, for example, the Netherlands, France and Germany. International cooperation is therefore essential for developing collective infrastructure for CO_2, hydrogen, methanol, ammonia and electricity. Besides potential competitiveness gains for Flemish companies, international cooperation is also important to achieve the required volumes. Such cooperation can also be a precondition for EU funding (e.g. the Connecting Europe Facility).

International cooperation on collective infrastructure is a possible next step within the participatory process on infrastructure needs, as these insights can support discussions with various partners. Given the potential impact of any cooperation, it is important that Klimaatsprong be kept informed of developments in this area.

Identifying and removing barriers to collective infrastructure

To accelerate the transition to a low-carbon industry, barriers to developing collective infrastructure must be identified and removed. These are specific additions or refinements to earlier recommendations. The proposed policy actions are:

- Improving the legal certainty of permits (reduce the impact of appeals)
- Updating the Flemish hydrogen strategy and the Flemish CCUS vision note in line with the conclusions and recommendations of the updated roadmap (e.g. greater emphasis on low-carbon hydrogen)
- Finalising the H_2 Decree
- Drawing up a roadmap for the logistics chain of the future to maximise plastics recycling and ensure sufficient biomass (including spatial planning)
- Launching consultations on grid flexibility and stability and on tackling congestion (e.g. adjusting the "first come, first served" principle for new connection agreements and enabling flexible connection agreements)

Improving the legal certainty of permits

An efficient, legally certain and transparent permitting process is important for the climate transition of the basic industry in Flanders. CO_2-reducing projects are often innovative and unique, and therefore not always easy to fit under existing legislation. Moreover, both conventional and renewable energy projects, as well as energy transmission and distribution infrastructure, face increasing difficulties in obtaining and retaining permits (including due to appeals).

The Flemish Government is working through a commission on an action programme to improve permitting.

Given the importance of this initiative for the basic industry's transition, Klimaatsprong can be consulted in this process or kept informed of developments.

Updating the Flemish hydrogen strategy and the Flemish CCUS vision note

The Flemish Government intends to update the Flemish hydrogen strategy, supported by a study on the use of low-carbon hydrogen and potential support for the import, production, infrastructure and use of hydrogen and its derivatives. The insights and recommendations from the current roadmap study can support this update.

Additional attention is needed for the role of CCUS alongside hydrogen. An update of a Flemish CCUS vision note is also required. This will also contribute to a potential system approach to infrastructure projects.

The update of the Flemish hydrogen strategy will very likely be completed before Klimaatsprong's work under the new programme note gets under way. If desired by the stakeholders involved, Klimaatsprong can build on this vision. The timeline for a possible update of the Flemish CCUS vision note is unknown and can be monitored in consultation with VEKA.

Finalising the H_2 Decree

It is widely recognised that hydrogen and hydrogen-derived energy carriers will play an important role in the energy transition of the Flemish basic industry. The H_2 Decree must be finalised to clarify and strengthen the legal and policy frameworks for hydrogen infrastructure. There is already a Flemish decree for CO_2 transport, but there is also a need for a clearer framework for CO_2 infrastructure (e.g. rights of way). This can be examined further in the context of updating the Flemish CCUS vision note. Again, coordination between the regional governments and the federal government is emphasised.

As part of the 2024–2029 Energy and Climate policy note, work is underway on a regulatory framework for the distribution of hydrogen via hydrogen networks in the Flemish Region. Given the importance of this initiative for the basic industry's transition, Klimaatsprong can be consulted in this process or kept informed of developments.

Drawing up a roadmap for the logistics chain of the future

The 2020 roadmap recommended a thorough study of the availability of (sustainable) biomass for the industrial transition. To reduce uncertainty on this point, that recommendation is repeated here. The updated roadmap study also stated that logistics chains for plastics recycling and biomass must be optimised. A study should determine how these logistics chains can best be organised to supply industry with sufficient feedstocks. Developing a roadmap for the logistics chains of the future is necessary to maximise plastics recycling and ensure sufficient biomass. This also includes providing space for the required infrastructure. Existing waste processing infrastructure in Flanders plays a crucial role here and can be expanded to meet new requirements.

The role of logistics chains within the circularity and biomass pathways will most likely be included in the work under those respective themes – for example, integrated into the study on bio-based chemistry in Flanders or the work on the circular hub.

Given the importance of circularity within the industrial climate transition, there is a need to monitor developments in this area. Collaboration between the various initiatives should be central. Klimaatsprong can prepare an advisory note on this theme or further elaborate the action as a project.

Launching consultations on grid flexibility and stability and tackling congestion

Demand for electricity has logically increased in recent years. Electrification in industry and other sectors, and the expansion of data centres, have driven demand for heavier connections so rapidly that grid operators are warning of potential capacity problems. To reduce grid congestion and increase flexibility, the needs of companies must be addressed proactively. If Flanders succeeds in tackling these issues proactively, it can become a competitive advantage. Energy supply and security are key factors in investment decisions.

During preparation of this roadmap, VEKA launched consultations on grid flexibility and stability. For congestion management a working group was set up including the Cabinets for Economy, Energy and Environment, VEKA, VLAIO, the Department of Environment and the grid operators Elia and Fluvius. Elia and Fluvius have also strengthened their congestion management action plans to support industry's investment plans as much as possible. This consultation is encouraged. Representatives of the basic industry must be involved in these discussions. Klimaatsprong is uniquely positioned to contribute thanks to its broad stakeholder base and diversity of insights. Again, there is a need to conduct this debate in the wider context and potential synergies with other initiatives.

In the short term, specific measures can be explored, including adjusting the “first come, first served” principle for new connection agreements and enabling voluntary flexible connection agreements. There are also opportunities for congestion management at the local level (e.g. industrial estates). For instance, collaborations can be explored at the industrial estate level, enabling companies to coordinate among themselves to avoid congestion. The Netherlands has previously faced acute congestion; those insights can be taken into the ongoing discussions.

Long-term measures are also needed. In this context, all parties benefit from an overarching long-term vision – for example via the Flemish Energy and Climate Plan. This forms the basis for industry to draw up investment plans for their sites – for example, via a concrete transition plan – which in turn provides the basis for grid operators to align their investment plans optimally with industry needs (including through EnergieGRIP). It is important that companies are sufficiently encouraged to prepare transition plans and that these insights can be made available in anonymised form in the context of infrastructure investment planning.

Given the importance of this initiative for the basic industry’s transition, Klimaatsprong can be consulted in this process or kept informed of developments. Feedback is needed because there is potential for cross-fertilisation between insights from the ongoing consultation and the knowledge within Klimaatsprong.

Focus on affordable energy

Affordable energy is an essential condition for the competitiveness of Flemish industry. Policy recommendations to safeguard affordable energy include:

- Accelerating the availability of competitively priced renewable energy
- Exploring options for small modular reactors in Flanders
- Implementing a coordinated policy with the federal government based on the energy norm to reduce energy costs
- Providing clarity on distribution network tariffs for industry

Accelerating the availability of competitively priced renewable energy

Accelerating the availability of competitively priced renewable energy is crucial to lowering energy costs and supporting the transition to a low-carbon industry. This includes investments in renewable sources such as wind and solar, as well as improving storage and distribution infrastructure. The Flemish Coalition Agreement also works towards a stable investment climate for renewable energy production.

Given the importance of this initiative for the basic industry’s transition and its potential impact on the mandate regarding collective infrastructure needs, Klimaatsprong should be kept informed of developments and consulted where possible.

Exploring options for small modular reactors in Flanders

In addition to renewable energy, nuclear energy can also form part of a balanced and sustainable energy mix. Small modular reactors could provide a sustainable and affordable energy source for industry. It is important to examine the possibilities and feasibility of this technology in Flanders. This has been assigned to WEWIS in the Flemish Coalition Agreement. VLAIO is also currently exploring participation in an IPCEI Nuclear programme that would start in 2026.

Given the importance of this initiative for the basic industry’s transition and its potential impact on the mandate regarding collective infrastructure needs, Klimaatsprong should be kept informed of developments.

Implementing a coordinated policy with the federal government based on the energy norm

Federal energy policy helps determine energy costs, investment in green energy, the energy mix and the stability of the electricity grid – all of which directly affect the competitiveness of energy-intensive sectors in Flanders. A coordinated policy with the federal government is necessary to keep companies' energy costs competitive. This action is part of the integrated action plan for Flemish industry. There are, however, also measures that can be taken within the Flemish Government; proposals will be developed under the action on distribution network tariffs (see below).

Given the importance of this initiative for the basic industry's transition, Klimaatsprong should be kept informed of developments.

Creating clarity on distribution network tariffs for industry

It is important for Flemish policy to provide clarity on distribution network tariffs for industry. This recommendation is a specific focal point within the broader discussion on affordable energy. Flanders itself can also take measures to make energy costs more predictable and manageable – for example through Flemish public service obligations for electricity and natural gas, as well as alternative financing mechanisms for infrastructure investments (see also "mechanism to avoid a first mover malus").

Given the importance of this initiative for the basic industry's climate transition, a project track could be launched within Klimaatsprong to develop proposals for the competent authorities. These proposals should focus on options that fall within the Flemish Government's powers regarding energy costs, and not on the coordinated policy with the federal government.

5.1.4. Recommendations on innovation and talent

Innovation remains a key element in the transition to a climate-neutral industry. The 2020 roadmap study and this update make it clear that deep emission reductions in industry are only possible through large-scale process and energy innovations that will only become widely available after 2030. Moreover, innovation does not stop there – these new processes will also need further optimisation to increase their economic competitiveness (e.g. cheaper ways to capture CO_2 or more efficient electrification of heat).

The Flemish government has made climate innovation for the basic industry a priority – among other things via the spearhead clusters (e.g. Catalisti and Flux50) and the Moonshot programme, but also via other support instruments through VLAIO. These instruments are operating at cruising speed, focusing on the innovation challenges identified in the 2020 roadmap.

The tension around innovation arises, on the one hand, from the time required for innovation – especially large-scale industrial processes – to reach maturity, and, on the other, from the pace at which emission reductions must occur. Since the 2020 roadmap was developed, European climate targets have been significantly tightened, which in practice means that the 2050 ambition level for industry in the 2020 roadmap would now have to be achieved a decade earlier.

This study therefore identifies the following priorities for innovation. First, the need to accelerate the valorisation of Flemish R&D investments. Second, the importance of deploying new support mechanisms to reach higher technology readiness levels more quickly and easily.

For talent, the study notes concerns about shortage occupations in industry and declining interest and quality in STEM in Flanders. Delivering the industrial transition will require not only people willing to work in industry, but also people with the right skills to work with new technology and other innovations.

Accelerating the valorisation of Flemish R&D investments

As noted above, it is important that innovative technologies developed in Flanders actually contribute to achieving a climate-neutral and competitive industry in Flanders. There is a risk of substantial basic and strategic research being supported without timely translation into industrial implementation at high TRLs (e.g. 8–9).

Possible policy recommendations to mitigate this risk include:

- strategic reform of the spearhead clusters;
- accelerating the Moonshot programme with a view to valorisation; and

- making greater and better use of European levers.

Reforming the spearhead clusters and strategic research centres with "Mission-Oriented Innovation" (from TRL 3 to 9) as a central element

In Flanders, the spearhead clusters play an important role as active conveners (e.g. between industry, research institutions and government) in stimulating and accelerating technological innovation in the sectors they represent. They are therefore well placed to further implement mission-oriented innovation. This can be done by defining specific large-scale goals more clearly and, above all, by mapping the (technological and non-technological) barriers to achieving these goals, then removing them one by one through specific policy advice and their own activities. Alignment with the strategic research centres that work at higher TRLs is relevant here. The Moonshot programme is a good example of identifying and solving technological challenges, but it is largely limited to the early phases of innovation and commercialisation pathways.

The Flemish industry plan announced that the Flemish R&D&I instruments will be aligned even better with companies' needs and that maximum effort will be made to valorise Flemish knowledge and research institutions. Given the importance of this initiative for the basic industry's transition, Klimaatsprong should be kept informed of developments.

Accelerating the Moonshot programme with a view to valorisation

The Moonshot programme is supporting promising research towards a climate-neutral and circular Flemish basic industry. The programme has prompted Flemish research institutions to place greater focus on the challenges set out across its four routes.

Translating Moonshot-funded research into industrial applications remains a challenge if it is to contribute in time to climate neutrality in the Flemish basic industry. New (process) technologies for industrial application often have long development times.

It is therefore positive that the Moonshot programme is paying increasing attention to so-called "later-stage innovation" up to TRL 5–6. Scaling to higher TRLs requires different instruments (see below). For Moonshot, it remains important both to continue developing a broad pipeline of new ideas (at low TRL) and to have sufficient resources to grow new technologies to higher TRLs (6 to 9). This could be achieved, for example, by adjusting the programme's scope or by selecting projects and routes more explicitly for stronger valorisation potential.

It is also recommended to examine to what extent more Moonshot projects can obtain an extension and complement through EU programmes such as Horizon Europe. A strong National Contact Point (NCP) operation (via NCP Flanders[135]), aligned with Catalisti to better link to EU research and project funding, can help achieve multiple objectives and lower the barrier to valorisation. Furthermore, the full support toolbox should be mobilised to help Moonshot projects[136] scale (e.g. towards start-ups and scale-ups). This includes programmes such as IPCEI, EFRO, EIC and the aforementioned Horizon Europe programme.

(The innovation working group under) Klimaatsprong can take an advisory role in exploring acceleration of the Moonshot programme and implementing the above recommendations. Conversely, Moonshot can provide regular feedback to Klimaatsprong. In this way, mutual strategic feedback can be organised so both initiatives can respond optimally to each other, while respecting Moonshot's existing governance.

Active support for participation by Flemish companies and research institutions in EU research programmes and EU support mechanisms

European research programmes (e.g. Horizon Europe) and support mechanisms (e.g. the EU ETS Innovation Fund) are important to leverage limited Flemish funding for research and further development of new technology. For EU-level

[135] https://ncpflanders.be
[136] There are already eight Moonshot projects participating in EU-funded research programmes.

research programmes, additional administrative support could increase the success rate of projects with a Flemish lead[137]. There is also likely a need for a solid analysis to map barriers for Flemish actors in these programmes. An example raised during the workshop was the difficulty of getting Flemish research institutions and companies to collaborate under ERA-NETs. Flemish positioning in European channels that design and implement these research programmes could also be strengthened via the National Programming Committees (NPCs), which can proactively translate Flemish research priorities to the EU level.

The innovation working group under Klimaatsprong can, at VLAIO's initiative, further map these elements and propose mitigating actions.

Flemish projects already have a high success rate in obtaining EU funds for large-scale projects, particularly via the EU ETS Innovation Fund. VLAIO's (company-focused) account management approach plays an important role. As competition with neighbouring countries for these limited funds will only increase, the innovation working group under Klimaatsprong has already developed an initiative to support Flemish companies submitting projects to EU support mechanisms (such as the Innovation Fund and the future Decarbonisation Bank (CfD mechanism) under that fund). This concerns a metaphorical "backpack" of actions the Flemish government can take (often with limited financial input) to increase the chances of Flemish projects in EU support calls. Implementation and evaluation of this "backpack" require further follow-up by VLAIO and VEKA.

Klimaatsprong (and its innovation working group) can continue to play an advisory role.

Deploying new support mechanisms for scaling technology

As noted above, bringing new technology to higher TRLs (towards and above TRL 6) is a challenge. This study, and the workshop on policy instruments organised in that context, proposes the following recommendations for this specific barrier:

- a specific support programme to bridge the so-called "Valley of Death";
- strengthening the capacity of research institutions and companies to realise innovation scale-up; and
- simplified permitting for demonstration projects and innovative first-of-a-kind investments.

Support programme to bridge the Valley of Death

Bridging TRL 6 to TRL 8 and higher is a well-known "valley of death" for innovation. This is not only because significantly more financial resources are needed to scale a technology, but also because a grey zone emerges: research institutions (which can work up to TRL 6) lack the capacity to develop further, while industry still sees the risks for such early-stage investments as too high. Moreover, the technology is often developed not by an industrial end user but by a "technology provider" (usually at the request of end users).

In terms of support, technology innovation towards TRL 7 often ends up in a funding gap: it is ineligible for classic R&D support and too early for investment aid. The innovation working group under Klimaatsprong drafted a proposal to create a new industrial demonstration fund by combining these two mechanisms (innovation and investment support). This proposal was not taken up.

The working group could carry out a new needs analysis to substantiate specific support. During stakeholder interactions, the following elements already emerged:

- support for Front End Engineering Design (FEED), as it generates better know-how on the costs of further development[138];
- filling a possible financing gap (e.g. CAPEX and OPEX); and
- providing the necessary infrastructure to test technology at scale.

[137] See also the strengthened collaboration with NCP Flanders mentioned earlier.
[138] Following existing similar support for projects seeking EU funding.

To gain further insight into barriers to TRL scale-up, it would be useful to analyse the results of the Flemish TRL-8 call[139]. It could also be considered to develop a new specific programme under EFRO[140], since Flanders has previously supported EFRO projects at TRL 7–8.

The innovation pool can also be enlarged by creating more room for foreign innovations seeking a location and/or industrial partner for demonstration projects. Cooperation with Flanders Investment & Trade (FIT) can be strengthened for this purpose.

Finally, the innovation ecosystem can be reinforced by encouraging activities by (mainly foreign) technology providers in Flanders, or even by developing home-grown technology providers (e.g. spun out of research institutions).

In addition, insights already obtained during the R&D&I system analysis under the "Flemish Acceleration" can be taken on board[141]. A "Central R&D&I Steering Group" has launched a strategic dialogue with all relevant stakeholders. This consultation should result in broad and/or sector-specific agendas on knowledge, innovation, valorisation and simplification, with public and private actors committing jointly. Initiatives within Klimaatsprong can build further on the insights gained in this process.

Given the importance of this theme in the industrial climate transition, Klimaatsprong (and its innovation working group) can prepare an advisory note on this theme or further elaborate the action as a project.

Support for research institutions and companies to scale up innovation

Building on the above, we can also look specifically at how research institutions and companies can promote further scale-up and how to improve this. Funding for research at universities and strategic research centres could, for example, place greater emphasis on infrastructure that enables scaling up to TRL 6. The Moonshot LSI projects are a good example.

There is also too little insight into how research institutions plan to further valorise their own research through technology transfer (e.g. via spin-offs, start-ups, etc.). This can be addressed by, among other things, using data from existing databases (e.g. Horizon). We can also look at the example of the Flanders Institute for Biotechnology (VIB), which has a strong start-up culture and its own fund for this purpose. In addition, the Baekeland mandates could potentially be expanded to facilitate a start-up's first years.

(The innovation working group under) Klimaatsprong could examine this further or help steer a VLAIO study on the topic.

Removing regulatory barriers to innovative scale-up

Industrial demonstration projects and first-of-a-kind (FOAK) installations, like most other (large) investments on a site, require an environmental permit. The usual way to limit the administrative burden for such innovative investments is to use regulatory sandboxes. This process is already underway as part of simplifying permitting procedures. Regulatory sandboxes do have a limitation: once a zone is fully used, no new initiatives can be added. It could be considered to introduce, alongside sandboxes, specific simplified permitting procedures – time-limited – for demos and FOAK installations. Once such a temporary permit expires, the installation must comply with the normal permitting conditions.

Given the importance of this initiative for the basic industry's transition, Klimaatsprong should be kept informed of developments.

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[139] From 2023.

[140] The European Regional Development Fund. The Flemish ERDF programme subsidises projects in Flanders that translate the objectives for a smart and sustainable Flanders into practice. https://www.vlaio.be/nl/vlaio-netwerk/europees-fonds-voor-regionale- development

[141] R&D&I system analysis underpins the Flemish productivity offensive "Flemish Acceleration" | Department of WEWIS

Further developing talent and investing in it fully

Talent and skills for the industrial climate transition is a theme that has not yet been addressed under Klimaatsprong. The topic is an important bottleneck that also emerged in this study's competitiveness analysis. During the workshop, stakeholders stressed that talent is best not bundled under innovation. Although there are overlaps, different policy competences are involved (e.g. education, employment, etc.) and different actors in society.

The talent theme also falls outside the scope of Klimaatsprong and will therefore not be addressed within Klimaatsprong. During the policy workshop, however, several initiatives to support talent were discussed:

- increasing the inflow into industry of certain profiles;
- using sector covenants; and
- structurally preparing workers for the (technological) transition in industry.

Increasing the inflow into industry of certain profiles

At present, industry already faces several shortage occupations (e.g. maintenance technicians), which can put productivity and competitiveness under pressure. Improving local cooperation between industry and VDAB could help mitigate this. Further, investments could be considered in more specific training courses organised jointly by VDAB and companies.

Sector covenants as a lever for the industry's transition needs

The Flemish Government concludes sector covenants[142] with the sectoral social partners of sectors. SERV supports the implementation of these covenants. In these agreements, the sectoral social partners commit to carrying out actions and projects in their sector relating to:

- aligning education with the labour market;
- inflow, lateral inflow, progression and retention;
- lifelong learning and skills policy;
- workable work; and
- diversity and inclusion.

Based on the above list, it seems possible to also include the impact of the industrial climate transition in the covenants.

Implementing "Net-Zero" industry academies to prepare workers for the transition

The shift to new technology in industry can have a significant impact on workers. To address this structurally, use can be made of the "Net-Zero" academies being implemented under the EU's Net-Zero Industry Act[143].

The "Net-Zero" academies are designed to meet the demand for skills in net zero technologies. They are not physical institutions (and as such fully respect Member States' competence over education and training), but take the form of organisations, consortia or projects with three core functions:

1. develop curricula, content and teaching/training materials for education and training. This content is co-designed with industry and other relevant stakeholders to ensure it is up to date and matches actual skills needs;
2. disseminate the content via local education and training providers, which can range from companies to centres for vocational education and training to social partners such as trade unions, depending on local needs; and
3. develop qualifications for voluntary use by Member States and their education and training providers, to facilitate transferability between jobs and cross-border labour mobility.

[142] https://www.vlaanderen.be/werken/sectorconvenants
[143] https://ec.europa.eu/newsroom/growth/items/823315/en

Such academies have already been launched for battery technology and solar energy. It is expected that other value chains (e.g. raw materials) will also get academies. The Flemish Government can, together with like-minded Member States, ask the European Commission to develop academies for net zero technologies in, for example, the (petro)chemicals, refining and steel sectors. Regardless of the European track, launching such academies autonomously can also be considered, in cooperation with educational institutions and social partners.

5.2. Elaboration of the assignments allocated to Klimaatsprong in the Flemish Coalition Agreement

The Klimaatsprong programme guides the transition to make energy-intensive industry in Flanders carbon-circular and low-CO_2 by 2050 without losing its competitiveness. Klimaatsprong's mandate is regulated via a programme note, valid for five years. This study serves to support the drafting of the new programme note by defining concrete actions for the next five years.

To put this approach into practice for the next five years, choices inevitably have to be made. Klimaatsprong cannot execute the entire set of proposed policy recommendations. This does not mean that non-selected initiatives are therefore subordinate or should not be implemented. As noted, actions may already have been initiated or may simply fall outside Klimaatsprong's focus. In addition to selecting policy recommendations, the full list of actions can be reviewed periodically so that the development of these themes is closely and proactively monitored.

In the Flemish Coalition Agreement, some assignments are already explicitly allocated to Klimaatsprong. The update of the roadmap "Towards a carbon-circular and low-CO_2 Flemish industry", with associated long-term objectives, is also part of the provisions of the Coalition Agreement.

In the discussion that follows, the assignments from the Flemish Coalition Agreement allocated to Klimaatsprong are discussed in more detail. Inspiration was taken from the preceding discussion as well as insights from the roadmap study. The order of the assignments follows the order in the Coalition Agreement.

Overview of the relevant paragraphs from the Flemish Coalition Agreement, in the order of discussion:

- "We will develop a **framework for the transition to climate neutrality** via the Flemish Klimaatsprong and, in consultation with the sectors, evaluate general and sector-specific objectives. We will **report annually on the progress of the necessary industrial transition** and adjust instruments where needed."
- "Within Klimaatsprong we will investigate whether we can develop a **programme-based cluster approach**, using on the one hand the climate roadmaps that energy-intensive companies which have joined the Energy Policy Agreement (EBO) must prepare by the end of this year, and on the other the inventories already drawn up of the specific heat demand and residual heat supply of all EBO companies."
- "The Flemish Government will also launch within Klimaatsprong a **participatory process** between infrastructure operators, large industrial clusters, major SME zones and government to determine **infrastructure needs**, and to examine how these can be met through collective infrastructure (electricity, power grids, hydrogen networks, heat networks, infrastructure to liquefy and transport CO_2…). The Flemish Government will prioritise the largest infrastructure projects for the future, based on CO_2 reduction potential."

Monitoring the progress of the industrial transition

As mentioned earlier in the full overview, it is important that Klimaatsprong keeps watch over the overall progress of the industrial transition. It is therefore recommended to establish an evaluation framework within Klimaatsprong that can track both its own initiatives and the overall progress of the industrial transition on an annual basis. The basis for this is the updated roadmap "Towards a carbon-circular and low-CO_2 Flemish industry".

Annual reporting on progress in the transition should rely as much as possible on existing data, reports and studies to avoid additional administrative burdens. Where necessary, a partnership for data sharing between companies and government can be established in consultation with the relevant stakeholders. The insights from the reporting must be sufficiently action-oriented to enable appropriate adjustments. First, proposals for the substantive content are discussed, followed by the process.

Annual reporting requires a thoughtful selection of parameters. It is important that the selection focuses on parameters on which Klimaatsprong itself can have a direct impact. In addition, duplication or inconsistencies with existing reports should be avoided. One possible option is to draw up, and update annually, an inventory of strategic projects linked to progress within the roadmap. This is an overview table with the status of decarbonisation projects and their reduction potential. In practice, this inventory can be managed within Klimaatsprong (e.g. by VLAIO), supplemented by input from those involved and from other bodies (e.g. VEKA, WEWIS, FIT, etc.). This also makes it possible to track how many announcements actually move forward and remain operational in subsequent reports. In this way, close adjustments can be made for projects of major importance to the climate transition of the basic industry.

An overview can also be included of public funds invested (Flemish, European) through support to projects (financial support, risk coverage, tailored company guidance) and investment in studies and knowledge development in support of Klimaatsprong's objectives.

Given the role of innovation and technological developments in the roadmap as a whole, indicators from Moonshot projects and its own monitoring can be added in consultation with Moonshot.

With a view to competitiveness, indicators such as the price of gas and electricity (including comparisons with neighbouring countries, the EU, the US and China) or imports and exports can be considered. These are, however, rather supplementary parameters overall, given Klimaatsprong's limited influence on them.

For additional elements, inspiration can be found in Section 3.2: "Evolution of Flemish industrial activity in the (petro)chemicals, refining and steel sectors". For various parameters there are already existing reports available, including emissions, energy consumption, production volume, energy mix, added value, investments, imports, exports and number of employees. These can be consolidated into a report tailored to Klimaatsprong. It is important to rely on publicly available sources in a readily reproducible format. This can avoid complex preparations and high workloads over time.

Preparing both the development of the concrete reporting format and the annual reporting itself can be taken on by VLAIO, in cooperation and consultation with VEKA. A project-based governance framework should be set up within Klimaatsprong in which sector representatives can contribute to the selection and definition of concrete indicators. These can be validated by the Permanent Consultative Body. The actual reporting can be scheduled annually for a meeting of the Permanent Consultative Body and the Sounding Board Group. After the members have taken note of the results, a discussion can be organised to identify actions or themes for which an advisory note can be prepared within Klimaatsprong. The modalities of this process are part of a broader discussion on governance. It is important that this annual reporting is assigned a full and proper role within this structure.

Exploring the possibilities of setting up an organisational cluster approach for the follow-up and coordination of cross-company projects

In exploring and, where appropriate, developing a cluster approach, Klimaatsprong can take an active role. A project structure can be launched within Klimaatsprong. This approach centres on cooperation between Klimaatsprong, the Flemish seaports and various departments within the Flemish Government. Insights and resulting actions are to be prepared as far as possible in consultation with the relevant stakeholders. The initiative must under no circumstances lead to additional administrative burdens or the creation of an additional complex coordination structure.

The starting point is to map the existing successful collaborations and projects considered crucial for achieving climate neutrality in Flemish basic industry. A data-driven approach is important here, as cluster dynamics are fluid. It is important to have a clear understanding of how prevalent and extensive cluster collaboration is. There are already exchange and cooperation projects. Interactions with these stakeholders can provide insights into how the cooperation came about and what might be needed to realise future collaborations. This also makes it possible to identify barriers and to formulate targeted proposals for measures to remove these obstacles.

It is also possible that information or insights are already available from existing studies or reports. One potential source to explore is the climate roadmaps drawn up by individual companies under the Energy Policy Agreements (EBOs). In addition to insights into broader infrastructure needs, these also include preconditions and obstacles. An aggregated report of the first climate roadmaps is currently being prepared. It is still too early to have a clear view of the usefulness of this data in this context. This option should be clarified further alongside the identification of other potential sources. As noted earlier, an evaluation of the EBOs is under way and follow-up actions depend on the outcome of that process.

Mapping the current situation is only a first – albeit crucial – step in preparing and identifying potential measures. At this time there is insufficient information to define concrete proposals or measures for a collaborative approach to support complex projects considered crucial for the industry's path to climate neutrality. It is important to involve and consult the right stakeholders when developing this further. The aim is to identify critical projects together with the stakeholders and support their delivery in a targeted way so that these projects reach a Final Investment Decision (FID) as quickly as possible.

The project depends on direct access to decision-makers and political choices regarding priority projects. Parties involved include federations, ports, knowledge institutions, departments within the Flemish Government and the Flemish Government itself. Success will depend on available financing, obtaining permits and public support and participation processes. The initiative is closely linked to several actions discussed earlier in the text, including the participatory process on infrastructure needs and the account management approach included under policy steering.

Participatory process to determine infrastructure needs

The end goal of this action is to make collective infrastructure a strategic workstream in support of the basic industry's climate transition. Beyond identifying locations, it is important to map and quantify needs. In addition, a thorough analysis will be required to ensure that infrastructure projects are actually realised. The outcomes of this process must ultimately feed into other workstreams, such as interregional and international cooperation. The discussion above also makes it clear that periodic follow-up is needed on the progress of the various initiatives. Within Klimaatsprong, it is useful to start a project to map infrastructure needs. The explanation below proposes content elements that could be included in this project.

Infrastructure is critically important both for the region's competitiveness and for progress in the industrial climate transition. The transition pathways for all sectors are invariably linked to infrastructure and energy needs. This collective infrastructure is diverse, comprising electricity, hydrogen and heat networks and infrastructure to liquefy and transport CO_2. This also means that a participatory process requires active involvement from various stakeholders, including infrastructure operators, large industrial clusters, major SME zones and government. By extension, there is also a role for the Flemish Utilities Regulator, the other regions and even international partners.

Within Klimaatsprong's governance it is important that these different actors can contribute freely. In some cases, certain information cannot be shared among participants. A system is needed in which crucial information that would otherwise be confidential can be centralised and anonymised. In addition, specific expertise will be required as the discussion evolves to a more detailed level. A mechanism is needed to remunerate this expertise, beyond mere consultancy. Knowledge may exist among participants and their time should be deployable on a project basis. The governance should distinguish between a small group that prepares the working documents and the broader group of stakeholders to be consulted for further refinement. Some flexibility will be needed to respond to the precise needs within each discussion. Practically, it must be possible to mobilise a small group of experts to prepare sub-topics, after which these insights are integrated into the whole.

The roles of electricity, hydrogen and heat networks and infrastructure for liquefying and transporting CO_2 cannot be treated in isolation. To structure the discussion, a first step can be to map where potential offtakers are located. Initially, this can be based on where certain activities are carried out and by indicating the potential for electricity, heat, hydrogen (and derivatives) and CO_2. Again, this overview will be dynamic and can never be exhaustive; it merely provides a basis for targeted data collection needed to estimate concrete needs.

In addition to locations, it is important to map the actual needs. This includes estimated quantities as well as the modalities or specifications for the infrastructure. Again, the importance is emphasised of conducting this analysis in a way that can contribute to cross-vector, cross-sector and cross-border synergies. This will require a targeted search for supporting data. An interesting source is the EBO climate roadmaps. As noted, the possibilities here can only be explored in consultation with VEKA after completion of the ongoing evaluation.

Infrastructure needs are not static and will most likely shift over time, for example driven by market dynamics and technological developments. A concrete example mentioned in the roadmap update is that breakthroughs in technological options for high-temperature heat could raise electricity demand. Such evolutions illustrate the need for a dynamic instrument that makes it possible to quantify the consequences of these shifts. The outcomes should allow the joint action plan to be adjusted appropriately when basic assumptions change. Various modelling tools exist to support such projections; a concrete option is further developing the model created as part of the Energiestudie 2050+.

The outcomes of this process must ultimately feed into other workstreams, such as interregional and international cooperation. As a minimum, the result should include a clear visual overview of users (if possible supplemented with production and import options), supported by an instrument that can quantify needs.

Ideally, a clear timeline is drawn up for delivering the key infrastructure projects. The Flemish Government has expressed the wish to prioritise the largest infrastructure works for the future based on their CO_2 reduction potential. This means prioritising projects that make the greatest contribution to reducing CO_2 emissions. It is advisable to devote sufficient attention, as part of this initiative, to the modalities of this prioritisation.

In addition, a thorough analysis will be required to ensure that infrastructure projects are actually realised. This analysis can be carried out from various perspectives – operational, regulatory and financing. It will likely be organised in specific working groups or projects targeting specific issues. Examples already discussed include mechanisms to avoid (spread) first mover malus, efficient and effective permitting policy and a clear regulatory framework for infrastructure (e.g. hydrogen and CO_2).

The discussion above also makes it clear that periodic follow-up is needed on the progress of the various initiatives. This governance should be considered separately from the initial, more project-based setup. Such follow-up can also be integrated into Klimaatsprong’s general operations for broad monitoring of progress in the climate transition.

6. Annexes

Annex 1: Analysis of various technology and project databases

IEA Clean Energy Technology Guide

To check the completeness of the technology list (developed in the 2020 context analysis), we first used the International Energy Agency's "Clean Energy Technology Guide" database[144]. The Clean Energy Technology Guide is an interactive database containing information on almost 600 individual technology designs and components across the entire energy system (including the demand side) that contribute to achieving net zero emissions. For each of these technologies, the database provides information on maturity level and a compilation of development and deployment plans, as well as cost and performance improvement targets and the leading players in the field. The database is kept up to date on a regular basis. This analysis used the state of play as of October 2024.

For this analysis we only looked at technologies for the (petro)chemicals, steel and refining sectors, as well as general industrial technologies (mainly for heat and steam production) and CC(U)S technologies not mentioned in the foregoing sectors but with potential industrial application.

For chemicals, the IEA database contains 30 technological options:

- 6 options for ammonia production, including: biomass gasification; carbon capture (via chemical absorption, cryogenic capture and physical absorption and adsorption); electrolytic hydrogen; and hydrogen via methane pyrolysis
- For the production of aromatics (including benzene, toluene and xylene): production from lignin (biomass) and from methanol
- The database contains 7 options for chemical recycling of polymers, including solvolysis and pyrolysis.
- The use of bio-ethanol via gasification of lignocellulosic biomass to ethylene and the fermentation of ethanol to ethylene
- For the production of high-value chemicals (via steam cracking) the database proposes two carbon capture options (chemical and physical absorption), catalytic cracking and electrification of a steam cracker
- The production of methanol with carbon capture (absorption and adsorption of CO_2), from biomass and waste gasification, using CO_2 and electrolytic hydrogen, and hydrogen obtained via methane pyrolysis

For iron and steel production, the database includes 23 technological options, including:

- CCUS in conventional blast furnaces, in DRI (direct reduction of iron ore) reactors and for reduction in (new) smelting technology
- Partial substitution of coal by hydrogen in blast furnaces
- Partial substitution of coal by biomass in blast furnaces
- The use of hydrogen in DRI: fully or partially replacing natural gas
- The use of ammonia as feedstock in a DRI
- The use of biogas in a DRI
- High- and low-temperature electrolysis for iron production
- The reuse of CO_2 (via thermochemical coupling to CO) in a blast furnace
- The reduction of iron ore using alkali metals

For the refining sector, the IEA database lists three options: carbon capture at catalytic cracking (via oxy-fuel or post-combustion) and carbon capture for process heat production (e.g. boilers) and for hydrogen production in a refinery.

For industrial heat production, the database contains 25 (overlapping) options, including:

- The use of biomass (for low, medium and high temperature): bio-coal (via pyrolysis or torrefaction), fluidised bed boilers and biomethane

[144] https://www.iea.org/data-and-statistics/data-tools/etp-clean-energy-technology-guide

- Combustion of ammonia or hydrogen for low-, medium- and high-temperature heat
- Electrification (high temperature): concentrated solar, electric arc and plasma furnaces, induction, microwave, radio wave and ultraviolet heating
- High-temperature heat via rotor compression (RotoDynamic heater, up to 1,700°C)
- Low- and medium-temperature heat: same as above, except for concentrated solar and electric arc/plasma furnaces; industrial heat pumps
- Thermochemical storage that uses electricity to drive reversible endothermic and exothermic reactions (approx. 1,000–1,500°C)

In addition, the database lists several examples of high-temperature heat storage (with potential industrial applications), such as storage using molten salts and solid materials with high thermal capacity.

Finally, the IEA provides around 30 options for hydrogen production, including many with carbon capture (from gas, coal or biomass), electrolysis and methane pyrolysis.

The production of synthetic fuels and biofuels is largely left outside the scope of this analysis (as in the 2020 context analysis).

Global IEA Clean Energy Demonstrations Database

The IEA Demonstration Projects Database aims to map significant demonstration projects for clean energy technologies worldwide. For each project, where available, it provides information on location, sector/technology grouping, status, capacity, timelines and financing.

From the IEA "clean energy demonstrations" database we selected projects in the chemicals, steel and oil refining sectors. This yields 200 pilot and demo projects relevant to these sectors. These demonstrations span various development phases, with many in feasibility study and construction; fewer are already operational.

Current industrial pilot and demonstration projects focus strongly on technologies such as electrolytic hydrogen (H_2), carbon capture and storage (CCUS) and innovative recycling methods.

In steel, the emphasis is on substituting coal in blast furnaces with electrolytic hydrogen. Examples include H2Stahl in Germany, Baowu Steel in China and H2Future in Austria. CCUS applications are also being developed, for instance Carbon2Chem in Germany and Steelanol in Belgium, where steel off-gases are converted into useful chemicals or fuels.

In (petro)chemicals, the focus is on producing green ammonia and methanol using electrolytic hydrogen or CCUS. Examples include the Songyuan Hydrogen Industrial Park in China (large-scale ammonia) and methanol projects such as "Haru Oni" in Chile with a capacity of 750 kt per year. Innovative recycling techniques are being introduced too, such as chemical depolymerisation at Carbios in France and hydropyrolysis in the UK. The database contains just one demo project in oil refining (CCS on a catalytic cracker).

The dataset shows a clear spread of industrial climate neutrality projects across technologies and sectors:

- Ammonia production: There are about 50 projects targeting green ammonia, mainly based on electrolytic hydrogen (H_2-to-ammonia). Some large projects, such as the Songyuan Hydrogen Industrial Park in China, exceed 600,000 t of ammonia per year.
- Methanol production: Around 40 projects focus on sustainable methanol production, including CO_2-based and electrolytic hydrogen routes (H_2-MeOH). Major examples include the Haru Oni project in Chile (750 kt/year) and several in Europe, such as "Green CCU Hub Aalborg" in Denmark.
- CCUS applications: There are more than 30 projects focused on carbon capture and utilisation (CCUS), both in the steel and (petro)chemicals sectors. Examples include the Steelanol project in Belgium and the Kairos@C project in the (petro)chemicals sector, which plans to capture 1.4 million t CO_2/year.

- Hydrogen use in steel: 20+ projects focus specifically on electrolytic hydrogen in steelmaking (H_2-steel), e.g. H2Stahl in Germany and Baowu Steel in China.
- Recycling and circular economy: Approximately 10 projects focus on innovative recycling techniques, such as chemical depolymerisation and hydropyrolysis (e.g. Carbios in France and Licella in Australia).

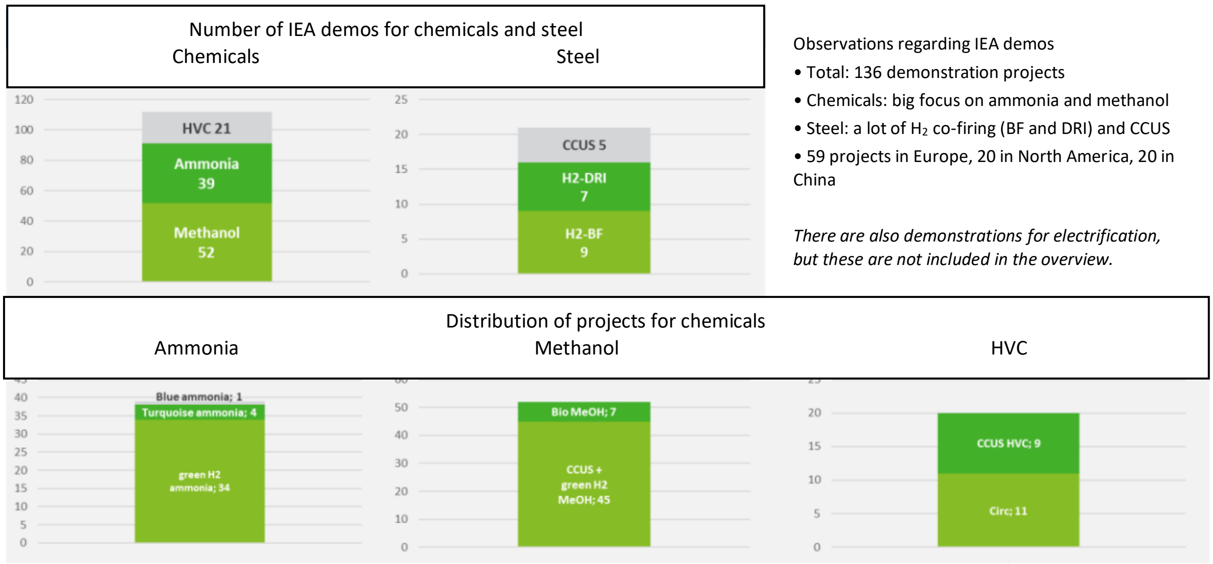


Figure 35: Overview of projects in the IEA global demo database

For hydrogen projects we also consulted the IEA's dedicated database[145] that tracks hydrogen production investments. This includes all existing and planned investments to the extent known by the IEA.

Globally, it lists just over 2,000 electrolytic hydrogen projects (from concept to operational). Of these about 630 are operational, most at very small scale (< 1 Kt H_2 per year). Counting projects with a final investment decision (FID) or under construction brings the total to roughly 930 worldwide. Among these are some larger ventures, such as hydrogen production in Sweden for a DRI steel project (> 100 Kt H_2/year) and the NEOM green hydrogen project in Saudi Arabia (370 kt H_2/year), alongside projects in India and China. In total, if realised as planned, these projects would lead to 23 GW of installed electrolysis capacity globally by 2030, or about 3 Mt H_2 (assuming 20 kg H_2/MWh and 80% full-load hours).

For hydrogen production using CCS, the database lists 114 projects (from concept to operational). Operational (incl. demo) projects are fewer – 22, some still missing parts of the full CCS value chain. Including FID and under-construction projects brings the total to 38, which together could produce about 4 Mt H_2 per year by 2030 worldwide.

EU ETS Innovation Fund projects

The EU ETS Innovation Fund, established through an amendment to the EU ETS in 2018, is an advanced financing mechanism set up under the European Union's Emissions Trading System (EU ETS) to accelerate the development and demonstration of innovative low-CO_2 technologies. Funded by a share of the revenues generated from auctioning emission allowances within the EU ETS, the Innovation Fund aims to support projects that can significantly reduce greenhouse gas emissions in energy-intensive sectors, as well as in sectors such as waste management, industrial processes and energy. It is expected that around €40 billion will be available in the period 2020–2030 for projects financed with ETS proceeds. By prioritising large-scale, transformative projects, the fund not only contributes to industrial decarbonisation, but also to the creation of new market opportunities in emerging clean technologies.

[145] https://www.iea.org/data-and-statistics/data-tools/hydrogen-production-projects-interactive-map

One of the key elements of the Innovation Fund is its focus on bridging the gap between research, development and commercialisation. The fund supports projects that are at an advanced stage of development and have already demonstrated technical and economic viability in pilot or pre-commercial phases. This approach helps successful projects move closer to large-scale deployment and market integration, enabling them to play a key role in achieving Europe's climate goals. In addition, by fostering collaboration among industry, academia and research institutions, the Innovation Fund acts as a catalyst for knowledge exchange and technological innovation, thereby strengthening Europe's leadership in the global transition to a low-carbon economy[146].

Since its launch, there have been four calls for projects under the fund, for both large- and small-scale projects. In 2023, part of the fund's resources also became available via an auction for hydrogen and RFNBO-related projects. Through a premium, this auction provides additional financial support to make more market-ready projects with higher OPEX economically viable[147].

For the analysis in this study, the Innovation Fund dashboard developed by the European Commission was used[148]. The analysis focuses on projects in the chemicals, steel and refining sectors.

Of the 207 Innovation Fund projects approved so far, 30 concern hydrogen applications (production, use, transport and storage), 21 are in the chemicals sector, 9 in refining, 8 in steel production and 3 relate to CCS (carbon capture and storage) with a focus on transport and storage.

Belgian project proposals have been fairly successful within the fund, with 13 approved initiatives (8 of which in Flanders) receiving a total EU funding contribution of nearly €1.3 billion. These include 2 projects in the (petro)chemicals sector, 2 hydrogen projects and 1 project each in steel, refining and CCS.

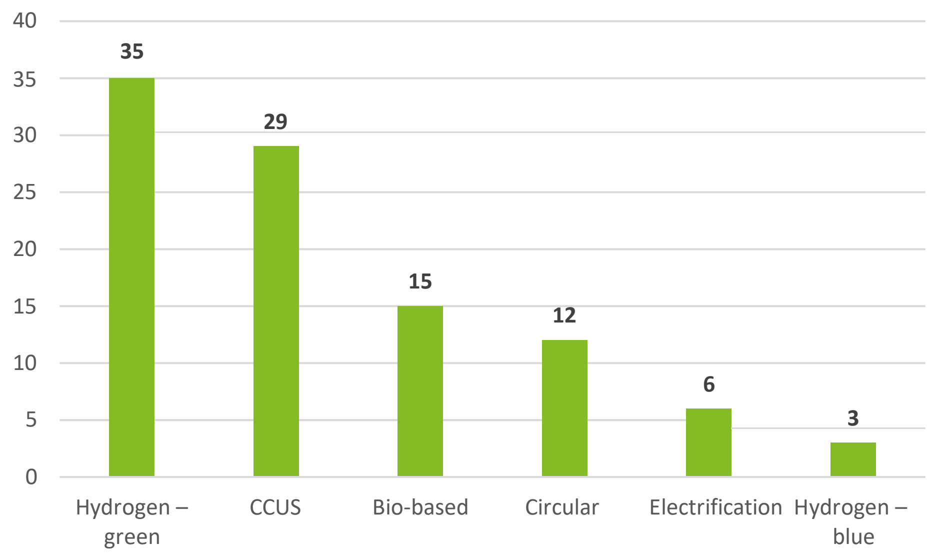


Figure 36: Overview of project types under the EU ETS Innovation Fund (focus on chemicals, steel and refining). Data obtained via the EU ETS Innovation Fund dashboard[149]

Based on the Innovation Fund projects (either under implementation or invited for signature) linked to industrial sectors (around 90 projects in total), the following can be inferred.

The projects funded by the Innovation Fund show a strong focus on CCUS (29 projects), including:

[146] https://climate.ec.europa.eu/eu-action/eu-funding-climate-action/innovation-fund/legal-framework_en
[147] https://climate.ec.europa.eu/eu-action/eu-funding-climate-action/innovation-fund/competitive-bidding_en#:~:text=In%202023%2C%20the%20Innovation%20Fund,receive%20support%20on%20their%20production.
[148] https://dashboard.tech.ec.europa.eu/qs_digit_dashboard_mt/public/sense/app/6e4815c8-1f4c-4664-b9ca-8454f77d758d/sheet/bac47ac8-b5c7-4cd1-87ad-9f8d6d238eae/state/analysis
[149] https://dashboard.tech.ec.europa.eu/qs_digit_dashboard_mt/public/sense/app/6e4815c8-1f4c-4664-b9ca-8454f77d758d/sheet/bac47ac8-b5c7-4cd1-87ad-9f8d6d238eae/state/analysis

- 2 projects for offshore CO_2 storage
- 8 projects for methanol production
- 5 projects for e-methane production
- 2 blue hydrogen projects
- 2 projects for CO_2 storage via mineralisation
- 4 projects for CO_2 capture (and use) in the cement industry
- 2 CCUS projects in the steel sector

There are 35 hydrogen-related projects (including blue hydrogen and excluding other CCUS), comprising:

- 7 projects using hydrogen in transport (including RFNBO)
- 4 aimed at ammonia production
- 12 related to electrolytic hydrogen production
- 3 concerning the use of hydrogen in steel production
- 1 project for hydrogen production via waste gasification

As regards circularity, 12 projects were identified, including 8 linked to chemical recycling and 1 project on methanol production from waste (in addition to the waste gasification hydrogen project above). There were 15 projects identified on the use of biomass, the majority oriented toward biofuels, and 1 lignin project toward biopolymers. Furthermore, there are currently 6 projects relating to electrification in industry (2 for iron and steel production, 2 in the glass and ceramics sector, 1 in non-ferrous and 1 in chemicals).

Moonshot projects

The Flemish Moonshot innovation programme started in 2019. It supports Flemish research institutes developing breakthrough technologies for climate-friendly processes and products. These technological innovations serve the broader goal of a systemic transformation of our industries. Bold innovations help Flanders' basic industries become carbon-circular and CO_2-neutral.

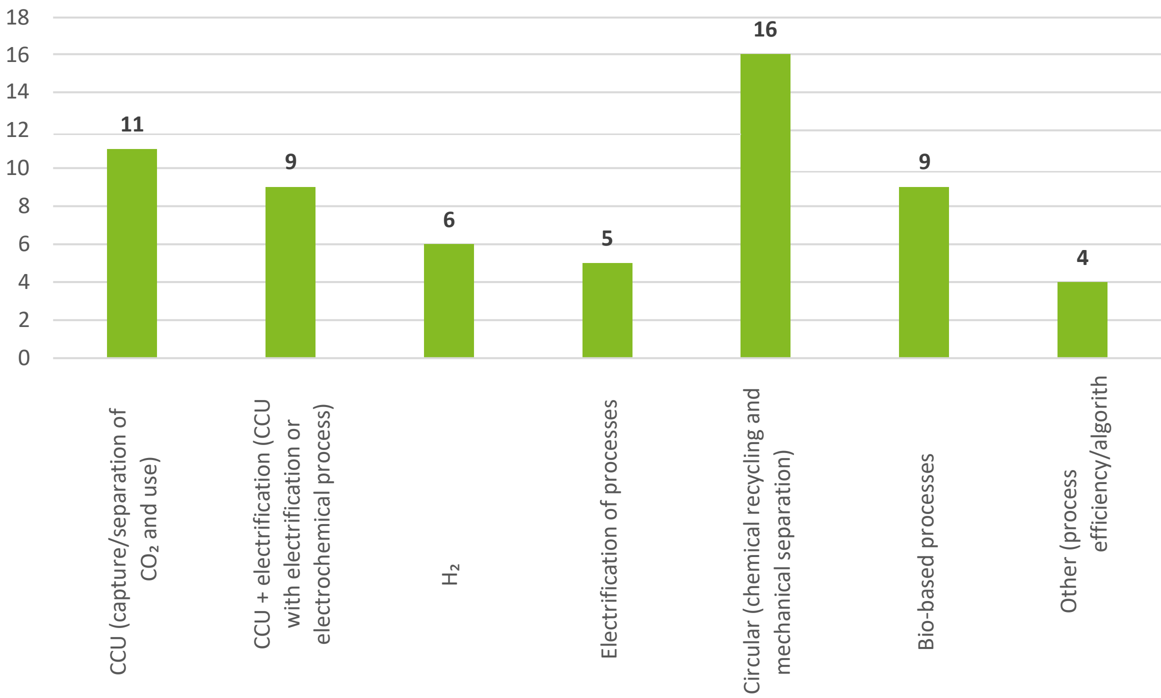


Figure 37: Moonshot projects, number per theme (CCU, CCU with electrification, hydrogen, electrification, circular economy, bio-based applications and other projects). Status as of March 2025.

About 60 Moonshot projects were analysed. There are 52 “early stage innovation” (ESI) projects, most of which aim(ed) to bring a technology to TRL 4. There is also a growing number of “later stage innovation” (LSI) projects, including several that graduated from an ESI. Most of these projects aim to reach TRL 5–6 (larger pilot installation). For the recent ESI projects, it will be challenging to reach TRL 9 (market-ready technology) by 2040, even if the follow-on trajectory proceeds very smoothly. The difficulty lies mainly in scaling beyond TRL 6 (pilot project), because the move to – and execution of – demonstrations at industrial production scale requires a great deal of time[150]. For the current LSI projects (as a follow-up to an ESI project), this is theoretically possible, provided the scale-up proceeds smoothly.

Research on CCUS in the broad sense accounts for the most projects (20) within the Moonshot programme. The projects range from innovative, energy-efficient separation of CO_2 from flue gases to the use of CO_2 towards new platform molecules and co-electrolysis for hydrogen. A subset of these projects also links to process electrification, both via the electrochemical CCU route and through the electrification of heat.

Projects on the circularity of polymers are the second most studied domain in the Moonshot programme (16), with a strong focus on overcoming technological barriers to the chemical recycling of various polymer types beyond the classic PE, PP and PET.

The use of biomass in chemical processes is the subject of 9 Moonshot projects. The focus lies mainly on lignin-based applications, as well as the broader framing of biomass applications in biorefining towards basic chemical products and the link with process electrification.

There are a limited number of hydrogen projects (5–6), 4 related to production and 2 to storage of hydrogen. Electrification figures in only 4 projects, but with potentially large impact due to the highly innovative nature or the possible major impact of a few technologies, such as the electrification of steam cracking or the use of higher-temperature industrial heat pumps.

[150] Important innovative processes such as Steelanol needed more than 10 years to scale to TRL 8–9.

Annex 2: Extended summary of the MIX scenario in the 2020 roadmap study

The 2020 roadmap[151] was underpinned by a quantitative model that simulated future industrial production in Flanders**.** To substantiate this, a quantitative model was developed that allows the potential developments in Flanders' industrial production to be simulated. Concretely, the model allows assumptions to be made concerning:

- The production level per type of industrial product
- The technology mix used to make the various products
- The efficiency improvements expected per technology
- Possible fuel switches within each technology
- The application of CO_2 capture for each technology

The model then mapped the impact of these assumptions on greenhouse gas emissions, energy and feedstock consumption and the costs (CAPEX/OPEX) for implementing new innovative technologies. In line with that study's scope, the model did not cover the entire energy system (production and distribution of electricity or other energy carriers), did not treat developments in sectors outside the Flemish basic industry and did not include economic parameters. It is important to stress that the model used is not an optimisation model; it therefore does not automatically compute the most cost-efficient route to a desired outcome (e.g. emissions reductions by 2050) via backcasting. Rather, it is a simulation model in which the end result and the path to it are the consequence of the assumptions and choices the user inputs (forecasting). This makes it possible to transparently map the impact of varying assumptions. Based on predefined scenarios, we ran simulations with the model.

Using this model, a number of exploratory scenarios were developed to underpin the roadmap. Based on the model described above, a number of scenarios for the roadmap were identified:

- First, a BAU reference scenario (without interventions) was calculated to chart expected evolutions up to 2050.
- Next, the potential of each transition pathway was mapped separately. To that end, four "maximum scenarios" were developed, each maximising one of the four thematic pathways: BIO-max (biomass route), CIRC-max (circularity route), ELEC-max (electrification route incl. hydrogen) and CCUS-max (carbon capture route and use of synthetic fuels).
- Building on this analysis, three combined scenarios were then developed that deploy a mix of the four pathways: a central exploratory scenario (MIX) and two variations on it ("Var1" and "Var2"). For the key production processes, the variations account for alternative energy prices and, consequently, alternative technology choices, to examine the effect of these factors. This limited, additional analysis provides an initial indication of the effect of energy prices on choice of technology. A thorough analysis of the impact of energy and technology prices on the expected technology mix (e.g. via optimisation) falls outside this study's scope and requires further research. These scenarios are built on scientific research, consultation with various experts and validation under the project's governance. The underlying assumptions, technology choices, data points, etc., were discussed in multiple working sessions, further reviewed with experts and sector federations and finally discussed in the project steering committees. For the central exploratory scenario, a number of principles were observed, such as:
- Striving for significant emissions reductions by 2050.
- Maximally preserving the existing value chain (e.g. concentrated focus on those value chain steps that cause the most emissions; avoiding premature replacement of installations) and the existing roadmaps of industrial companies.
- Technology neutrality (not excluding any thematic pathway in advance).
- Incorporating innovative technologies that can be further investigated under an innovation programme.

[151] https://www.vlaio.be/nl/media/1502

- Circularity and a carbon-smart approach (maximising carbon valorisation by returning it to the value chain and thus avoiding atmospheric emissions).
- Pursuing industrial symbiosis.
- Avoiding major dependence on certain energy carriers and feedstocks.
- However, the cost efficiency/business case of the energy and technology mix used was not explicitly taken into account.

The scenarios were intended as explorations to map the potential of the various pathways, identify common elements, explore possible synergies and symbioses, get a sense of the order of magnitude of potential emissions reductions, energy and feedstock consumption and expected OPEX/CAPEX related to implementing new innovative technologies, and to identify key preconditions, challenges and opportunities. The scenarios should therefore not be viewed as forecasts of the future nor as a development path to be followed.

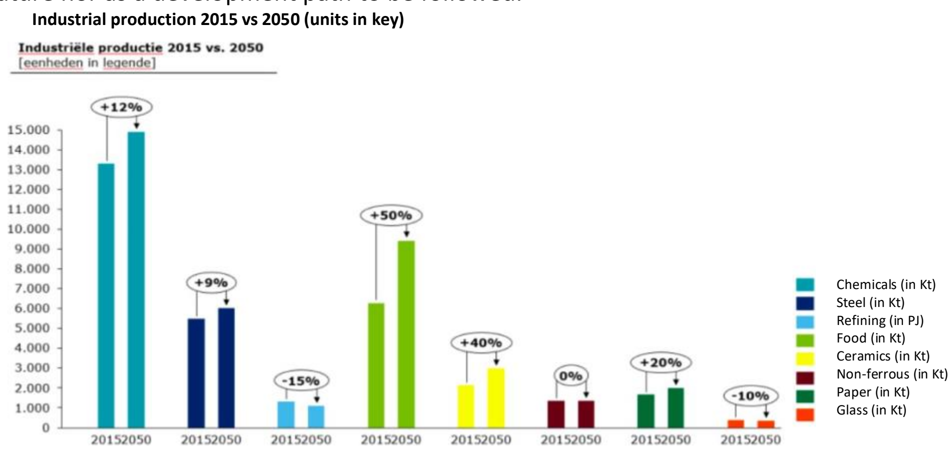


Figure 38: Evolution of production as assumed in the 2020 roadmap

The roadmap assumed limited generic growth in industry (following GDP growth). For chemicals, planned expansion of olefin production capacity in the Port of Antwerp was taken into account. For refining, the closure of a small refinery was included.

Chemicals

In the central exploratory scenario (MIX), a 90% reduction is achieved for the (petro)chemicals sector, assuming that today's low-TRL technologies can be implemented within this timeframe and become economically viable. In this scenario, reliance on CO_2 capture is more limited. By combining efficiency improvements, a switch to climate-friendly fuels and a switch to innovative technologies in electrification and H_2, circularity and biomass, greenhouse gas emissions fall by 51% by 2050. As a result, the need for CO_2 capture is reduced by 65% (4.9 Mt instead of 13.6 Mt per year) compared with the CCUS-max scenario.

Ammonia and H_2 will already achieve major greenhouse gas reductions by 2030. These sectors generate very pure CO_2 streams, which are most suitable for CO_2 capture. For these sectors, it is therefore assumed that CO_2 capture starts in 2025 and that by 2030, 89% of all emissions are captured. For the other product groups, new technologies and CO_2 capture are applied from 2035. These estimates are based on literature research, a stakeholder survey and input from the Antwerp@C project.

High Value Chemicals (HVC)

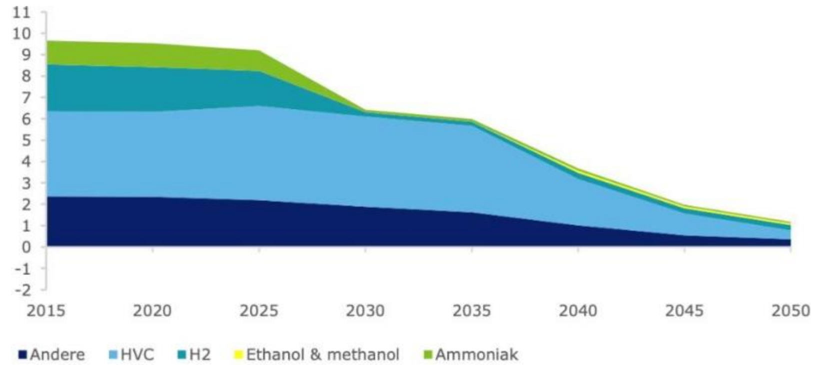
In the proposed exploratory scenario, HVC production switches from 2035 onwards to a combination of technologies. By 2050, in the central exploratory scenario (**MIX**):

- 24% of HVCs come via propane dehydrogenation (PDH)
- 22% of HVCs come via the chemical recycling of plastics
- 20% of HVCs are produced via electrification
- 15% of HVCs come via ethane steam cracking

- 15% of HVCs come via the MTO/MTA and/or ethanol dehydrogenation route (with ethanol/methanol mainly produced via CCU routes and, to a lesser extent, via bio-based routes)
- 5% of HVCs are produced from biomass

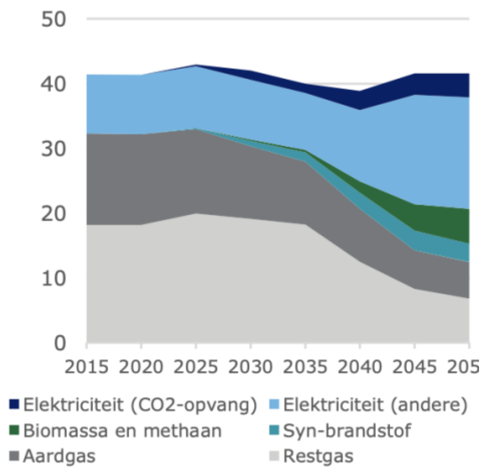
This technology mix also has a major impact on the feedstock mix for HVC production by 2050:

- 1.8 Mt (21.4 TWh – 26%) of plastic waste per year
- 0.275 Mt (1.3 TWh – 2%) of direct biomass use per year
- 2.2 Mt (11.2 TWh – 14%) of methanol per year
- 0.5 Mt (3.3 TWh – 4%) of ethanol per year
- In addition, the PDH process will still require 20.0 TWh of LPG/propane annually and ethanol steam cracking will require 12.3 TWh of ethane.
- The use of naphtha (via the electrification route) falls to 10.4 TWh in 2050.



Other HVC H_2 Ethanol & methanol Ammonia

Figure 39: Evolution of greenhouse gas emissions for the Flemish (petro)chemicals sector in the 2020 roadmap (MIX scenario)



Electricity (CO_2 capture)	Electricity (other)
Biomass and methane	Synthetic fuels
Natural gas	Residual gas

Figure 40: Evolution of energy demand for the (petro)chemicals sector in the 2020 roadmap (MIX scenario)

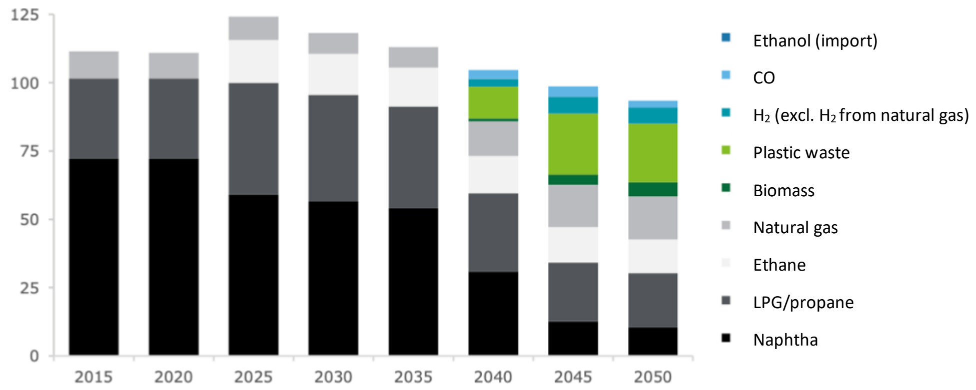
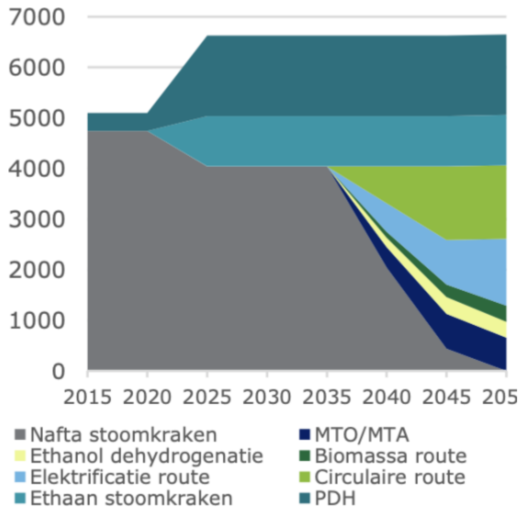


Figure 41: Evolution of feedstock demand in the (petro)chemicals sector in the 2020 roadmap (MIX scenario)



Naphtha steam cracking | MTO/MTA
Ethanol dehydrogenation | Biomass route
Electrification route | Circular route
Ethane steam cracking | PDH

Figure 42: Evolution of technologies for producing high value chemicals in the 2020 roadmap (MIX scenario)

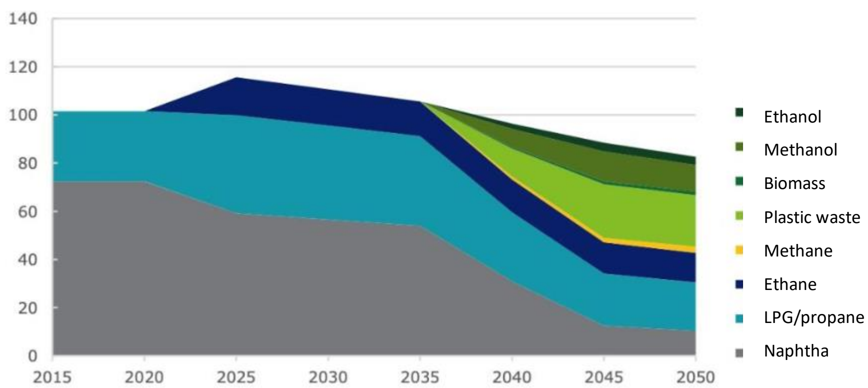


Figure 43: Evolution of feedstock demand for HVC production in the 2020 roadmap (MIX scenario)

Ammonia

Ammonia production is currently based on the Haber–Bosch technology route. By 2030, this route is fitted with carbon capture with a view to storing CO_2 emissions. From 2035, the Haber–Bosch route is gradually replaced by a low-carbon route (using H_2 from electrolysis). By 2050, 40% of ammonia production will proceed via the low-carbon route (based on electrolytic H_2) and 60% via Haber–Bosch with CO_2 capture. In addition, 20% of the energy use under the Haber–Bosch route will be electrified by 2050 (i.e. less natural gas) and a further 25% of the remaining natural gas use for energy purposes will be replaced by the use of synthetic fuels (not applicable to the natural gas use for feedstock purposes).

Furthermore, it is deemed theoretically feasible for CO_2 capture in ammonia to start as early as 2025. To play a role in emissions reduction, CO_2 transport and storage infrastructure must also be ready in the 2025–2030 period.

Hydrogen

Under the exploratory scenario, hydrogen demand triples from 8.2 TWh in 2015 to 24.9 TWh in 2050 (of which 4.7 TWh as feedstock for the production of synthetic fuels and 20.2 TWh as feedstock in the various sectors). The current production capacity for H_2 (via steam methane reforming, SMR) is retained and is equipped with CO_2 capture technology between 2025 and 2030. The rising demand after 2030 is further met by a combination of additional production via zero-emission technologies (mainly electrolysis, but also methane pyrolysis) and H_2 imports. In the central exploratory scenario (MIX), domestic production is as follows:

- 44% will be blue H_2 based on SMR combined with CO_2 capture. This will replace grey H_2 by 2030. CO_2 capture will be applied from 2025, increasing linearly so that by 2030 89% of end-of-pipe GHG emissions from SMR installations are captured.
- 41% will be green H_2 (via electrolysis – from small pilots between 2020–2030, such as power-to-methanol, and from 2030 larger industrial applications due to higher demand for synthetic fuels and synthetic methanol production).
- 15% will be turquoise H_2 (via methane pyrolysis, starting in 2035, with the steel sector as the main ultimate application).

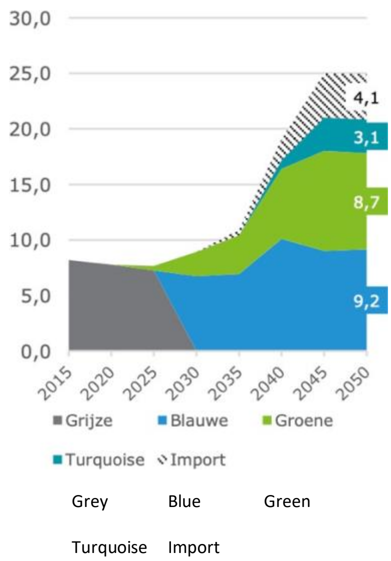


Figure 44: Evolution of hydrogen production according to the 2020 roadmap (MIX scenario)

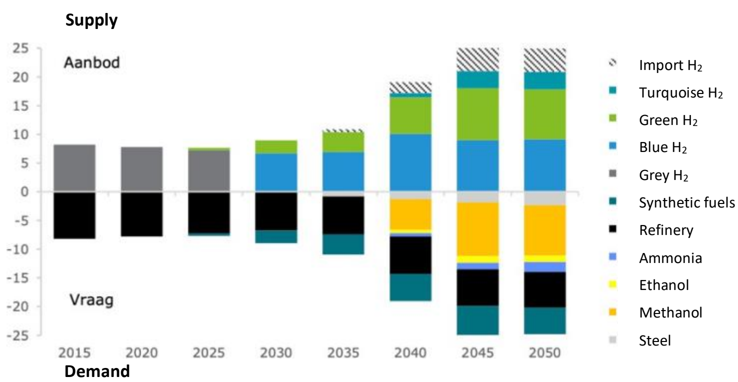


Figure 45: Evolution of hydrogen demand and supply in the 2020 roadmap (MIX scenario)

Refining

The central exploratory scenario (MIX) for refining estimated a reduction potential of around 88% of emissions relative to 2005, from 5.4 Mt CO_2e greenhouse gas emissions to 0.66 Mt CO_2e in 2050. This amounts to a decrease of 4.7 Mt CO_2e.

The emissions reductions between 2005 and 2050 are achieved in three ways:

1. Owing to a declining demand for refined fuels, we expect a limited 15% reduction in refining production capacity between now and 2030.

2. The potential for further efficiency improvements is assessed as limited, at 10% improvement between now and 2050. Together with a “fuel switch” from fossil fuels to synthetic fuels and electrification, this accounts for 21% of the emissions reduction.

3. A strong need for CO_2 capture as the principal mitigation instrument to capture residual emissions leads to a further 52% reduction in emissions.

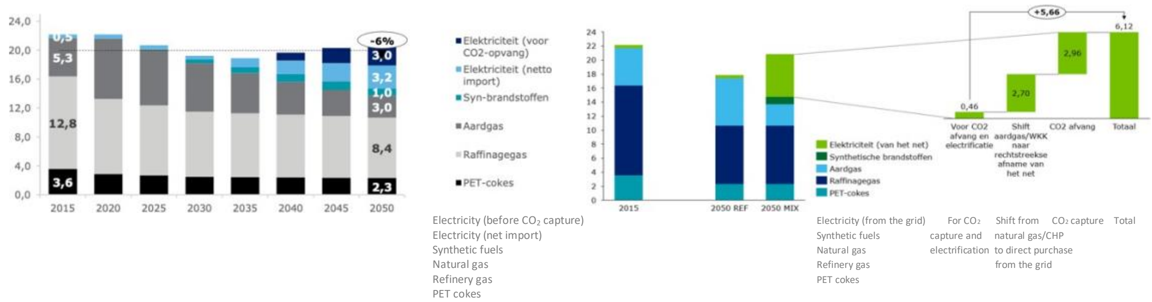


Figure 46: Energy use in refining towards 2050 according to the 2020 roadmap (MIX scenario)

Iron and steel

The central exploratory scenario for steel assumed the deployment of various routes to achieve significant CO_2 reductions. Despite a slightly rising production volume of 9%, the potential exists to reduce emissions by around 92% versus 2005 – i.e. from 9.7 Mt greenhouse gas emissions in 2005 to 0.7 Mt in 2050, a decrease of 9 Mt. In line with ArcelorMittal’s plans, the choice was made to retain the BF-BOF technology to produce steel. Emissions reductions can then be realised in two ways. On the one hand, there is potential for partial switching from coal to alternative inputs in the blast furnaces:

- Use of plastic waste and CO_2 which, via plasma gasification (IGAR technology), can be converted into H_2 and CO that can be used in blast furnaces as an alternative to coal (circular).
- Use of wood waste, or other bio-based residual waste, which after torrefaction (i.e. processing wood waste into bio-carbon) can be used in blast furnaces as a substitute for coal (biomass).
- Additional injection of H_2 into the blast furnaces to partially replace coal (electrification and H_2).

This can avoid 3 Mt of greenhouse gas emissions. The alternative H_2-DRI route – where steel production is largely based on H_2 – was not simulated in the central exploratory scenario. This option is not currently included in the roadmap of the integrated steelworks, ArcelorMittal, in Flanders – primarily because the costs of H_2 are still very high and the necessary H_2 networks are not yet in place, and also because of the very high investment and operating costs required to convert BOF routes completely within an existing, highly integrated steelworks. However, the BF-BOF route is compatible with the use of H_2 and, if H_2 becomes cheaper and the necessary H_2 networks are realised, a decision could be taken to inject more H_2 into the blast furnaces, or even to switch to H_2-DRI processes. *The choice to continue producing steel via BF-BOF nevertheless entails a potential risk if H_2 production becomes very cheap after 2035 – for example, due to innovations in electrolysers and the availability of sufficient renewable energy.*

Of the remaining emissions, a further 4.8 Mt CO_2 can be captured via CO_2 capture. There is strong potential to further valorise this CO and CO_2 by coupling to a chemical value chain. The captured CO_2 can be used to produce methanol and the captured CO can be used to produce either methanol (via the syngas route) or ethanol (via the Steelanol route). Both products are base products for HVC production and are new platform molecules that may have strong potential in Flanders. In this way, the carbon from steel is usefully valorised and emissions are avoided by reducing the use of naphtha from the refining sector.

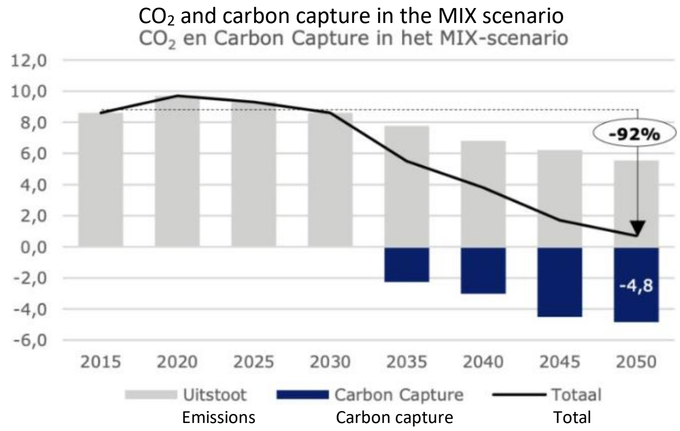


Figure 47: Expected use of carbon capture in the steel sector towards 2050 according to the 2020 roadmap (MIX scenario)

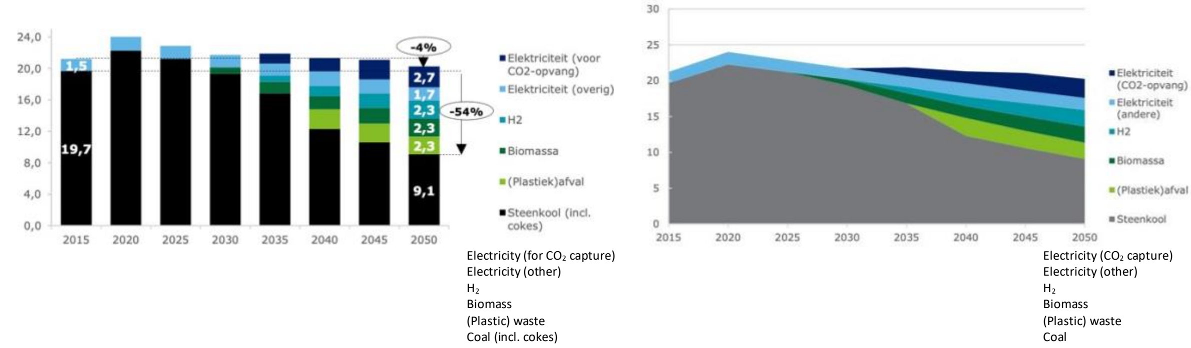


Figure 48: Energy and feedstock use in steel production towards 2050 according to the 2020 roadmap (MIX scenario)

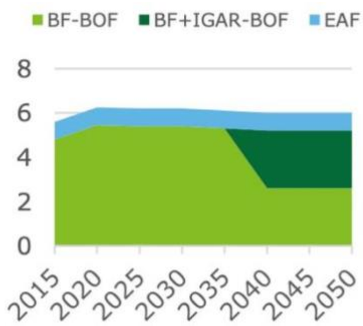


Figure 49: Evolution of production technology in steel towards 2050 according to the 2020 roadmap (MIX scenario)

General overview of technology deployment from the 2020 roadmap

The table below provides an overview of the application of (new) climate-friendly technologies for chemicals, steel and refining in the 2020 roadmap for the periods 2020–2030 and 2030–2050. A large share of the new technology is not expected until after 2030.

Table 17: Overview of technological choices and evolution in the 2020 roadmap (MIX scenario) for 2020–2030 and 2030–2050

Assumptions of the 2020 roadmap context analysis

Product	2020–2030	2030–2050
Chemicals: HVCs	Addition of new units: 15% ethane steam cracking (starts in 2020–2025, then remains constant through 2050); 24% propane dehydrogenation (rises to 24% by 2025, then remains constant through 2050).	Between 2035–2050, complete replacement of naphtha steam crackers by: shockwave reactor (15%); MTO (6%) & MTA (4%); ethanol dehydration (5%); bio-based, combined route (5%); catalytic cracking of waste (11%); chemolysis of waste (11%). 80% CO_2 capture; CO_2 capture starts in 2035 and increases to 80% by 2050.
Chemicals: Ammonia	Assumption that, via Kairos@C, the CO_2 emissions from ammonia are captured. This starts in 2025 and reaches a maximum of 89% capture in 2030.	40% replacement of Haber–Bosch by low-carbon technologies (use of H_2 and N_2) by 2050. Replacement starts in 2035. For Haber–Bosch, 20% of natural gas for energy switches to electricity; 25% of the remaining natural gas to synthetic fuels (for energy, not as feedstock).
Chemicals: H_2	Assumption that, via Kairos@C, emissions from SMR (H_2 and syngas) are captured. This starts in 2025 and reaches a maximum of 89% capture in 2030. Limited investments in electrolysis from 2025.	By 2050, 16% H_2 import; remaining domestic production as follows: 44% SMR (with CO_2 capture); 41% electrolysis; 15% methane pyrolysis. Methane pyrolysis starts in 2035.
Chemicals: Ethanol	85% capture of the remaining Steelanol production; CO_2 capture starts in 2035 and increases linearly to 85% in 2045.	12.5% import; 75% via the Steelanol route; 12.5% via the second-generation bio-ethanol route.
Chemicals: Methanol	No investments up to 2030.	The standard technology for production is based on syngas (CO + H_2). This starts at 100% in 2035. By 2050, 25% of all methanol is produced via biomass (starts in 2035 and grows to 25% by 2050). By 2050, 50% of all methanol is produced via the CCU route (CO_2 + H_2) (starts in 2035 and grows to 50% by 2050).
Refining: Refined fuels		80% capture; CO_2 capture starts in 2035 and increases linearly to 80% by 2050.
Refining: Naphtha		Net demand for naphtha is imported; no additional domestic production on top of (by-)production by refineries.
Refining: Biofuels		Only one technology per fuel type; bio-methane via integration of steam drying, steam electrolysis and gasification; bio-ethanol via second-generation bio-ethanol technology (lignocellulosic biomass to bio-ethanol).
Refining: Synthetic fuels		75% domestic production; 50% of all synthetic fuels are carbon-based (synthetic methane as gaseous, synthetic methanol as liquid); 50% of all synthetic fuels are non-carbon-based (H_2 as gaseous, ammonia as liquid). Synthetic methanol and ammonia are produced via the CCU route (CO_2 + H_2 and N_2 + H_2). The H_2 required as feedstock for synthetic fuels is produced via electrolysis. No improvements assumed for the production of synthetic methanol, methane and ammonia. Efficiency improvement of 38% by 2040 for production of H_2 via electrolysis (from 60 MWh in 2020 to 37 MWh in 2040 per tonne H_2).
Steel	Gradual implementation (see right).	13% via the EAF route (electric arc furnace) (unchanged vs today); 87% via the BOF route (basic oxygen furnace). 15% of coal is replaced by plastic waste and CO_2 (via IGAR technology); 15% of coal is replaced by H_2; 15% of coal is replaced by biomass (after transition to IGAR). Ultimately this leads to: 55% coal, 15% (plastic) waste, 15% H_2 and 15% solid biomass. 87.5% capture of remaining CO_2 from blast furnaces.
Heat: Low T (<200°C)	No electrification.	From 2035, electric boilers replace fuel boilers (linearly, up to 40% of total heat in 2050). Remainder via synthetic fuels and biofuels. No CO_2 capture applied.
Heat: Medium T (200–400°C)	No electrification.	From 2035, electric boilers replace fuel boilers (linearly, up to 20% of total heat in 2050). Remainder via biofuels and synthetic fuels. No CO_2 capture applied.
Heat: High T (>400°C)	No change.	60% capture on the fuel-gas boilers; CO_2 capture starts in 2035 and increases linearly to 60% by 2050. Remainder via synthetic and biofuels.

Annex 3: Summary descriptions of the various roadmap studies analysed to evaluate the 2020 roadmap study

ELIA "Powering industry towards Net Zero" (2024)

The ELIA study, "Powering industry towards Net Zero", sets out a vision for strengthening European industry through electrification and the use of low-carbon electrons. The study emphasises the important role electricity will play in this transition and anticipates a substantial rise in industrial electricity consumption in the coming years.

The study was carried out in close collaboration with more than 50 major industrial consumers and federations from Belgium and Germany (in particular the 50Hertz area, covering northern and eastern Germany). The research team modelled in detail the most energy- and emissions-intensive industrial sectors, which together account for about 70% of total industrial energy consumption in the regions covered. In addition to heavy industry, other sectors – such as data centres and parts of the food and beverages industry – were modelled, with high-level analyses for the remaining sectors.

The study uses a bottom-up model for these energy-intensive sectors. The model focuses on production processes by industry and considers different variants based on input from industry on their pathways to net zero and relevant literature. For each product and each scenario variant (including business-as-usual and climate-neutral options), the model determined the required feedstocks (fossil fuels, molecules such as hydrogen, biofuels) and energy carriers (electricity, fossil fuels, molecules) based on production volumes.

Three different scenarios were explored to examine the transition to net zero across three time horizons – 2030, 2040 and 2045/2050 (climate neutrality targets for Germany and Belgium).

- For 2030, a central scenario was established based on the short- to medium-term plans of industrial players.
- For 2040 and 2045/2050, three different scenarios were developed (FOS+CCUS, ELEC and MOL) to account for uncertainties in long-term decarbonisation trajectories. These scenarios differ in their assumptions regarding the uptake of fossil fuels with carbon capture, utilisation and storage (FOS+CCUS), electrification (ELEC) and low-carbon molecules (MOL).

By 2050, the Belgian industry is expected to undergo a profound transition towards net zero emissions. This transition spans a variety of technologies across sectors, with electrification and the use of low-carbon molecules (primarily imported green hydrogen and its derivatives) playing a central role, complemented by carbon capture, utilisation and storage (CCUS) for unavoidable process emissions.

Chemicals and refineries

- Electrification of steam production at low to medium temperatures – via industrial heat pumps and electric boiler installations – will become widespread in all scenarios.
- Low-carbon molecules, especially imported green hydrogen and derivatives, will be crucial as both feedstock and energy carrier, particularly in the MOL scenario. Refining of crude oil is expected to decline sharply.
- CCUS will be essential to offset process emissions from distillation and cracking, notably in the FOS+CCUS scenario.
- Demand for low-carbon molecules in this sector is expected to rise markedly by 2045/2050.

Steel

- A significant shift away from the traditional BF-BOF process is expected.
- Hydrogen-based DRI-EAF (direct reduction of iron ore combined with an electric arc furnace) is expected to become dominant in all scenarios.
- BF-BOF with CCUS will likely remain relevant in the FOS+CCUS scenario.

- Molten oxide electrolysis is viewed as a potential, longer-term route that is highly electricity-intensive.
- The transition will contribute to a substantial rise in electricity consumption in this sector.

Estimated impact for Belgium by 2045/2050:

- Electrification: Industrial electricity consumption is expected to increase by a factor of 2.4 to 2.8, to roughly 72–84 TWh compared with about 30 TWh in 2019.
- Hydrogen use and imports: Industrial demand for hydrogen (and derivatives) is estimated at 33–62 TWh by 2050. Given the limited domestic renewable potential, the vast majority of green hydrogen will need to be imported. If all needs were to be met via domestic electrolysis, this would require an additional 55–82 TWh of electricity, implying very high import dependence.
- CCUS: The potential for carbon capture is estimated at 8–17 Mt CO_2. Electricity use for CCUS processes is put at 4–9 TWh (derived from information on the energy intensity of capture technology, though not explicitly stated as a total for Belgium).

Summary

The Belgian industry's transition to net zero by 2050 will be marked by a substantial increase in electricity demand, a critical dependence on imported green hydrogen and other low-carbon molecules and the deployment of CCUS to handle large volumes of CO_2 emissions. These shifts require significant investment in electricity grid infrastructure, import and transport facilities for green molecules and CO_2, as well as supportive regulatory frameworks.

FLUXYS "North Sea Integration Model" (2024)

The FLUXYS study (and model), "Towards an optimal energy system for Belgium and neighbouring countries – Insights from the North Sea Integration Model", uses a simulation tool called the North Sea Integration Model to analyse interactions between electricity, hydrogen, methane and CO_2 infrastructure for Belgium and other North Sea countries, with the aim of achieving net zero emissions by 2050. The model's primary objective is to minimise total system costs while meeting the carbon neutrality constraint.

Methodology

The model applies an integrated view of the entire energy system. It is a modern simulator that helps to understand the drivers behind the development of an integrated energy system. It is not a forecasting tool, but a means to explore different scenarios and derive insights. The model approaches the system from a central planning and dispatch perspective, with a single "system operator" taking investment and operational decisions with perfect foresight and knowledge to minimise total system costs. The geographical scope covers Belgium and nine neighbouring countries (grouped into seven clusters), plus a North Sea cluster for offshore activities. Model inputs include scenarios for final energy demand (hourly time series), renewable production potential (hourly production time series), import assumptions (availability and costs), technical parameters for all technologies, cost assumptions for all technologies and a CO_2 reduction target. The study mainly uses the Global Ambition and Distributed Energy scenarios for final demand, developed by European transmission system operators (TSOs). The optimisation within the model determines the optimal capacities for each technology to be installed by 2050 and how they should be dispatched hour by hour. Outputs include optimal capacities and dispatch of technologies, energy not served and curtailments of renewable energy, total system costs and the marginal costs of energy carriers and CO_2 capture.

Key insights and results (Global Ambition scenario):

- Achieving a net zero energy system in the North Sea countries by 2050 is considered realistic and requires a combination of both electrons (electricity) and molecules (methane and hydrogen).
- Massive deployment of renewable electricity generation is necessary, mainly from wind (onshore and offshore) and solar PV.

- Electrolysers play a crucial role by converting surplus renewable electricity into hydrogen, acting as demand-side flexibility and dampening electricity price fluctuations, while producing renewable hydrogen.
- Energy storage – batteries for daily balancing, hydrogen storage for weekly/seasonal balancing and methane storage for seasonal balancing – is essential to ensure supply at the right time.
- Interconnection capacity between countries optimises the energy system and enhances security of supply by pooling renewable resources.
- Carbon capture, transport and storage (CCS) is necessary to reach net zero CO_2 emissions, by capturing emissions from biomass and waste, low-carbon hydrogen production and industry, with storage in the North Sea.
- In Belgium, given the lower potential for renewable electricity, there is greater reliance on electricity imports and hydrogen imports (including low-carbon hydrogen produced locally via SMR and imports by ship). Significant gas imports (including LNG) are also needed to balance the methane system.
- Gas-fired power stations remain necessary – especially in winter – to ensure electricity supply despite the dominance of renewables.

Key insights and results (Distributed Energy scenario):

- This scenario is characterised by a more electrifying final energy demand, with higher electricity demand and lower methane and hydrogen demand compared with the Global Ambition scenario.
- There is a stronger focus on decentralised technologies such as PV and batteries.
- The overall trends in technology deployment resemble those of the Global Ambition scenario, but with adjustments reflecting the shift in demand.
- Total CO_2 emissions decline slightly due to the lower demand for methane, which reduces the need for carbon capture from some sources and leads to the introduction of some Direct Air Capture (DAC) capacity.
- The total cost of energy supply is slightly lower, but the average energy price is slightly higher owing to the more electrifying mix.

The study highlights the complex interaction between the various technologies and infrastructures needed to deliver a carbon-neutral energy system in the North Sea region. It underscores the need for an integrated approach and takes account of multiple possible future scenarios.

Cefic Carbon Managers (2024)

The Carbon Managers study by Cefic (2024) sets out how the European chemical industry can become climate-neutral by 2050. The study uses a new (iC-2050) model that maps the chemical value chain in detail.

In the 2050 "Base Case" scenario, the iC2050 model projects significant shifts in energy use, the feedstock mix, the deployment of carbon capture and the types of technologies used by the European (petro)chemicals sector.

The 2050 "Base Case" depicts a chemical industry that is far less dependent on fossil fuels for both energy and feedstocks. This is achieved through:

- Increased electrification, leading to a substantial rise in direct electricity consumption, especially for heat generation.
- A shift in the feedstock mix: a decline in fossil feedstocks and a strong increase in bio-based and recycled feedstocks.
- An expansion in the use of carbon capture and storage (CCS), with most captured CO_2 stored geologically and a portion utilised as an alternative feedstock in combination with hydrogen. A large share of the CO_2 from biomass use is also captured, offsetting the remaining emissions in 2050.

- The adoption of various innovative production technologies such as partial electrification of steam cracking, alternative production routes for methanol and olefins and the scale-up of chemical recycling.

Energy in 2050:

- Final energy consumption: Final energy use in 2050 is estimated at roughly 2,250 PJ. The breakdown by energy vector shows a significant increase in direct electricity consumption compared with 2019, with electricity becoming the largest energy vector. Electricity used for heat also grows substantially, while consumption of other heat and steam declines.
- Fuel consumption: Fuel use by source in 2050 shifts away from traditional fossil fuels. Consumption of natural gas and fuel oil falls markedly versus 2019. Biomethane emerges as a major fuel source, while the use of woody biomass also rises.
- Electricity consumption: The breakdown of electricity use in 2050 indicates that the main growth drivers are olefin production (cracker electrification) and hydrogen production. Heat generation by electric boilers is expected to account for 20% of total electricity consumption.
- Installed heat capacity: Total installed capacity of heat generation technologies declines due to energy efficiency improvements and direct electrification. Biomethane and electric boilers become the principal heat sources, replacing gas- and oil-fired boilers, with biomass boilers also playing a role.

Feedstocks and raw materials in 2050:

- Feedstock mix: The total mass of feedstocks consumed by the (petro)chemicals sector is projected to be about 15% higher than in 2019 due to demand growth. The composition, however, changes drastically:
- The share of fossil feedstocks falls to around 35% of total consumption, with lower naphtha and LPG use for steam cracking and a shift to lower-emission feedstocks such as ethane and py-naphtha.
- The share of bio-based feedstocks rises to over 40% of total use, including sources such as bio-naphtha, bio-reformate and biomethane.
- Feedstocks from chemical recycling of polymers become a major source, accounting for 14.6% of total feedstock consumption; this includes py-naphtha from the pyrolysis of plastic waste.
- Feedstocks such as bio-naphtha and bio-reformate are fully utilised because of their low-emission characteristics for producing olefins and aromatics. The availability of woody biomass declines, prompting a shift towards biomethane for fuel. Lignocellulosic biomass and sugar-rich crops are only partially used, as alternative production routes for olefins and methanol are more cost-effective.

Carbon capture and storage (CCS) in 2050:

- The total volume of CO_2 captured rises to nearly 35 million tonnes.
- Most of this captured CO_2 is stored through geological storage (CCS).
- A smaller share is used as an alternative feedstock in combination with hydrogen (carbon capture and utilisation, CCU).

Technologies used in 2050:

- (Partial) electrification of steam cracking becomes a core technology for cutting direct emissions from traditional steam crackers.
- Alternative production routes gain importance, such as producing methanol from biomass and CO_2-hydrogen (CCU) and dehydrating bio-ethanol to make ethylene.
- Chemical recycling technologies – especially pyrolysis of plastic waste – are deployed and scaled up, accounting for 45.7% of total polymer volume in 2050. Gasification of mixed plastic waste to methanol is also included.
- Methane pyrolysis is used for hydrogen production.

- Steam cracking: Traditional steam crackers increasingly switch to lower-emission feedstocks such as ethane, py-naphtha and bio-naphtha. Carbon capture is also applied, reducing the share of greenhouse gases emitted.
- Olefins production: While steam cracking remains an important route, alternative technologies such as dehydration of bio-ethanol and methanol-to-olefins gain significant prominence.
- Heat generation: The dominant heat generation technologies in 2050 are biomethane and electric boilers, which replace fossil-fuelled boilers. Biomass boilers also contribute.
- Hydrogen production: By 2050, hydrogen is produced via a range of technologies, including steam methane reforming (SMR), methane pyrolysis and, to a lesser extent, autothermal reforming (ATR).

Plastics Europe (2023)

The “Plastics Transition Roadmap” builds on an earlier report, “ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe”, which examined how to achieve Europe’s 2050 goals. This new roadmap replaces Plastics Europe’s earlier “Voluntary Commitment, Plastics 2030” with a more comprehensive set of ambitions covering all aspects of the plastics life cycle.

The study is structured around strategic pillars to make plastics circular, drive life cycle emissions to net zero and promote the sustainable use of plastics.

It uses forecasts based on aggregated results from a survey of Plastics Europe members – representing a substantial share of the European market – and an analytical model drawing on diverse sources, including literature reviews, individual interviews and market research, to forecast the future of plastics. Indicators are defined to monitor progress on circularity and greenhouse gas emissions, with evaluation and reporting every two years.

By 2050, the roadmap projects various headline figures for technologies and sets assumptions on multiple aspects of the plastics system. Key figures and assumptions include:

Circularity:

Total plastics production in Europe in 2050 is 64.5 Mt in a scenario where reuse tempers growth. Without this tempering through reuse, production could reach 76.2 Mt. The model assumes a constant production-to-consumption ratio (currently 1.01), leading to projected plastics consumption of 64 Mt in 2050.

By 2050, 33% of plastics produced in Europe could be circular. The model assumes a recycling rate (collection for recycling minus sorting losses) of 70% by 2050. Circular plastics comprise:

- Mechanically recycled plastics: 15.3 Mt (24%)
- Chemically recycled plastics: 12.4 Mt (19%)

Biomass:

Plastics from biomass amount to 11.4 Mt, or 18% of total production. This is modelled as an even split between bio-based and bio-attributed plastics, with 50% from first-generation and 50% from second-generation biomass.

Carbon capture and storage (CCUS):

Together with energy efficiency, low-carbon fuels and electrification, CCS is projected to reduce the remaining scope 1 and 2 CO_2e emissions by 55 Mt. Plastics made from captured carbon are expected to reach 3.2 Mt by 2050, contingent on scaling CCS to supply the captured carbon.

Hydrogen:

Producing methanol using captured CO_2 and low-carbon hydrogen is a key pathway for CCU-based plastics. The methanol requirement for this in 2050 is estimated at 8.7 Mt. The roadmap underlines the need for a substantial scale-up of low-carbon hydrogen production and infrastructure.

35% of plastics production would still rely on fossil feedstocks, using, among other things, electric crackers and CCS.

PATHS2050 Coalition VITO–EnergyVille (April 2025)

The PATHS2050 Coalition brings VITO at EnergyVille together with five major Belgian industrial partners: ArcelorMittal, BASF, Elia, Fluxys and Luminus. The collaboration focuses on sharing and stress-testing insights on Belgium's future energy system. The core aim is to lay the groundwork for robust routes to net zero greenhouse gas (GHG) emissions in Belgium by 2050. The project develops multiple possible routes to 2050. These routes and insights are based on Belgium's most detailed techno-economic energy system model (TIMES-Be) and rigorous, data-driven analyses. The model computes various net zero scenarios and seeks the most cost-effective solution. It is set up to assume and achieve net zero CO_2 emissions by 2050; other greenhouse gases such as N_2O, CH_4 and F-gases are outside the model's scope.

Key findings:

- All three modelled scenarios successfully reduce CO_2 emissions to near zero by 2050.
- High CO_2 prices, assumed at €480 per tonne by 2050, are effective in cutting emissions but are not sufficient on their own to achieve net zero in Belgium, necessitating additional policy measures.
- Final energy demand (excluding feedstocks) in Belgium is expected to fall by a third by 2050, mainly through efficiency improvements and electrification of end uses such as buildings (heat pumps) and road transport.
- Electricity use is expected to more than double in all scenarios, from 80 TWh in 2025 to 155–170 TWh in 2050. Electrification is identified as a no-regret measure, particularly for building heating and road transport.
- Meeting the rising electricity demand requires a significant increase in power generation and capacity, calling for accelerated investment.
- Expanding offshore wind (inside and beyond Belgian territorial waters) is a no-regret and essential option, requiring grid connections and reinforcements.
- Building out PV capacity is also critical, with a target of at least 40 GW by 2050.
- New gas turbines (CCGTs, CHP) are needed to replace retiring nuclear capacity and can run on synthetic gas, biomethane or hydrogen in a net zero future. At least 7.5 GW of fuel-based thermal capacity is needed by 2050, potentially rising to 9.3 GW depending on the scenario.
- Belgium remains a net importer of electricity in all scenarios, with imports ranging from 7 TWh/year (ROTORS, REACTORS) to more than 30 TWh/year (IMPORTS).
- Carbon capture and storage (CCS) will play a crucial role in reducing hard-to-decarbonise CO_2 process emissions, although it is not economically viable for power generation. The model assumes scaling to 20 million tonnes per year from 2030. A future without CCS is feasible but more expensive and requires significantly higher imports of green molecules.
- Methane remains important in the energy system, though its use declines sharply by 2050. It is phased out in low-temperature heating but persists for high-temperature industrial processes. Gas turbines are increasingly used as peaking plants towards 2050.
- Biomethane and biomass (29–43 TWh together by 2050) are used in maritime transport, industry and for electricity/heat production. By combining biomass with CCS in industry, negative emissions can be achieved.

- Green molecules (hydrogen, e-methane, ammonia, etc.) gain importance, driven mainly by EU legislation for international transport (aviation, maritime). Their role in total final energy demand is limited by cost compared with electrification. International transport alone will account for at least 57 TWh in all scenarios.
- The supply of green molecules depends heavily on imports, driven substantially by demand for international transport fuels, rising to at least 69 TWh by 2050 and potentially exceeding 100 TWh in the IMPORTS scenario.
- Domestic production of green hydrogen via electrolysers coupled to renewable energy sources is expected to be negligible, with some exceptions such as production enabled by nuclear Small Modular Reactors (SMRs) or as industrial by-products.
- Large-scale domestic low-carbon electricity generation helps to lower long-term system costs, despite the need for substantial upfront investment.
- The ROTORS and REACTORS scenarios have similar total system costs and require annual investments of about €12.5 billion in the electricity sector between 2040 and 2050.
- The IMPORTS scenario likewise shows comparable total system costs, potentially around €3 billion lower by 2050 if imported molecules are inexpensive. However, this scenario is more exposed to price volatility; if molecule prices are higher, it could become the most expensive scenario, with annual costs increasing by €8.6 billion by 2050.

Industry-specific:

The analysis of the industrial sector within the PATHS2050 project has been significantly refined and reviewed in collaboration with industrial partners and federations, using the detailed techno-economic energy system model TIMES-Be. The model makes it possible to examine multiple pathways for the industrial sector to reach net zero greenhouse gas emissions by 2050. Key decarbonisation strategies explored include process electrification, the adoption of low-carbon fuels and clean molecules and the deployment of carbon-capture technologies. The modelling assumes stable levels of industrial activity, with energy use treated as an endogenous variable to capture interactions with the rest of the energy system.

As for final energy demand, unlike the transport and residential sectors – where demand falls markedly through electrification (such as electric vehicles and heat pumps) – industrial electrification generally does not lead to substantial demand reductions. In fact, more energy may be needed to decarbonise existing production processes. While the industrial energy mix is transformed profoundly, total final energy demand in industry is expected to be only about 3% lower than current levels (roughly 124 TWh) by 2050.

The industrial energy mix will change drastically by 2050:

- Fossil fuels still account for 66% of the mix by 2030. This share falls to 50% by 2040 and further to 25–40% (33–50 TWh) by 2050 – down from today's 66% (83 TWh). Demand for fossil energy is expected to be 30% lower by 2040 compared with 2025 (an average reduction of about 23 TWh).
- Electricity becomes the dominant energy carrier. Industrial electricity demand is expected to rise by 50–80%, amounting to an additional 20–30 TWh by 2050. By 2030, industrial electricity demand increases by +6 TWh – potentially more if carbon capture and storage (CCS) is constrained – and by +14 TWh by 2050. Industry will account for 25–40% of the total growth in electricity consumption in Belgium by 2050.
- The shift to industrial electrification occurs in two waves: an early phase (2025–2030) for low-temperature heat (industrial heat pumps) and primary steel (electric arc furnaces based on direct reduction of iron, DRI), followed by a second wave (2045–2050) including electric naphtha-cracker furnaces, fully electric CCS and electrified casting/rolling furnaces, especially in the ROTORS scenario. The thermal capacity of industrial heat pumps reaches 1.2 GWth (nearly 0.6 GWe) by 2050.

- Hydrogen demand changes significantly. It falls from 6 TWh to 3 TWh by 2030 due to imported ammonia replacing domestic production. By 2050 its role diverges by scenario: it almost disappears in the IMPORTS scenario, which relies entirely on imported ammonia with no new industrial uses. In the ROTORS and REACTORS scenarios, hydrogen use shifts from chemicals to steel, non-ferrous metals and non-metallic minerals, rising to 7 TWh. REACTORS requires an additional 3 TWh for continued domestic ammonia production.
- Combined use of biomethane and biomass reaches 29–43 TWh by 2050 (domestic and imported). Solid biomass consumption in industry reaches 9–15 TWh by 2050 (40% of the total available). Solid biomass is used mainly in industry for energy and for power/heat production (combined heat and power, CHP). By combining biomass with CCS in industry, negative emissions can be achieved.
- Clean molecules (e.g. hydrogen, e-methane, ammonia, synthetic fuels) gain importance, particularly driven by EU regulation for international transport. Although their role in total final energy demand is limited compared with electrification because of cost, they are needed for remaining refining activities, industrial feedstocks and potentially power generation (4 TWh in ROTORS/REACTORS, up to 20 TWh in IMPORTS). Their supply depends strongly on imports, driven by demand for international transport fuels.

Feedstock use is expected to remain largely unchanged, assuming industrial activity stays stable. Without targeted policy, fossil feedstock will likely remain dominant (90 TWh by 2050), as alternatives are more expensive. Partial imports of ammonia and methanol synthesis (9 TWh of e-methanol feedstock in ROTORS, reducing fossil feedstock by 14 TWh) can modestly curb fossil feedstock use.

In terms of emissions reduction:

- Current industrial CO_2 emissions are about 27 MtCO_2, a 35% reduction compared with 1990.
- By 2030, all scenarios forecast a further reduction of about 4 MtCO_2, equating to a 46% cut relative to 1990 levels. Significant reductions are achievable in sectors such as paper, food and ammonia by 2030.
- From 2030 to 2040, the pace of reduction diverges: ROTORS declines steadily (4% per year) to 14 MtCO_2 (limited CCS). REACTORS and IMPORTS accelerate (14% per year) to 5 MtCO_2 (faster large-scale CCS, stronger incentives). By 2040, industry will have reduced emissions by 45–80% versus current levels.
- By 2050, all scenarios achieve a 95% reduction in industrial emissions relative to today and 97% relative to 1990.
- The CO_2 intensity of final energy use in industry is expected to fall from nearly 215 gCO_2/kWh today to 8–13 gCO_2/kWh by 2050.

Carbon capture, utilisation and storage (CCUS) plays a crucial and dominant role in decarbonising industry in all scenarios, contributing 50–70% of total emissions reductions (13–18 MtCO_2) by 2050. The remaining reductions (7–14 MtCO_2) come from electrification, biomass and clean molecules. Captured volumes range from 14 to 20 MtCO_2 per year by 2050. The model assumes CCS scales to 20 million tonnes per year from 2030 and remains constant to 2050, except in ROTORS where storage is limited. CCS is first deployed in sectors with highly concentrated emissions, such as ammonia and ethylene oxide (the Kairos@C project around 2030).

As the CO_2 price rises (to €295/t between 2035 and 2040), the non-metallic minerals sector scales up CCS. After 2040, adoption extends to steel, high-value chemicals and refineries. Broad CCS rollout in chemicals, steel and non-metallic minerals accelerates the transition in REACTORS and IMPORTS. A future without CCS is feasible but more expensive and requires higher imports of green molecules. CO_2 storage costs outside Belgium are expected to fall to €37/t by 2050. The ROTORS scenario, with limited storage capacity (10 $MtCO_2$/year), reuses captured fossil carbon for methanol synthesis (CCU), although current EU legislation offers limited credit for CCU unless permanent. CCUS may require between 7 and 10 TWh of energy by 2050.

Annex 4: Overview of stakeholders consulted in the interviews

Organisations
VLAIO
VEKA
OVAM
Department of WEWIS
Department of Environment
Essenscia
Steelbel
Energia
Febeg
VOKA
ACV
ABVV
ACLVB
BBL
Fluxys
Elia
Port of Antwerp-Bruges
North Sea Port
BASF
Arcelor Mittal
Borealis
Ineos
Total Energies
Air Liquide
Catalisti
VITO
Worley
Cefic

Annex 5: Summarised technology insights from interviews

Chemicals

Electrification

All companies are looking at electrification, but major investments are not yet forthcoming. The higher cost of electricity is a key factor. For now, only smaller investments are being made in e-boilers, which can be used, for example, to meet additional heat demand. To date there are no indications of large e-boiler investments before 2030. A promising option is the collective provision of steam via e-boilers. This can improve the cost efficiency of e-boilers in terms of both OPEX and CAPEX.

Electrification of large process installations such as steam crackers is advancing technologically and should certainly be available at scale by 2035. In addition to the price of electricity, the availability of CO_2-free electricity also plays a major role.

Besides cutting direct emissions, companies are focusing on reducing scope 2 indirect emissions. In that context, several large companies have already concluded power purchase agreements for green electricity and/or invested in renewable energy themselves. These investments appear to be primarily demand-driven from further down the value chain (e.g. customers seeking to decarbonise products).

On electrification, the conclusion is that the 2020 context analysis probably underestimated the potential, but that the large-scale shift from fossil-fired steam to e-boilers will only occur from 2030 onwards and will depend mainly on the cost of electricity.

CC(U)S

CC(U)S remains a very important component in the plans of the Flemish chemicals (and steel) industry. If imminent final investment decisions (FIDs) go ahead this year, there is a realistic chance that by 2030 the main emission reductions will already come from CCS. The initial focus will be on processes with high CO_2 concentrations (e.g. SMR/ATR, ethylene oxide). Technologically this is more or less ready. With the addition of cryogenic capture and purification of CO_2, it will also be easier to meet the standards for CO_2 transport and storage.

Key barriers at present are CAPEX – which has risen sharply in recent years due to inflation – and uncertainty around implementation of the REDIII directive (which emphasises targets for the use of green hydrogen in industry but is ambiguous on blue hydrogen).

After 2030, and provided capture from low-CO_2-concentration residual gases is further developed and made more efficient, the use of CCS can grow further. This will then need to be weighed against the investment and especially the operating costs of electrification.

In this respect, the assumptions in the 2020 context analysis remain valid, with the caveat of higher electrification after 2030.

Hydrogen

Interviews with stakeholders and several roadmaps examined indicate that the role of hydrogen production via electrolysis in Flanders will be (very) limited – most likely with the exception of electrolysis for producing RFNBOs, for which binding targets exist on the refining side.

The use of hydrogen will most likely be confined to feedstock for processes and the production of RFNBOs. Depending on European targets, the latter could, however, drive greater demand for green hydrogen. The likelihood that hydrogen boilers will ever be economically viable is small.

Blue hydrogen will be the norm in Flanders in the short term, provided the planned CCS-related investments go ahead.

There is still great uncertainty about the scale and type of hydrogen imports. Green methanol and ammonia appear (also based on investments abroad) to be possible frontrunners.

The 2020 context analysis and roadmap already backed blue hydrogen but also envisaged large investments in local electrolysis capacity. The latter needs to be revised.

Circularity

On plastics circularity (at the materials level) and, in particular, chemical recycling, progress on large projects and new investments is lagging somewhat. For example, there remain (limited) technical and economic challenges in solvolysis of PET, among others. The other technology now often chosen is pyrolysis of plastic waste, producing outputs that can be used as drop-in feed in conventional crackers. The drop-in potential can be quite high (compared with the 10% used in the past). The main bottlenecks here are the availability of a clean/consistent stream of plastic waste. To scale up this technology, investment will be needed primarily in the upstream value chain and logistics. Another challenge concerns the higher costs of this type of recycling, especially in a competitive polymers market. The lack of more binding targets for plastics recycling, combined with the need to safeguard the competitiveness of this production (e.g. against low-cost imports), is holding back further growth and investment.

Steel

Based on expert interviews, reporting and projects funded by the ETS Innovation Fund, the pathway for Flanders still appears to be a combination of the options mentioned above. The most likely option emerging is:

- Replacing one blast furnace with DRI together with one or two electric arc furnaces (EAFs) which, in addition to processing sponge iron from the DRI, can also recycle a larger quantity of scrap steel.

- The DRI will initially use natural gas as feedstock but can switch to hydrogen later without issues. The hydrogen itself will most likely be produced via an ATR (autothermal reformer) with CCS through a linked project in the Ghent seaport. Large-scale use of electrolytic hydrogen for steel production in Flanders seems unlikely due to the high cost and the lack of cost-efficient options to import hydrogen at scale in the short term (before 2030) or medium term (before 2040).

- Another blast furnace can use a combination of the technologies mentioned above: hydrogen injection, biomass waste, gasification of (plastic) waste and CCU via the Steelanol process.

The 2020 context analysis and roadmap did not account for the possible development of a DRI and EAF installation. Practical differences from the above plans will include, among other things, a greater use of recycled steel in Flanders, together with a more limited (but still substantial) deployment of CCS – for blue hydrogen used in DRI and for reducing emissions from the existing blast furnace. Given the currently difficult context for steelmaking in Europe, there remains a major question mark over when – or whether – investments in new production facilities, and DRI in particular, will be made. In any case, in the short and medium term it seems unlikely that DRI will use electrolytic hydrogen.

Refining

According to interview feedback, little changes for refining compared with the 2020 roadmap. Carbon capture remains an important mitigation option – initially for local hydrogen production and later possibly for catalytic crackers and boilers. Electrifying lower-temperature heat is also a possibility.

The refining sector will also focus more on sustainable aviation fuels (mainly via biomass) and RFNBOs (renewable fuels of non-biological origin), driven by European standards that create demand for these products. This also means the industry is very likely to invest at larger scale in electrolysers for hydrogen production, because the higher costs can be passed through.

There remains great uncertainty about future refining needs in Europe due to the expected reduction in demand for fossil fuels. As in the 2020 roadmap, the assumption is that Flemish refineries – due to location, efficiency and integration with the (petro)chemicals sector – are more likely to be at the tail end of potential closures; but this remains a point to monitor closely.

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