Towards scenarios of industrial transformation in Belgium

CEEP-IT deliverable 1.1 - Selecting industrial transformation cases: results from literature and expert panel

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Contents

List of acronyms

AB	Advisory Board
AI	Artificial Intelligence
BE	Belgium
BOF	Basic Oxygen Furnace
CBAM	Carbon Border Adjustment Mechanism
CCS	Carbon Capture and Storage
CCUS	Carbon Capture Utilization and Storage
CEEP-IT	Climate-neutral Energy-Economy Pathways with Industrial Transformation
CGE	Computable General Equilibrium
CID	Clean Industrial Deal
DRI	Direct Reduced Iron
EAF	Electric Arc Furnace
EEIO	Environmentally Extended Input-Output
EII	Energy-Intensive Industry
ESOM	Energy System Optimisation Model
ETS	Emissions Trading System
GBFS	Granulated Blast Furnace Slag
GDP	Gross Domestic Product
HBI	Hot Briquetted Iron
HVAC	Heating, Ventilation, and Air Conditioning
ITC	Industrial Transformation Case
MTO	Methanol-to-olefins
NG	Natural Gas
NZIA	Net-Zero Industry Act
PUE	Power Usage Effectiveness
SMR	Steam Methane Reformer
TRL	Technology Readiness Level

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Executive summary

The CEEP-IT project aims to explore Climate-neutral Energy-Economy Pathways with Industrial Transformation of energy-intensive industry. Analysing industrial transformation in a comprehensive and integrated way requires a broad understanding of the industry's value chains, alongside the variety of options for climate-neutral and circular production in Belgium. This includes the value chain *upstream* of domestic energy-intensive production, in the form of the potential imports of different forms of energy, and final or intermediate energy-intensive commodities. It also includes the *downstream* markets such as construction, automotive, plastics and fertiliser that consume energy-intensive commodities and may be in transformation themselves. Moreover, new sectors could emerge, such as data centres or a materials recycling industry, that may generate additional energy demands.

This scoping report lays the foundation for the CEEP-IT model-based analysis of industrial transformation from an energy-economy perspective. In the report, we take stock of main relevant developments related to industrial transformation in Belgium as they unfold currently and possibly towards the future. To this end, we combined literature review and the perspectives from an expert panel covering industry perspectives from different sectors. Based on these insights, we derived a 'long-list' of so-called Industrial Transformation Cases: concrete cases of transformation, whether an innovative production route, a change of import of (intermediate) commodities, or a change of practice downstream altering energy-intensive product demand. The long-list was further condensed based on a qualitative evaluation (based on literature, expert interviews and own interpretation) of the impact and uncertainty, as an indicator of the relevance of each transformation case for scenario analysis.

Section 3 of the report presents the results of this analysis for main energy-intensive sectors in Belgium. In general, we find that all sectors are working towards the uptake of climate-neutral or circular production options, with innovative production routes being piloted and further investment being prepared. Yet, different barriers apply, with high energy costs as a common factor. Other barriers, such as the exposure to global competition (mainly steel, chemicals) or the reliance on CCS infrastructure (mainly cement, lime) are more sector specific. Our findings suggest that main global industry relocation risks apply for chemicals and primary steel, and to some extent for cement, with other sectors being more locally bound. Yet, for most sectors trade flows within Europe are common, making relocation intra-EU relevant to consider. Transformation cases reflecting industry relocation (i.e. shift from domestic production to imports) are potentially more disruptive than downstream market developments, which are more gradual in nature.

Considering downstream markets, we addressed the future of construction as a main potential driver of the demand for commodities like cement, steel, glass and brick. This will depend on the level of new-built versus renovation, the uptake of alternative building materials, and government infrastructure spending among other factors. With high current growth rates, datacentres are highly relevant to consider as emerging energy demands. However, their future growth rates and power consumption is highly uncertain, depending on efficiency improvements, the speed of uptake of artificial intelligence and the regional allocation of datacentres to Belgium. We also touched upon the potential role of batteries, plastics and metals recycling in the Belgian future industrial landscape.

As described in Section 4, ITCs considered of highest relevance were consequently clustered under three main storylines. All storylines portray a climate-neutral Belgium in 2050, but differ in terms of the level of industrial relocation and the nature of economic shift, whether to innovative economic sectors or more traditional services. The qualitative storylines triggered substantial debate during the expert panel workshop. Discussions highlighted - amongst others - the important role of carbon capture and storage in the transformation to climate-neutral industries and the challenge of accurately representing production costs for climate-neutral and circular processes. Potential change of import of (intermediate) commodities was considered relevant to analyse, provided that impacts on the economy, carbon leakage, strategic autonomy are addressed. Participants also recommended a more concrete specification of the economic shift to existing or emerging sectors in response to potential industry relocation.

The main value of the current report is that it lays a comprehensive basis for the further quantification of industrial transformation cases for developing modelled scenarios. We distinguished trends that have a relatively low level of uncertainty that should be adopted under each scenario as baseline trends. Increased levels of circular steel, a shift in graphic paper consumption towards packaging, increasing demand of flat and fibre glass and waste heat recovery for the production of bricks are examples under this category. Other possible developments that were considered having high uncertainty are to be adopted differently under each scenario. Main examples cover innovative circular production routes (such as the chemical recycling of plastic waste), new types of imports (such as sponge iron import), long-term demand outlooks (such as for cement and concrete), and emerging demands (for example from data centres). In the CEEP-IT modelling framework, such developments will be implemented as different types of economic shocks: shocks in international competition, shocks in the input composition of the production processes of firms, and broader economic evolutions driving the demand of energy-intensive commodifies.

The next main research step is to prepare the CEEP-IT modelling framework to cover the transformation cases and qualitative scenarios discussed in this report. The updated CEEP-IT modelling framework will consequently be applied to elaborate on the current qualitative storylines and analyse different modelled Climate-neutral Energy-Economy Pathways with Industry Transformation.

Acknowledgements
We would like to thank all members of the expert panel and advisory board for their valuable feedback and recommendations.

1 Introduction

1.1 The CEEP-IT project

Positioned as one of the most energy-intensive regions in Europe, Belgium will need a great transformation of the energy system to support a climate-neutral economy. This challenge is particularly grand for the industrial sector which accounts for roughly 46% of Belgian final energy and non-energy demand[1]. Recent studies have investigated how to transition industry to net-zero in Belgium (Elia, 2022; Fluxys & Elia, 2025; VITO/EnergyVille, 2025). Key messages include that electrification of industrial processes could double electricity demand by 2050 under cost-optimal scenarios, in addition to important roles for clean molecules (up to 25% of final energy demand) and Carbon Capture Utilization and Storage (CCUS).

These studies, however, tend to put lesser focus on one of the key uncertainties in the Belgian energy-economy system, namely the development of energy-intensive production levels themselves. They typically rely on the assumption that industrial production levels in Belgium remain constant or increase lightly, with only a few exceptions for refineries, food and the digital sector (data centres). Yet, industry production levels themselves could be subject to change for various reasons, ranging from relocation in response to rising energy costs and global competition to emerging downstream demands that are yet difficult to foresee. This in turn, could have a significant impact on both on energy system planning, as well as on the economy, strategic autonomy, and jobs.

The CEEP-IT project will therefore explore climate-neutral energy-economy pathways with *industrial transformation* of Energy-Intensive Industry (EII) where change of production levels is central to the analysis. Industrial transformation is interpreted broadly, including both improved efficiency, electrification and switching to alternative fuels and feedstocks needed to achieve a net zero industry, as well as transformations that imply a change of industrial activity. The latter may imply significantly *lower energy demand* for industry, for example, due to industrial relocation (Verpoort et al., 2024) or higher efficiency in downstream sectors. They may equally imply the emergence of *new or significantly increasing energy demands*, such as for data centres, the recycling industry and battery production. These transformations may have important impacts on the energy system and the larger macroeconomic system, which themselves evolve in interaction.

To analyse these impacts and interactions, the project aims to advance modelling methodologies by integrating different model types (see Box 1). These include energy system optimisation models, computable general equilibrium, and environmentally extended input-output models. Modelled energy-economy pathways will consequently further our understanding about main impacts for industry and energy of various external developments and policy shocks. This understanding is crucial for robust energy system planning that ensures security of supply and economic viability under a range of future conditions.

[1] Based on Eurostat values reported for 2019. Total demand includes final energy consumption, final non-energy consumption and net input for coke ovens and blast furnaces. Refineries are excluded.

Box 1: Modelling approaches in CEEP-IT

A **Computable General Equilibrium (CGE) model** is a comprehensive economic modelling framework used to analyse the interconnections within an economy. It captures the relationship among different economic sectors, such as households, industry and institutional bodies. The model is based on general equilibrium theory, which assumes that the entire economy should be considered as a system in which supply and demand equilibrate in all markets simultaneously. CGE models are a mathematical description of the relationships between different economic variables (e.g. supply and demand). CGE models can assess the impact of various shocks, and policy implementations, providing a holistic perspective of production, consumption, and distribution across sectors, as well as the set of commodity and factor prices (wages and rental rates) that ensures equilibrium.

Energy System Optimisation Models (ESOMs) are partial equilibrium models focusing solely on the energy supply and demand sectors instead of general equilibrium models covering all economic sectors. They contain a detailed, bottom-up, techno-economic description of the energy system, reflecting the investment and operational characteristics of different supply and demand side energy technologies. ESOMs normally utilize linear programming to maximise total welfare, equivalent to minimizing total, discounted energy system costs in the case of inelastic energy service demands. They do so by optimizing energy technology investments and operations from a central (or 'social') planner perspective, usually assuming perfect foresight over the timeline considered. Typical outputs include future estimates of technology capacity and operation, marginal prices of energy commodities/materials, and greenhouse gas emissions across the energy system.

An **environmentally extended input-output (EEIO)** analysis allows the analysis of global value chains and environmental impacts linked to local consumption. The input-output tables show the input needed to produce one euro of output where each cell shows the payment of the corresponding column to the corresponding row while total revenue should equal total expenditures for every account. The input-output tables are calculated from the supply and use tables. The supply table shows the supply of goods and services by product and by producing industry. It distinguishes supply between domestic industries and imports. A use table shows the use of goods and services categorised by product and by type of use. This includes intermediate consumption by industry, final consumption expenditure by households, government and non-profit institutions serving households, gross capital formation and exports.

1.2 This report

This first scoping report lays the foundation for the CEEP-IT modelling work. It does so by taking stock of the most relevant development related to industrial transformation in Belgium as they unfold currently and possibly towards the future. Concretely, it reports on the results of the first Work Package (WP1) of CEEP-IT. This WP included the following main tasks:

- Select and characterise a set of main Industrial Transformation Cases (ITCs) to be analysed in the project (T1.1)
- Set up an expert panel comprising representatives of industry, society and research to support the project in selecting and understanding the most relevant trends of industrial transformation in Belgium to be explored in the pathways (T1.3)

- Translate identified trends and ITCs into exogenous parameters and policies feeding the linked energy-economy model system (Task 1.2)

To describe the outcomes of these tasks, the reports is structured as follows:

- Section 2 reports on relevant methods and concepts. This includes the conceptual framework for analysing industrial transformation, the way the expert panel and further research process was set up.
- Section 3 describes our main findings on industry transformation in Belgium. Departing from a brief historic perspective we describe for main industrial sectors relevant issues, drivers and trends that may guide future production in Belgium. For each sector, relevant ITCs are identified and classified according to their potential impact and uncertainty. This chapter is based both on literature and on insights from the expert panel interviews
- Section 4 presents our first steps towards industrial transformation scenarios. Drawing from the expert panel workshop, it describes a first qualitative outline of industry transformation scenarios to be modelled, consistently mapping ITCs under each storyline. It also includes a first proposal for translating the qualitative scenarios to common scenario assumptions and policies entering the CEEP-IT modelling framework.
- Section 5 describes our main conclusions and how the results will be used in the next phases of CEEP-IT.

2 Methods and concepts

2.1 Dimensions of industrial transformation

Industry transformation is typically interpreted as the transformation from a fossil-based to a 'climate-neutral' or 'carbon-neutral' industry with net-zero emissions (Material Economics, 2019). It is also referred to as the 'decarbonisation' of energy-intensive industry (Draghi, 2024) or even the green industrial revolution (Climact & BBL, 2021). Industry transformation is not only about climate. Circularity is an important environmental ambition expressed under the EU's clean Industrial Deal (EC, 2025b) that goes hand in hand with climate-neutrality, but from the perspective of the use of scarce materials is seen as an end in itself. Sustained competitiveness is considered a prerequisite to transformation. This competitiveness – in fact - is currently under pressure (Section 3.1.3), which could lead to some level of deindustrialisation with associated impacts on the EU's economy and strategic autonomy. At the same time, various developments downstream from the energy-intensive sectors could further alter the production landscape. Computing and AI, clean energy technologies, automotive and defence (Draghi, 2024) are all examples of downstream sectors whose development is significant to capture industry transformation in the energy-intensive industry.

In the CEEP-IT project we therefore adopt a broad interpretation of the concept of industry transformation covering three main dimensions illustrated in Figure 1. The first dimension 'carbon neutral & circular production' considers all transformation routes in industry via renewed climate-neutral and circular value chains (which is a study in itself). The second dimension 'Industrial relocation' considers transformation of domestic industries by relocating (parts of) the value chains abroad. Relocation[2] thus typically considers increased imports of intermediate or final products (consistent with regulations under the Carbon-Border Adjustment Mechanism - CBAM), for example in response to better renewable energy availability elsewhere or other competitive pressures. Also increased production in Belgium could be considered under this dimension. Although our primary geographical focus is the Belgian energy-economy system, it is important to distinguish global and intra-EU relocation, since these play out very differently on aspects of 'level playing field' and strategic autonomy. The third dimension 'downstream market developments' refers to changes in downstream production and consumption, which directly impacts the upstream energy-intensive industries.

Under each dimension we consequently identify multiple ITCs specific to different industrial sectors. An ITC thus reflects a concrete case of transformation, whether an innovative production route, a change of import of (intermediate) commodities, or a change of practice downstream altering energy-intensive product demand.

[2] Note that we do not necessarily consider a company to move abroad. Although geographical shifts of production level could occur within one company, it can also reflect a loss of market share to a global (or EU-based) competitor.

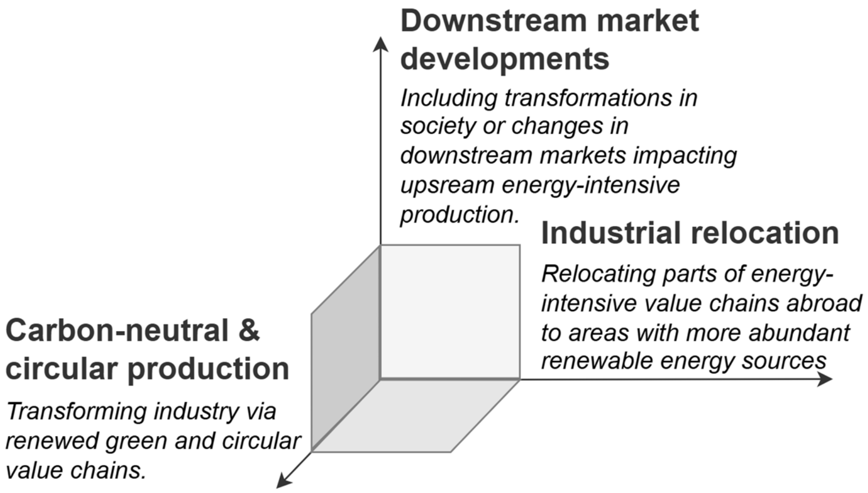

Figure 1: Dimensions of the Industrial Transformation Cases.

2.2 Steps in the research process

The methodological design was structured along several steps to progressively move from a broad exploration of possible ITCs to a refined and realistic set of sectoral and cross-sectoral transformation pathways. This process combined literature review, stakeholder engagement, and collaborative scenario building.

Step 1: Preparation phase and identification of ITCs ('longlist')

The process began with an extensive review of literature in order to identify a broad set of potential ITCs. This initial "long list" covered a wide variety of technological and organizational changes relevant to the industrial landscape. The objective was to map the state of knowledge, capture lessons from previous studies, and ensure that no major transformation pathways were overlooked at this early stage.

Step 2: Bilateral interviews with experts (towards a 'shortlist')

The second step consisted of bilateral interviews with industrial actors, federations, and sectoral experts for each of the industrial sectors targeted. These exchanges served to challenge and refine the longlist of ITCs that had been established through the preparation phase and anchor them to the specific context of Belgian industries. To achieve this, introductory presentations were developed for each industry sector with an overview of main ITCs derived from literature. Interviewees were then invited to react to a series of guiding questions, such as:

- Does the proposed ITC appear realistic in the context of your sector and the industrial reality in Belgium?
- Which ITCs seem most plausible and relevant?
- Are there additional ITCs that should be considered and that were not identified through the literature review?

This step was essential to move from a broad, literature-based longlist to a more robust and validated shortlist, while integrating the perspectives, knowledge, and realities of industrial stakeholders.

Step 3: Expert panel workshop and qualitative scenario development

Once the short list of ITCs had been consolidated, an expert panel workshop was organized. The panel brought together two groups: stakeholders / sector experts previously interviewed on a bilateral basis and the members of the CEEP-IT Advisory Board including system operators, policy representatives and NGOs. Ahead of the workshop, three draft scenario storylines were prepared aiming to capture plausible and diverging industrial futures. For each storyline, the most consistent ITCs under the storyline were pre-identified per sector to stimulate debate and provide a concrete starting point for discussion.

The workshop was designed using a world café approach, with one discussion table dedicated to each scenario. This interactive format encouraged collaborative exchange and iterative refinement. The main objectives were to:

- Challenge and co-create scenario narratives: Assess the realism of each storyline and enrich it with additional elements, making the scenarios more concrete, credible, and collectively owned.
- Clarify enabling conditions: Identify the policy requirements and systemic changes needed for each scenario to unfold, as well as the policies that could drive or constrain different futures.
- Validate ITCs across sectors: Re-examine the ITCs pre-identified for each scenario, testing their relevance in a cross-sectoral perspective. This collective exercise helped to move beyond a sector-by-sector vision and toward a more integrated understanding of potential industrial transformation pathways in Belgium.

Step 4: classifying ITCs by impact and uncertainty
As final step, each ITC were classified by impact and uncertainty as outlined in Table 1. The qualitative judgements were made by CEEP-IT researchers combining multiple inputs: literature, interviews, and expert panel workshop. The classification was consequently used to rank ITCs on their relevance for including in the scenarios as follows (e.g. Wulf et al., 2011):

- Low impact: relatively unimportant to include in scenarios
- High or medium impact / low uncertainty: relevant to include as a baseline development under all scenarios
- High or medium impact / high or medium uncertainty: relevant to include differently under each scenario

We highlight that classification of impact and uncertainty is meant mainly as a discussion tool in the context of scenario analysis. The qualitative evaluation of impact and uncertainty is to some extent ambiguous, context dependent and subject to discussion.

Table 1: Descriptive guideline for classifying ITCs by impact and uncertainty

	Low	Medium	High
Impact	Low potential impact for the energy-economy system, with limited application potential (for a technology) and / or limited amount of change expected	Medium potential impact for the energy-economy system, with significant application potential (for a technology) and / or significant amount of change expected	High potential impact for the energy-economy system, with high application potential (for a technology) and / or a transformative change expected
Uncertainty	The ITC is likely to occur with limited uncertainty about its extent	The ITC is somewhat likely to occur with significant uncertainty about its extent	It is uncertain whether the ITC will occur and to what extent

From research steps to results

The results of steps 1 and 2 and 4 are described under Section 3. The results of the expert panel (step 3) are further developed in Section 4.

2.3 Sectors analysed and stakeholder engagement

The list of sectors analysed, along with the number of interviews conducted and representation during the expert panel workshop, can be found in Table 2. A list of involved organisations is included in Appendix 1. In addition to main production sectors, we included emerging sectors like data centres and a main downstream sector in the form of the construction sector. The latter was not studied in the same level of depth as the other sectors; however, it was considered relevant to include it, as it drives and defines the demand in the steel, cement, glass and brick industries. Efforts were made to involve representatives from data centres in the analysis, although engaging those representatives in our research process was ultimately not possible. Furthermore, actors from system operation, policy, NGO and research organisations were invited to the expert panel workshop to provide additional cross-sectoral perspectives.

Table 2: List of sectors analysed, along with the number of interviews conducted and participation at the expert panel workshop (sectors in italics were not analysed, but added to show participation during the workshop)

Sectors	Interviews	Workshop
Steel	4	1
Chemicals & Fertiliser	2	2
Cement & Lime	4	2
Bricks	1	1
Glass	2	1
Paper, pulp & printing	1	1
Construction	2	1
Emerging sectors: data centres, clean tech in Belgium	-	-
System operators		3
Policy		1
NGO		1
Research		3

3 Industry transformation in Belgium

This section gives an overview of the prospects for industry transformation in Belgium. After a brief historical perspective on Belgian energy-intensive industry, a more detailed overview on current production landscapes and Industrial Transformation cases for main energy-intensive sectors are provided. The section closes with three cases that are of cross-sector relevance (the future of construction) or reflect potentially emerging demands (data centres, clean tech in Belgium).

3.1 Historical perspective

3.1.1 From industry to services

Energy-intensive industry (EII) in Belgium has historically played an important role in the Belgian energy-economy system. Van Gompel (2024) provides a comprehensive overview of the development and role of manufacturing[3] in Belgium from a macroeconomic perspective. The historical development trend of economic value added can be characterised as a decline in relative terms, and a growth in absolute terms (Figure 2). In the 1970s, manufacturing still represented about one third of the Belgian GDP, which declined to some 13% today. Current day, main subsectors in terms of economic value added (i.e. share relative to total industry) are pharmaceuticals (23.0%), food (16.2%), chemicals (12.0%) and metals (10.5%). Compared to other EU countries, the pharmaceuticals and chemical sector stand out as relatively strong sectors, followed by food and metals. The top five sectors in terms of energy intensity (chemicals, basic metals, pulp and paper, non-metallic mineral, wood and wood products, see Figure 3) account for roughly 4% of total value added and 2% of overall employment in Belgium (Swartenbroekx & Verdini, 2025).

The reduction in the share of industry in the Belgian GDP does not imply an absolute deindustrialization. In fact, the Belgian industry sector has experienced steady annual real added value growth of 1.3% on average over the period 1995-2023. Yet, the services sector has been growing more rapidly with an annual growth rate of 2.1% on average over the same period. Van Gompel (2024) provides various reasons for this structural shift from manufacturing to services. First, our consumption patterns have changed towards services, such as health care (due to an aging population), increased childcare and cleaning services (due to enhanced female labour participation) and the emergence of ICT. Secondly, the industry sector has experienced significant productivity gains due to technology advance as well as increased international competition because of globalisation, resulting in lower price increases in manufacturing compared to services. Finally, outsourcing tasks that are not part of the core industrial activities - such as transport, catering or cleaning – has moved jobs and value added to services. All-in-all, since the 1970s, jobs have shifted to the services sector, with a net loss of 675.000 jobs in Belgian industry, but an increase in total employment of 1.350.000 persons due to job creation in services.

[3] Covering NACE codes BB (mining and quarrying) and C (manufacture of products), excluding the category C19 (manufacture of coke and refined petroleum products) being considered part of the energy sector.

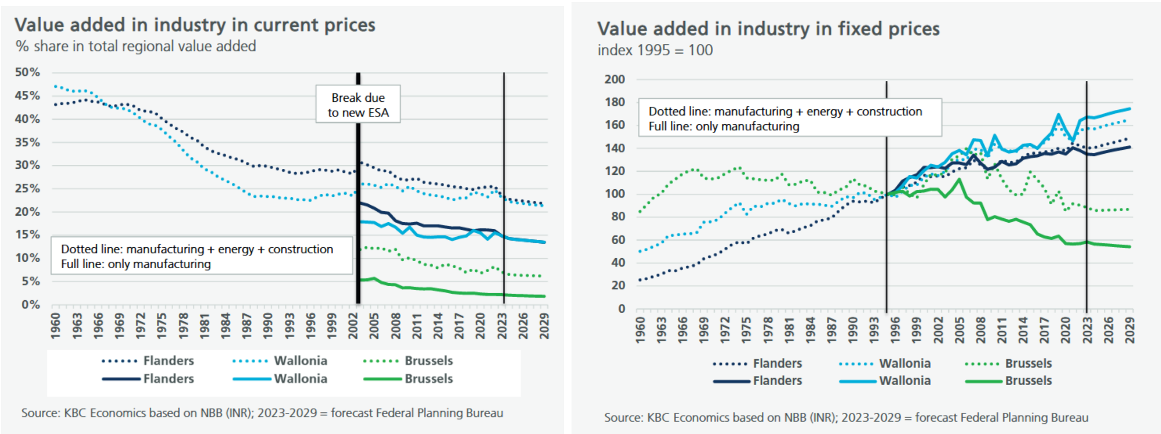

Figure 2: Industry value added in relative and absolute terms. Source: (Van Gompel, 2024)

3.1.2 What about energy consumption?

Although the term 'energy-intensive industry' is widely used and has an intuitive interpretation, there is no strict definition of what an energy-intensive sector is (Swartenbroekx & Verdini, 2025). Swartenbroekx & Verdini therefore rank energy intensity of industry sub-sectors in Belgium based on the ratio of final energy consumption over economic value added (Figure 3) to be able to define energy-intensive sectors at least in relative terms. The top-four energy-intensive sectors from this analysis – i.e. those that in principle would be most affected by energy prices – are chemicals, basic metals, pulp and paper and non-metallic minerals. In contrast, the economically important sub-sector of pharmaceuticals comes out low on the energy-intensity scale.

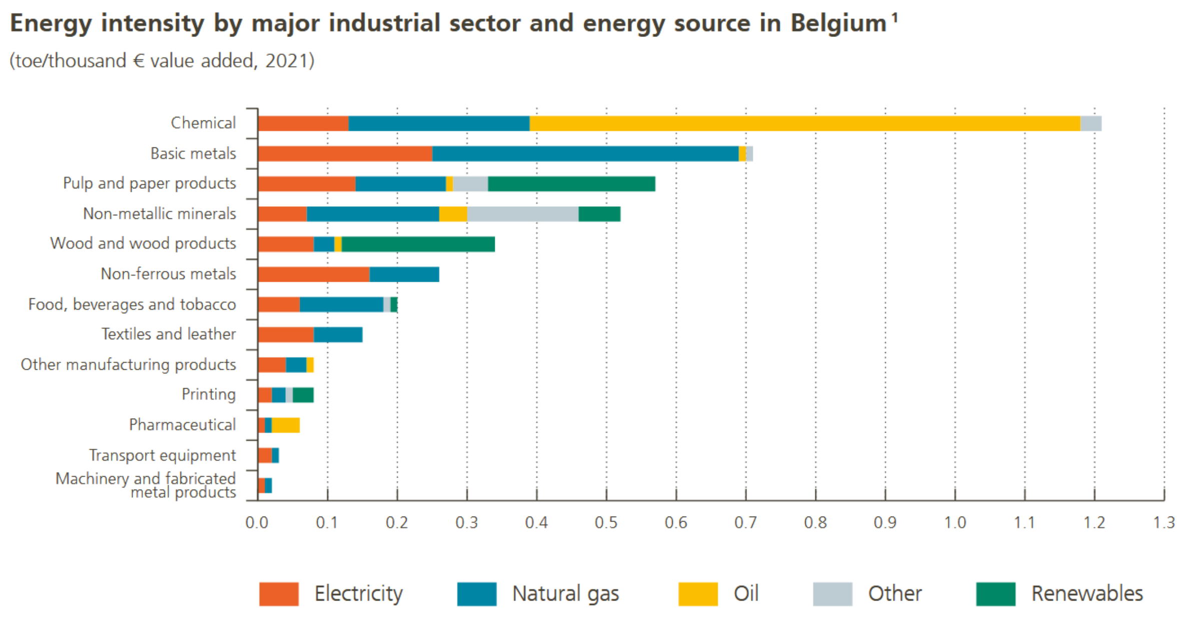

Figure 3: Energy intensity of major industrial sector in Belgium based on the ratio of final energy consumption over economic added value. Source: (Swartenbroekx & Verdini, 2025)

Looking at total energy consumption (Figure 4), one finds that - whereas the share of industry in GDP has been in decline - its share of energy consumption has not. Although there is variability over the years, the share of industrial energy consumption to Belgian total energy consumption has been roughly stable within the range of 40%-50%. In absolute terms, energy consumption for chemical (inc. non-energy consumption) has been on the rise, while that of iron and steel has been in decline.

Alongside changes in energy efficiency and fuels, this development can be attributed to changes in in production. Production decline has occurred mainly for steel (from 12 Mt in 1990 down to 8 Mt in 2022), and to a lesser extent for cement, lime and glass, while the chemical sector still made important expansions in Port of Antwerp in the 1990-ies. Greenhouse gas emissions consequently have fallen most strongly for steel, but a more gradual decline was registered across other sectors as well (Wyns et al., 2025).

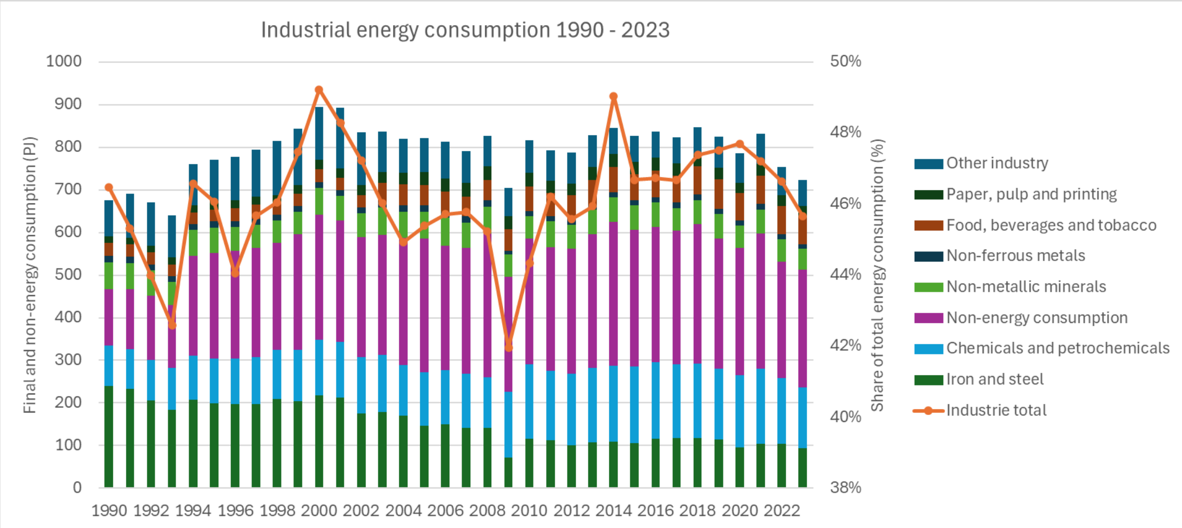

Figure 4: Industrial energy consumption in Belgium over the period 1990 – 2023. Source: STATBEL[4].

3.1.3 Industry under pressure

In recent years, several pressures have emerged on EIIs in Belgium (Swartenbroekx & Verdini, 2025) and the EU at large (Draghi, 2024). Following (Draghi, 2024) and without aiming to be comprehensive, main pressures can be summarised as follows.

1. High energy prices: Energy naturally is a relatively large component of EIIs cost structures, and particularly since the 2022 energy crisis, EU faces significantly higher energy costs than its main global competitors. In 2024, Belgian industrial electricity and gas prices were a factor 2-3 higher than in the United States (Swartenbroekx & Verdini, 2025).
2. High emissions costs: Although less substantial than the energy costs per se, emission allowances required under the EU ETS do further increase the pressure on total energy costs. Since 2020, ETS prices have been rising to above 60€/ton[5]. Although there are other regions like Australia, California and China with a carbon pricing system, their carbon prices are typically lower (Swartenbroekx & Verdini, 2025).
3. Relevant investment needs to decarbonise. Climate-targets and ETS pricing require substantial investment with long-term investment cycles. Yet, the business cases for these investments are difficult with uncertain potential operational cost advantages that rely on low electricity and low-carbon fuel prices. Moreover, carbon price volatility and general policy instability contribute to investment risk.

[4] https://statbel.fgov.be/nl/themas/energie/energiestatistieken-economische-sector-en-energiebron: Total industrial energy consumption includes final energy consumption industry sector, final non-energy consumption and net input for coke ovens and blast furnaces. Refineries are excluded. Total final energy consumption additionally includes final energy consumption of other sectors (residential, commercial, agriculture, fisheries) and domestic transport.
[5] E.g. https://tradingeconomics.com/commodity/carbon

4. An unlevel playing field and complex regulation: Besides differences in energy and CO_2 costs, the global level playing field is compromised by uneven financial support, where high subsidy levels in other global regions have contributed to building overcapacity. Moreover, the relatively complex EU regulations put additional pressure on EIIs through raised compliance costs, delayed investment, and relatively high administrative burden.

EU policy attempts to combat these pressures, putting forward strategies to reconcile low-carbon policy with competitive industry in the Clean Industrial Deal (CID) (EC, 2025b). The importance of EIIs is highly recognized, both for its economic importance, as well as for reasons of 'strategic autonomy', i.e. to avoid critical dependencies on other global regions for the supply of energy-intensive commodities and green technologies. To this end, the CID sets the framework for policy implementation on different domains: affordable energy, market creation for green commodities, financing and investment support, circularity and access to materials, global markets and partnerships and the support for skills and workers. Circularity is highlighted as a main priority, to improve the affordability and accessibility of essential materials whilst reducing dependencies to global supplies, with a significant potential as a growth market. The EU's competitiveness compass (EC, 2025a) furthermore outlines tailor-made action plans for energy intensive sectors, such as chemicals, steel and metals.

The carbon border adjustment mechanism (CBAM) has been put forward as a main policy to create a more level playing field and will apply in its definitive regime from 2026 onwards[6]. Yet, some main challenges apply (Draghi, 2024; Swartenbroekx & Verdini, 2025). First, it is important that CBAM covers entire complex value chains. Otherwise, CBAM can be circumvented by shifting imports to downstream products not covered by CBAM. This leads to an enhanced risk of carbon leakage, also because the production costs of domestic downstream industries would increase compared to their global competitors. Moreover, since CBAM only covers imports, the cost disadvantage for the export of energy-intensive commodities outside the EU would remain.

In Belgium, policy focusses on electrification, CCUS, green hydrogen, heat networks and off-shore wind as key enablers of industrial transformation (Belgian Government, 2021). The federal Hydrogen Vision (Belgian Government, 2022), for example, positions renewable hydrogen and derivatives like ammonia, methanol and synthetic fuels as an important venue to ensure energy availability for difficult-to-electrify sectors, mainly in industry. Consequently, efforts are ongoing to implement hydrogen[7], as well as carbon[8] infrastructure to facilitate CCUS. Moreover, significant expansions of the electricity grid are planned, including the 'Prinses Elisabeth' island[9] as a connection hub to renewable electricity from offshore wind. On the regional level, energy-intensive industries are stimulated to adopt energy efficiency measures via voluntary energy agreements and other support measures[10, 11].

Despite all efforts, industry still faces many challenges and concerns for transitioning to climate-neutral, circular *and* competitive production processes. Industries make the case that competitive pressures are 'acute' (ERT, 2024) and policy change is needed 'urgently' (Business Europe, 2025). The availability and affordability of low carbon energy and CCUS, de-risking investment, creating demand for low carbon products and ensuring a global level playing field are all needed to avoid (further) deindustrialisation. One can say EU and Belgium industry is at a 'cross-road' of green transition and

6 https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en
7 https://www.fluxys.com/en/projects/hydrogen-preparing-to-build-the-network
8 https://www.fluxys.com/en/projects/carbon-preparing-to-build-the-network
9 https://www.elia.be/en/infrastructure-and-projects/infrastructure-projects/princess-elisabeth-island
10 https://www.vlaio.be/nl/begeleiding-advies/duurzaam-ondernemen/klimaat-en-energie/specifiek-voor-energie-intensieve-bedrijven-ets-bedrijven
11 https://energie.wallonie.be/fr/accords-de-branche.html?IDC=6152

deindustrialisation pathways with high uncertainty about its future development. This makes the topic highly relevant for scenario analysis. As a starting point for this analysis, the following sections take a closer look at how the challenges for competitiveness and decarbonisation materialise for main energy-intensive sectors in Belgium.

3.2 Iron & steel

3.2.1 Current iron & steel production landscape

3.2.1.1 Production in Belgium

According to the Belgian Steel Federation (2024), Belgium produced 7130 kton of steel in 2024, of which 78% primary steel, 20% secondary steel (stainless steel) and 2% other alloy steels. Primary steel is produced by ArcelorMittal, which manufactures primary steel coils that are subsequently processed by a range of smaller finishing companies. In the secondary steel segment, several players are active, including Aperam (2.2 Mton/yr[16]) and THY Marcinelle (0.35 Mton/yr[16]). Furthermore, a number of companies – such as NLMK[12], Liberty Steel[13], SEGAL[14] and Industeel[15] (a subsidiary of ArcelorMittal) – do not have their own on-site electric arc furnace (EAF), but are also active in processing steel slabs into hot or cold rolled steel products and galvanization of steel coils[16].

Figure 5 illustrates the current iron and steel production landscape in Belgium, distinguishing between primary and secondary steel value chains. Primary steel production follows the basic oxygen furnace (BOF) route, in which iron ore is reduced in blast furnaces using coke and then refined with oxygen to produce high-quality steel. Secondary production relies on EAFs that melt recycled scrap steel, offering a more circular and less carbon-intensive process.

12 https://eu.nlmk.com/en/strip/la-louviere/
13 https://libertysteelgroup.com/be/?lang=en
14 https://www.segal.be/
15 https://industeel.arcelormittal.com/product/
16 https://github.com/IndustryDataHub/BelgHub

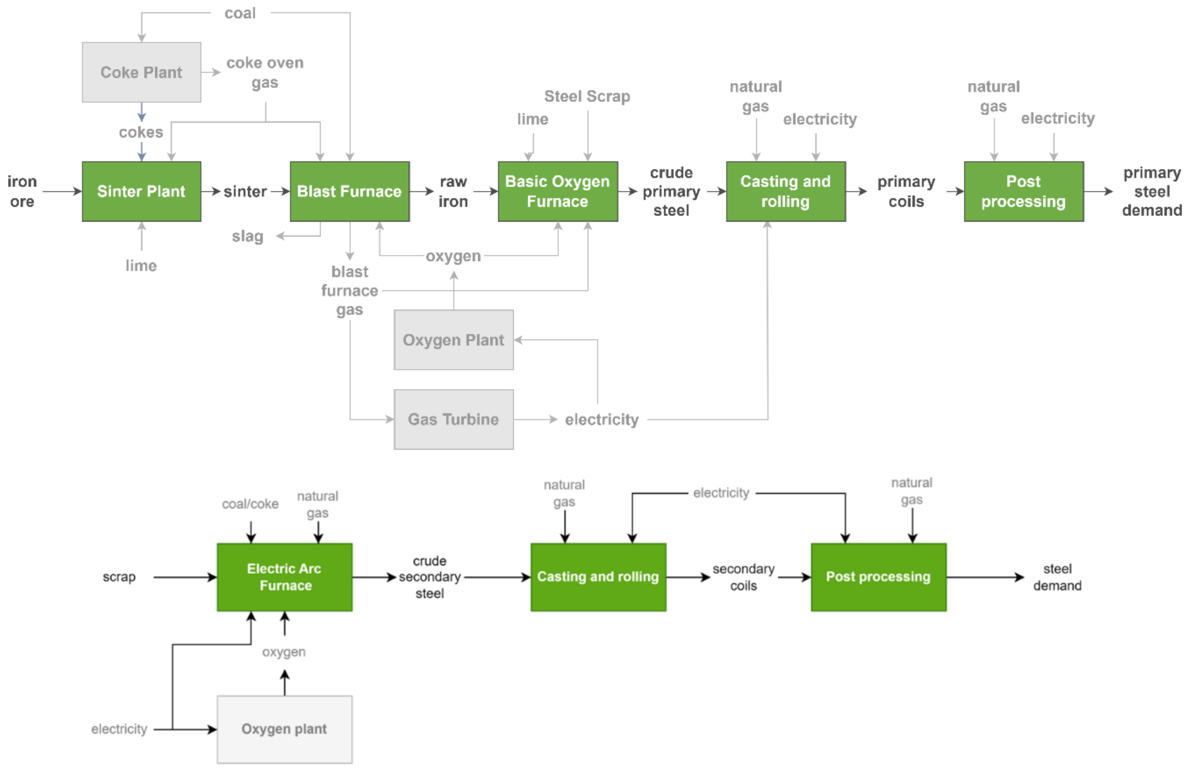

Figure 5: Current primary (above) and secondary (below) steel production value chains in Belgium.

3.2.1.2 Downstream markets and trade

Belgium's iron and steel sector is a technologically advanced and export-oriented industry, producing both primary and secondary steel coils and galvanized products for construction, automotive, and machinery applications. At the European level, almost 37% of European steel is used in the construction sector, 20% goes to automotive industry, with other end-uses such as mechanical engineering, metal goods, tubes, domestic appliances and other transport and sectors (Figure 7).

Being a net exporter, Belgium is strongly integrated in the European steel market and acts as a transit hub for other EU countries as indicated by the data in Table 3. In 2024, Belgium imported about 11.76 million tonnes of steel, with Germany (1.83 Mt), Russia (1.37 Mt), and the Netherlands (1.34 Mt) as its top suppliers. Belgium exported around 15.20 million tonnes, mainly to Germany (4.65 Mt) and France (3.03 Mt), followed by the Netherlands (2.42 Mt), Italy (0.74 Mt), and Poland (0.66 Mt). From a global perspective, the EU trade balance (Figure 6) shows a shift from the EU being a net exporting nation to a net importing nation during the last decade, importing between 25 and 30 kton/yr while exporting between 15 and 20 kton/yr outside the EU.

Table 3: Steel[17] import and export to and from Belgium in 2024. Data obtained from International Trade Administration global trade monitor[18].

Belgian steel import 2024		**Belgian steel export 2024**	
Exporting country inside EU	**Mton**	**Importing country inside EU**	**Mton**
Germany	1.83	Germany	4.65
Netherlands	1.34	France	3.03
France	1.04	Netherlands	2.42
Spain	0.3	Italy	0.74
Italy	0.23	Poland	0.66
Luxembourg	0.16	Spain	0.31
Total BE steel import from inside EU	**4.9**	Czech Republic	0.21
Exporting country outside EU	**Mton**	Sweden	0.15
Russia	1.37	Denmark	0.13
Vietnam	0.88	Austria	0.12
Taiwan	0.86	Romania	0.1
India	0.82	**Total BE steel export to inside EU**	**12.52**
China	0.68	**Importing country outside EU**	**Mton**
Korea, South	0.62	United Kingdom	0.4
Turkey	0.39	Turkey	0.39
United Kingdom	0.29	United States	0.34
Indonesia	0.21	Mexico	0.25
Japan	0.18	Egypt	0.16
Total BE steel import from outside EU	**6.3**	**Total export BE to outside EU**	**1.54**
Total import BE from other	0.56	Total export BE from other	1.15
Total import BE	**11.76**	**Total export BE**	**15.21**

[17] This includes flat and long products, pipes and tubes, semi-finished and stainless-steel products as defined in the steel mill product category definitions: https://www.trade.gov/sites/default/files/2021-04/product-definitions.pdf

[18] https://www.trade.gov/data-visualization/global-steel-trade-monitor

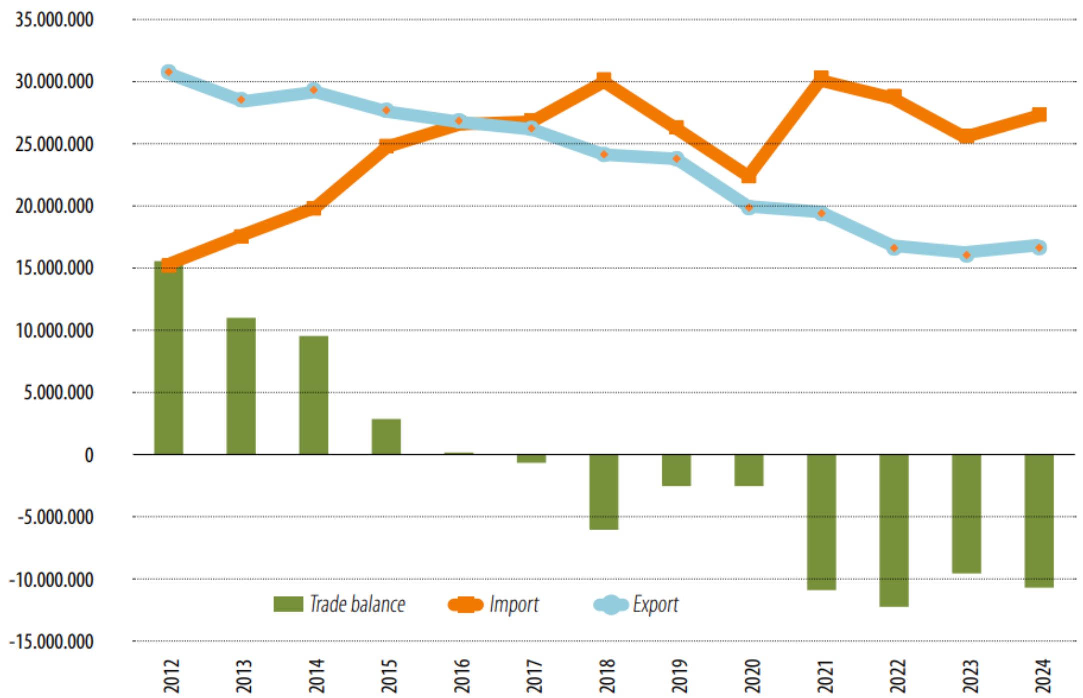

Figure 6: EU trade balance in tonnes for finished steel (Belgian Steel Federation, 2024).

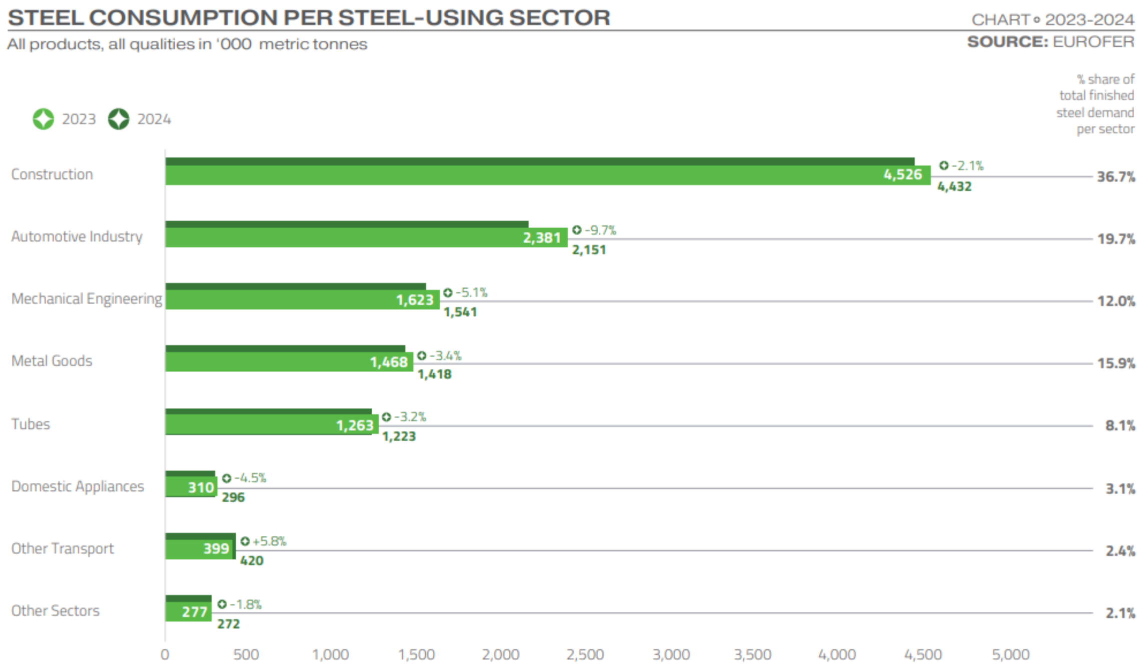

Figure 7: Consumption of steel by sector of economic activity according to EUROFER report European steel in figures 2025 (EUROFER, 2025b).

3.2.1.3 Recent developments and challenges

There are various challenges surrounding the competitivity of European steel. EUROFER (2025a) identifies four challenges the European steel industry is facing: (1) global steel overcapacity, (2) unfair trade practices, (3) high energy costs and (4) an unlevelled playing field on climate ambition. Chinese surge of exports, which peaked in 2015, created a massive disruption in the world's steel market, with a particular negative impact on the EU (GFSEC, 2024). In the meantime, the European steel industry has gained a renewed role in strategic autonomy regarding defence and the energy transition (EUROFER, 2025a).

EUROFER (2023) furthermore outlines four conditions that are required to harmonize competitiveness with the green transition and circularity: (1) ensure access to affordable, fossil-free energy and key raw materials like steel scrap, (2) provide clearer, faster, and more flexible EU funding focused on deploying low-carbon steel projects, (3) create lead markets for green steel through procurement, quotas, or lifecycle-based GHG pricing, (4) Trade policy that levels the playing field with global competitors. Consequently, the 2025 Steel and Metals Action Plan by the European commission (European Commission, 2025a) addresses three priorities to attempt to safeguard the European steel industry: (1) closing the loopholes in the CBAM, (2) reducing energy prices and (3) addressing leakage of valuable secondary resources such as steel scrap.

In Belgium, primary steel industry has been in favour of the H2-DRI-EAF route using natural gas as a transition feedstock[19]. The technology route enables the use of natural gas in the short term and provides the potential to switch to green hydrogen in the long term once it becomes commercially available. However, the current investment climate in Belgium has hampered these decisions. In 2024, the announcement was made to put the plans on hold[20], mainly due to high energy prices for hydrogen that were anticipated. Current strategies aim to invest in the EAF first, and to wait for a clearer outlook before making the investment decision for the DRI plant. In the meantime, the EAF could be fed with the molten pig iron (or referred to as 'raw iron' as in Figure 5) coming from the blast furnace[21]. In case of substantial financial support, a DRI could still be built later[22].

The innovative Steelanol project, converting blast furnace exhaust gasses into ethanol, has had a successful deployment of the pilot plant on the ArcelorMittal site. However, unstable policy outlooks have jeopardized its business case, as Steelanol struggles to qualify for key fuel labels needed to establish a lead market and generate demand under European targets. Yet, Steelanol could reduce overall carbon emissions in Belgium's energy system while lowering its total system costs (Correa Laguna & Lenaerts, 2023).

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19 https://automotive.arcelormittal.com/news_and_stories/news/2022_DecarbonizationInvestments
20 https://corporate.arcelormittal.com/media/press-releases/arcelormittal-provides-update-on-its-european-decarbonization-plans/
21 https://www.ispatguru.com/use-of-hot-metal-in-electrical-arc-furnace/
22 In the Netherlands, Tata steel recently signed a letter of intention for this production route, albeit with significant financial support from the Dutch government. See: https://www.tatasteel.com/newsroom/press-releases/india/2025/tata-steel-signs-the-non-binding-joint-letter-of-intent-with-the-government-of-the-netherlands-and-the-province-of-north-holland-on-integrated-decarbonisation-and-health-measures-project/

3.2.2 Industrial Transformation Cases

Tables 4 and 5 provide an overview of all relevant ITCs for the iron & steel sector that have been discussed with the industrial experts.

Table 4: Overview of ITCs and interview insights for primary steel.

	ITC	Impact	Uncertainty
Carbon-neutral & circular production	Investment in DRI-EAF route in Belgium is successful.	**High** The DRI-EAF route could strongly reduce emission in Belgium. The PATHS2050 scenarios (VITO/EnergyVille, 2025) all indicate a 95%[23] reduction in primary steel making emissions due to the uptake of the DRI-EAF route, fed by H_2 in 2050. The technology would also have a significant impact on the energy system, increasing electricity demand by 4-7 TWh[23] in 2050 according to the PATHS2050 study.	**High** From the interview, it became clear that the business case currently not viable due to high energy prices in Belgium. It is still an option for the long-term. However, the future remains uncertain; investments in EAF first, DRI later depending on hydrogen/energy price outlook. Investments could shift to Spain/Dunkirk where energy is cheaper[24].
	Steelanol[25] becomes viable and additional capacity is built.	**Medium** Potentially transforms value chain with coupling between sectors. An EnergyVille study (Correa Laguna & Lenaerts, 2023) determined the energy system benefits from implementing the technology. Yet, despite this research and EU targets, demand for Steelanol and similar fuels has not materialized.	**Medium** Insights from the interview: Technical issues have been mostly solved, plant operates well on gas fermentation core technology, but not yet during long periods and reliable yet. Upscaling production relies on EU regulations (Delegated Act on co-processing[26]) that currently limit Steelanol eligibility as Steelanol as 'advanced biofuel' and 'recycled carbon' labels, blocking demand creation. Could improve if governments lead by example in procurement.
	Primary steel production is partially replaced with increased secondary steel production.	**Medium** Production of new steel by recycling steel requires up to 10 times less energy than the production of steel from virgin iron ore (Harvey, 2021). As a consequence, higher levels of secondary steel may significantly reduce carbon emissions and energy demand. Yet, scrap availability is insufficient to cover all demand; primary steel remains necessary.	**Medium** As such the trend towards higher levels of circular steel is undisputed. Steel recycling rates are already high (~80-85%) for scrap collected from end-of-life products (IEA, 2020). As a result, secondary steel demand can theoretically only increase with a factor 1/0.85 (IRENA, 2023). There is significant uncertainty about how much new scrap will be available and usable (Wang et al., 2021; Xylia et al., 2014, 2018). Most steel is recycled already; the gains are mainly to be made in quality (i.e., separation from contaminants like copper).

[23] https://perspective2050.energyville.be/results/main-edition-2025/industry-sector
[24] https://corporate.arcelormittal.com/media/press-releases/arcelormittal-provides-update-on-its-european-decarbonization-plans
[25] http://www.steelanol.eu/en
[26] Commission Delegated Regulation (EU) 2023/… of 5 June 2023 on the methodology to determine the share of biofuel and biogas for transport, produced from biomass being processed with fossil fuels in a common process

	Biomass use in primary steelmaking expands.	**Medium** Biomass could strongly reduce emissions and have a significant impact on the energy system, yet it is not expected to fully replace coke use in the blast furnace. The cost-optimal pathways of the PATHS2050 study (VITO/EnergyVille, 2025) suggest that increasing the Torero[27] capacity is less cost-efficient from a system perspective compared to other alternative technologies such as the DRI-EAF route. This suggests that scarce biomass resources might be more valuable in other sectors. Increasing the bio-based input does becomes viable when the Steelanol technology is also available to produce bio-based ethanol for the transport sector (Correa Laguna & Lenaerts, 2023).	**High** Many barriers apply: biomass prices rose during the energy crisis and remains high. In general, future biomass prices and availability is uncertain. One of the existing blast furnaces in Ghent is planning to be partially fed with bio-coal through the Torero plant[27], but increasing the share of the bio-coal to high volumes input would require some degree of retrofitting.
	CCS becomes a viable technology.	**Medium** The PATHS2050 study (VITO/EnergyVille, 2025) on climate neutral scenarios in Belgium estimates that approximately 20Mton/yr of CCS is needed to cover remaining emissions in industry, including those from the iron & steel sector, by 2050.	**High** Carbon Capture technologies have been and are being tested at ArcelorMittal operations: 3D project in Dunkerque and MHI (Mitsubishi Heavy Industries) pilot at AM Ghent to test the compatibility of commercial CC technologies with steelmaking process gases. Some innovative projects, such as the D-CRBN[28] pilot project in ArcelorMittal Ghent, have started operations successfully[29]. However, the future scalability of these innovative technologies, remain uncertain at this point in time.
Industrial relocation	Domestic DRI is replaced with import of sponge iron.	**Medium** A significant portion of energy demand will be replaced, some economic impact due to loss of activity. Verpoort et al. estimate an approximately 10% reduction in the production cost compared to a domestic H2-DRI-EAF route (Devlin et al., 2023; Verpoort et al., 2024). In contrast to these studies, a TNO report analysed cost premiums arising from imports of HBI or steel, focusing on transport costs (TNO, 2024). The report suggests that importing intermediates is consistently more expensive compared to domestic production due to the high transport costs. The industrial experts point out that at today's prices, the lower production cost overcompensates the extra transport costs.	**High** The interview indicated that this is a likely option if Belgian DRI is not competitive. Viability of domestic production depends on CBAM effectiveness. Research highlights industries such as steel (Devlin et al., 2023; Devlin & Yang, 2022) as particularly at risk, emphasizing region-specific cost benefits of relocating parts of the green value chain. However, a study by TNO (TNO, 2024) suggests the emergence of a high liquidity HBI-market appears unlikely in the short-term and uncertain in the long-term.
	Domestic steel production is replaced with import of steel slabs.	**High** A large portion of energy demand will be replaced, large economic impact due to loss of activity. The study by Verpoort et al. indicates a relatively small cost-benefit from	**High** The interview indicated that this is a possible scenario if high Belgian energy prices persist. Investments could shift to Spain/Dunkirk where energy is cheaper[24].

27 https://belgium.arcelormittal.com/torero-officieel-in-gebruik-genomen/
28 https://d-crbn.com/
29 https://corporate.arcelormittal.com/media/news-articles/world-first-trial-of-new-technology-to-recycle-co2-emissions-from-steel-production-begins-at-arcelormittal-gent-belgium

		importing slabs versus intermediate sponge iron (Verpoort et al., 2024), which means the positive impact on the production cost could be relatively small compared to the impact on the economic system. A TNO study estimate the cost difference between crude steel imports and sponge iron imports generally does not exceed 10% (TNO, 2024).	
Downstream market developments	A loss of competitiveness in the certain EU industries (e.g. automotive) results in a reduction of primary steel demand.	**Medium** No drastic decline expected soon, according to the interviews.	**Medium** The interview indicated that ArcelorMittal Ghent has a large share in automotive; demand pressures exist from Asian imports.
	Domestic steel demand reduces: higher materials efficiency or behavioural shifts in society.	**Low** No major demand reduction expected in coming decades, according to the interviews.	**Medium** According to the interviews, this could be relevant in long term.
	New markets or increase in production due to clean and emerging technologies.	**Medium** Demand growth could stem from increased investments in renewable energy and higher defence spending in Belgium/EU, based on interview insights. Meeting the Ostend Declaration's 300 GW[30,31] goal would need ~30 Mton of - about 2% of the EU's yearly 150 Mton output steel (EUROFER, 2025b).	**Medium** According to the interviews, it is unclear whether such demand growth would materialize in a significant way.

Table 5: Overview of ITCs and insights from interviews for secondary steel.

	ITC	Impact	Uncertainty
Carbon-neutral & circular production	Electrification or hydrogen use.	**Medium** Interview insights: More research and development is needed, as hydrogen can disrupt the processes (water formation).	**Medium** Interview insights: Companies are experimenting with electrification to replace natural gas, but no mature technologies yet.
	Alternatives: biogas, e-methane, CCS.	**High** The interviews indicated that these are more realistic options currently. Also needed to compensate residual emissions; CCS may deliver negative emissions for the iron & steel sector. Overall, the interview underlines that efficiency improvements in current fossil-based installations are still a priority.	**High** Interview insights: CCS cannot be applied everywhere due to low CO_2 concentrations and batch processes, but pilots underway.

30 https://northseasummit23.be/en/ostend-declaration/
31 https://industry.arcelormittal.com/repository2/fce/transfer/Windmills_UpdateFCE_May11.pdf

	Alternative technologies (oxy-fuel combustion or siemens turbo-heater)	**Medium** Interview insights: Alternative technologies for heating are explored but no applications yet. As the EAF in the secondary steel route is already decarbonized, the decarbonization potential in secondary steel plants is related to the hot rolling furnace.	**Medium** Interview insights: Alternative technologies are explored but no applications yet. Oxy-fuel combustion faces technical challenges for the hot-rolling furnace, as hot rolling requires uniform and controlled heating while oxy-fuel combustion often results in more extreme flame temperatures (Haapakangas et al., 2024). The turbo heater[32] process currently faces viability challenges, as its efficiency is around 65%, compared to approximately 90% for conventional electric resistance heating.
	Secondary steel production can increase due to increasing crap availability.	**Low** Interview insights: Already ~95% recycled material in EU stainless steel. Recycling system is strong in Europe but scrap availability remains strategic; some still exported to China. Strategic investments in recycling facilities are considered. Turkey accepts lower-quality scrap that EU rejects; quality, not availability, is the bottleneck for expanding secondary steel production.	**Medium** The interview indicated that possible future EU penalties for low-quality scrap suppliers could improve collection and availability of quality scrap.
Downstream market developments	A loss of competitiveness in the certain EU industries (e.g. automotive) results in a reduction of steel demand.	**Medium** Interview insights: Stainless steel is used in combustion engine components (e.g., catalytic converters). Shift to EVs could reduce demand. Household appliances (e.g., sinks, railcars) remain strong niches.	**Medium** Interview insights: The expected losses are limited. Belgium is still competitive for niche or secondary steel products. Niche but strong markets. Product mix is relatively more specialized.
	Domestic steel demand reduces: higher materials efficiency or behavioural shifts in society.	**Low** Interview insights: Only minor demand decreases expected; some substitution (e.g., steel replacing plastics in retail packaging) faces cost barriers.	**Medium** Interview insights: No significant impacts expected in the short term, but long-term could be relevant.
	New markets or increase in production due to clean and emerging technologies.	**Medium** Interview insights: Emerging and promising demand sectors: stainless steel for batteries, data centres, AI and energy transition opens multiple new niche markets. Stainless steel for H_2/CO_2 networks, storage tanks, cryogenic carbon capture.	**Medium** Interview insights: The development of these new markets is not an uncertainty, but if they will develop in Europe or Belgium is the question.
Industrial relocation	International competition reduces Belgian secondary steel production.	**Medium** Interview insights: Relocation to France more feasible due to lower electricity prices. Products/location-specific know-how make relocation difficult.	**Medium** Relocation outside EU unlikely given niche/specialized products, based on the interview insights. This indicates a low uncertainty in the short term. However, other nations might build up the 'know-how' in the long-term and catch up.

3.2.2.1 *Climate neutral and circular production*

Various options exist for transforming to climate-neutral and circular production. These include the DRI-EAF routes, enhanced secondary steel production with EAF, and mitigation technologies such as

[32] https://www.turbomachinerymag.com/view/siemens-energy-opens-turbomachinery-lab-for-decarbonization-technologies

CCS and partial coal substitution (Wyns et al., 2025). As described in Table 3, the H_2-DRI-EAF route is a key long-term decarbonization pathway for primary steel, offering substantial emission reductions but remaining economically uncertain due to high energy costs. Coal substitution with biomass use can contribute to lowering emissions but is constrained by high prices, limited availability, and process limitations. In contrast, secondary steel production is already highly circular - with around 80–95% recycled content in Europe - and provides significant energy and emissions savings, but its expansion is limited by scrap quality and availability rather than techno-economic challenges. Secondary steel production can be further transformed via additional electrification and fuel substitution (Table 4).

3.2.2.2 Downstream market developments

ITCs on downstream market developments cover both a reduction of steel demand and emerging steel demands from new markets. For example, demand pressures may arise from a gradual decline in automotive-related, though no drastic decline was expected by the respondents. New demand opportunities may partially offset this - especially from renewable energy infrastructure, newly emerging high-tech markets or defence investments, that all could generate additional steel demand. However, the extent in which these new demands could emerge remains highly uncertain. For secondary steel, Belgium's position in niche markets provides resilience with possibly various new applications. Overall, the sector's specialization and emerging clean-tech markets suggest stable to moderately positive prospects in the downstream steel market transition.

3.2.2.3 Industrial relocation

ITCs on industry relocation cover the increased imports of DRI or crude primary steel and enhanced international competition on secondary steel. While primary steel production faces relocation risks tied to high energy costs, secondary steel production remains comparatively resilient.

The risk of industrial relocation in Belgium's primary steel sector is generally characterized by a medium to high impact and high uncertainty. If domestic H_2-DRI production proves economically uncompetitive due to persistently high energy prices and regulatory barriers, importing hot briquetted iron (HBI) could become a viable alternative that reduces domestic energy demand but also weakens industrial activity and strategic autonomy. While some studies (Verpoort et al., 2024) suggest cost savings of around 10% compared to domestic DRI-EAF production, others (TNO, 2024) highlight that transport costs make large-scale HBI imports uncertain. An even more disruptive scenario involves replacing domestic steel production with imported slabs, which could have a higher impact on macro-economic indicators, with relatively small additional cost-savings from the energy system perspective (Verpoort et al., 2024). Moreover, uneven energy prices across Europe could trigger intra-EU relocation toward regions like Spain[24], undermining Belgium's competitiveness in green steel production.

For secondary stainless-steel production, the risk of relocation is considered medium. EAF based plants are already largely decarbonized and less energy-intensive, depending mainly on local expertise and the availability of quality scrap rather than primary energy sources. As such, secondary steelmaking was expected by the industrial experts to remain competitive in Belgium, at least in the short term, supported by regional demand for high-quality stainless steel and the existing know-how in Belgium.

3.3 Ammonia & fertilizers

3.3.1 Current fertilizer production landscape

3.3.1.1 Production in Belgium

Historically, Belgium has maintained an ammonia production capacity of around 830 kton/yr (Talieh Rajabloo, 2022). Of this, approximately 400 kton/yr[16] was produced at Yara's Tertre site, which has announced the closure[42] of its ammonia plant by 2026 as part of a strategic shift toward more competitive downstream activities[43], notably premium nitrate fertilizers and industrial nitrogen products. The remaining part of the ammonia production capacity in Belgium is covered by BASF. For fertilizers, Belgium currently has an approximate production capacity of 2500 kton/yr. However, the announced transformation of the Yara Tertre site[43], will increase this capacity to approximately 3100 kton/yr, partially replacing the decrease in ammonia production capacity with an increase in downstream fertilizer production capacity.

Today, ammonia is produced by combining hydrogen with nitrogen in the Haber-Bosch process. The hydrogen is currently typically made from natural gas in a Steam Methane Reformer (SMR), as visualized in Figure 8.

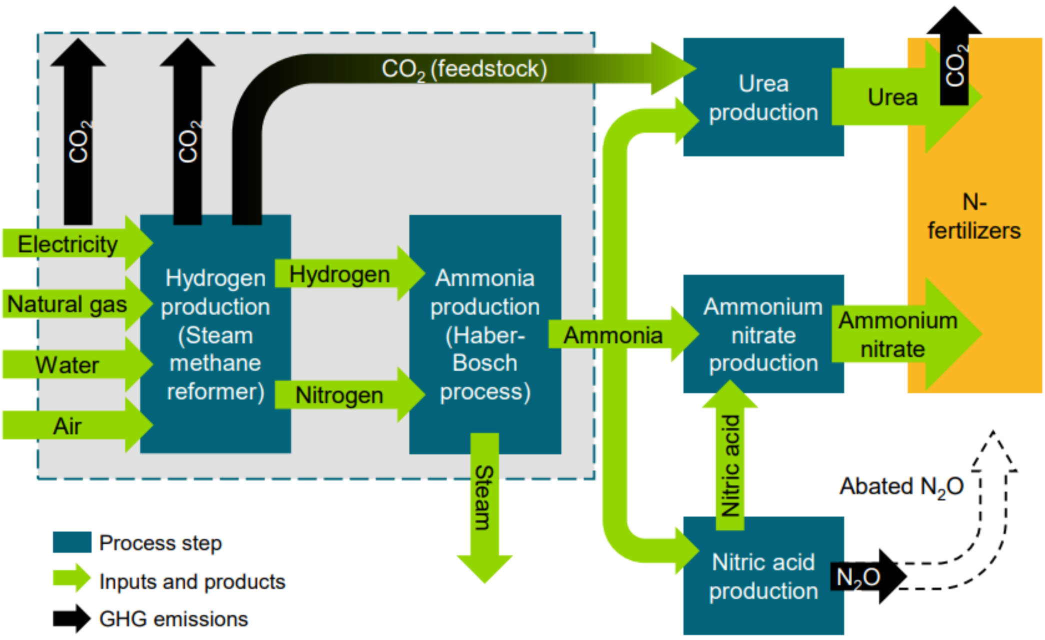

Figure 8 Conventional production routes for N-fertilizer in Belgium by Fertilizer Europe (IEA, 2021).

3.3.1.2 Downstream markets and trade

Globally, about 70% of ammonia is used for fertilisers, while the remainder is used for various industrial applications, such as plastics, explosives and synthetic fibres (IEA, 2021). According to the Roadmap for the European Fertilizer Industry (Fertilizers Europe, 2023b), historic ammonia production in Europe has remained relatively stable over the past decades, and the International Energy Agency (IEA, 2021) does not foresee any significant changes in European ammonia or urea production by 2050.

Table 6: Ammonia import and export quantities to and from Belgium in 2023 in kton. Data obtained from World Integrated Trade Solution[33].

Belgian anhydrous ammonia import 2023		Belgian anhydrous ammonia export 2023	
Exporting country	**kton**	**Importing country**	**kton**
Trinidad and Tobago	227.72	Germany	76.69
Russian Federation	177.65	France	7.42
Netherlands	59.58	Netherlands	0.56
France	59.41	Czech Republic	0.20
Algeria	49.98	Romania	0.04
Saudi Arabia	26.82	Denmark	0.08
Egypt, Arab Rep.	23.26	Finland	0.09
United States	40.65	Congo, Dem. Rep.	0.02
Germany	19.62	Libya	0.01
Austria	6.01	Spain	0.10
Libya	7.05	Austria	0.02
Other	0.07	Other	0.03
Belgian aqueous ammonia import		**Belgian aqueous ammonia export**	
Importing country	**kton**	**Exporting country**	**kton**
World	28.87	World	30.37
Total ammonia import BE	**726.68**	**Total ammonia export BE**	**115.64**

Table 7: Fertilizer import and export trade value to and from Belgium in 2023 in Million USD. Data obtained from World Integrated Trade Solution[34].

Belgian fertilizer import 2023		Belgian fertilizer export 2023	
Exporting country	**Trade Value MUSD**	**Importing country**	**Trade Value MUSD**
Canada	299.28	France	472.25
Netherlands	222.43	Netherlands	250.32
Germany	146.48	Germany	250.16
France	70.38	Spain	156.09
United States	57.79	China	143.96
Egypt, Arab Rep.	42.03	United Kingdom	67.09
Morocco	37.45	Italy	65.68
Algeria	33.17	United States	55.66
Russian Federation	29.64	Poland	35.78
Jordan	22.23	Turkey	35.61
Lithuania	16.31	Mexico	35.29
China	11.82	Vietnam	21.76
Other	57.14	Other	322.57
Total import BE	**1046.15**	**Total export BE**	**1912.24**

[33] https://wits.worldbank.org/trade/comtrade/en/country/BEL/year/2023/tradeflow/Exports/partner/ALL/product/281420

[34] https://wits.worldbank.org/trade/comtrade/en/country/BEL/year/2023/tradeflow/Exports/partner/ALL/product/31#

Belgium is a net importer of ammonia (Table 6), importing 727 kton and exporting 116 kton of ammonia in 2023, including 830 kton/yr of domestic production capacity (Talieh Rajabloo, 2022). The main sources of anhydrous ammonia were Trinidad and Tobago[35] (228 kton) and Russia (178 kton), while Germany (77 kton) was the primary export destination. In comparison, Belgium's fertilizer market is a net exporting market, importing 285 kton while exporting 1768 kton in 2021[36], including a domestic production capacity of approximately 2500 kton/yr[16]. Table 7 gives an overview of fertilizer trade in terms of trade value, highlighting that Canada and the Netherlands are the two main countries that export Fertilizers to Belgium, while France, the Netherlands and Germany are the main importers of fertilizers coming from Belgium.

For fertilisers, the EU equally is a net importer, importing roughly twice as much fertilizers as it exports with a 2024 trade balance of some 13 million tons[37]. In 2021, the European Union imported approximately 26 million tonnes of nitrogen fertilisers, nitrogen and phosphates intermediates[38]. These imports accounted for about 30% of nitrogen, 68% of phosphorus, and 85% of potassium fertilizer consumption within the EU. Eurostat data[37] shows how Fertilizer imports declined in 2024 to approximately 24 million tonnes. Similarly, exported volumes dropped from 13 million tonnes in 2021 to 11 million tonnes in 2024, with overall only a minor impact on the trade balance.

3.3.1.3 Recent developments and challenges

One of the most important developments is Yara's announcement that the Tertre site will close its ammonia unit[42] (400 kton/yr capacity) and will instead shift the focus of the site towards high-value nitrate fertilizers and industrial nitrogen chemicals[43]. Post-transformation, Yara expects the Tertre site to produce ~600 kton/yr of premium nitrate fertilizers and ~2500 kton/yr of industrial nitrogen products. Another relevant development is the emerging role of Belgium (particularly the Port of Antwerp) as an ammonia/hydrogen import hub[39].

3.3.2 Industrial Transformation Cases

Table 8 provide an overview of relevant ITCs for ammonia and fertilizers that have been discussed with the industrial experts.

3.3.2.1 Climate neutral and circular production

Various options for climate-neutral ammonia production exist, based on 'green' or 'blue' hydrogen, or biomass gasification (Wyns et al., 2025). In Belgium's ammonia sector, progress toward such carbon-neutral options remains limited. Blue ammonia could become cost-competitive with grey ammonia by 2030, but current energy prices and regulatory barriers - such as its exclusion from the RFNBO definition under RED III - mean no viable business case exists today, and green ammonia remains nearly twice as expensive. Circular production routes, such as waste valorisation or by-product recovery, offer only low impact with low uncertainty due to the lack of potential, even though broader EU initiatives like the Circular Economy Action Plan highlight opportunities for future innovation.

35 https://energynow.tt/blog/ammonia-production-and-export-in-tampt-face-significant-challenges
36 https://www.reportlinker.com/clp/country/527347/726366
37 https://agridata.ec.europa.eu/extensions/DashboardFertiliser/FertiliserTrade.html
38 https://eumonitor.vlaio.be/news/2774
39 https://www.portofantwerpbruges.com/nl/onze-haven/klimaat-en-energietransitie/waterstof

Table 8 Overview of ITCs and insights from interviews for ammonia/fertiliser.

	ITC	Impact	Uncertainty
Carbon-neutral & circular production	Blue/green ammonia routes	**Medium** A study by Business Europe (Business Europe, 2024) indicates the cost-gaps between grey, blue and green ammonia production in Europe. Blue ammonia is expected to become cost-competitive with grey ammonia by 2030 under a set of assumptions. Green ammonia, however, is expected to remain almost twice as expensive as blue or grey ammonia by 2030.	**High** The interviews indicated that blue or green ammonia production had no business case in Belgium today as grey ammonia is still the cheapest, both locally produced and imported. The ammonia sector is not attracting new investments. Currently, only local grey production continues. Blue ammonia is not included as an RFNBO (RED III). According to our respondents, even by 2030, green/blue remains more expensive.
	Biomass-based ammonia	**Low** Considered neither relevant nor desirable in Belgium context. Biomass-based ammonia production requires intermediate biomass-based hydrogen production, which is less efficient compared to other technologies. This can be considered as inefficient allocation of scare biomass resources. However, the AIDRES report (Girardin, Valee, & Correa, 2023) does suggest that biomass-based ammonia production could be a viable production route under certain assumptions.	**Low** Limited role in EU transition pathways. Uncertainty on future price and availability of biomass is a hurdle.
	Circular options (waste valorisation)	**Low** Circularity potential in BE seen as very limited. However, the Circular Economy Action Plan (Fertilizers Europe, 2023a) by Fertilizers Europe shows the potential for a circular fertilizer economy in Europe through, for instance, ammonium sulfate as a by-product from nylon production.	**High** Experimental routes (e.g. urine-to-urea) exist but scale and feasibility remain unclear.
Downstream market	Ammonia-based fertiliser demand reduces (due to alternative fertilizers)	**Medium** About 70% of ammonia is used for fertiliser production (Talieh Rajabloo, 2022). Alternative sources of fertiliser could therefore theoretically have a significant impact on ammonia production. A 2021 study by BBL estimates a -15% reduction in ammonia demand as a result of enhanced fertilizer use efficiency and alternative fertilizers (Bond Beter Leefmilieu, 2021).	**Low** Food demand is stable; fertilizer demand considered fixed regardless of price fluctuations. Forecast by Fertilizers Europe expects a 1%-6% reduction by 2030 based on the economic outlook and the anticipated evolution of Europe's cropping area[40]. To our knowledge, no specific outlooks are available on alternative fertilisers.

[40] https://www.fertilizerseurope.com/forecast/

	Ammonia use increases (e.g. in the transport sector)	**Low** No studies indicate significant impact in Belgium. No other main end uses were identified during the interviews. On a EU level, the Carbon Managers report (CEFIC, 2025) considers that by 2050 ammonia could account for about 12.5% of maritime fuel demand on an energy basis.	**High** Growing attention to ammonia as fuel/bunker fuel, but still niche and uncertain compared to fertilizer use. However, multiple projects on the use of ammonia in are ongoing. Moreover, Fluxys and Advario[41] are jointly developing an ammonia import terminal at the Port of Antwerp-Bruges, with operations slated to begin in 2027. This terminal will facilitate the import and distribution of ammonia, supporting its use as a fuel in various sectors, including transportation. Defence noted as potential user during the interview.
Industrial relocation	Import of ammonia due to global competition	**High** Core challenge: Belgium not cost-competitive. Rising energy prices drive risk of closures. Belgium does not set ammonia price; global lowest-cost producer dominates. Demand relatively inelastic, price fluctuates with global energy and feedstock costs.	**Medium** Closure of Yara Tertre was already announced in 2024. Yara[42,43] communicated its new strategy to shift the focus of the site towards its most competitive products, premium nitrate fertilizers and industrial nitrogen chemicals, aiming to strengthen its long-term competitiveness. A study by Business Europe (Business Europe, 2024) illustrates the large cost-gap between European and Chinese green ammonia by 2030, which highlights the risk of import outcompeting local production. The evolution of further closures or increased imports of ammonia remains uncertain.
	Increase in fertilizer import	**High** Russia is key supplier of fertilizer to Europe[44]. Import routes (e.g. Sluiskil terminal to Tertre) unclear and fragile, creating security risks.	**High** Concerning current geopolitical landscape, fertilizer imports could increase or decrease.

3.3.2.2 Downstream market developments

Demand for ammonia-based fertilizers - which account for about 70% of ammonia use in Belgium (Talieh Rajabloo, 2022) - could decline moderately due to improved fertilizer efficiency and emerging alternatives, though forecasts by Fertilizers Europe[40] project only a modest 1 - 6% demand reduction by 2030. Conversely, potential new uses of ammonia in the transport and energy sectors, such as maritime fuels or bunkering, remain in an early stage, with low current impact but high uncertainty. Overall, Belgium's ammonia demand outlook remains stable in the short term, but long-term shifts could emerge if ammonia gains traction as a transport fuel.

3.3.2.3 Industrial relocation

Industrial relocation ITCs include changes to the trade balance for ammonia or fertilizer. Belgium's ammonia industry faces a high impact and high uncertainty risk of industrial relocation driven by global cost competition and high domestic energy prices. Domestic production of ammonia is becoming less competitive, as shown by the closure of Yara Tertre in 2024[42]. The large cost gap between European and Chinese green ammonia further reinforces this trend.

41 https://www.fluxys.com/en/projects/ammonia-antwerp-terminal
42 https://www.fertilizerdaily.com/20241017-yara-tertre-to-close-ammonia-unit-in-major-site-overhaul/
43 https://www.yara.com/news-and-media/news/archive/2024/yara-intends-to-transform-tertre-plant-to-strengthen-long-term-competitiveness/
44 https://www.global-agriculture.com/crop-nutrition/europes-fertilizer-demand-struggling-amid-high-gas-costs-cheaper-imports

3.4 Ethylene & plastics

3.4.1 Current ethylene production landscape

3.4.1.1 Production in Belgium

Belgium's ethylene industry, historically centred in Antwerp and Ghent since the 1960s, is undergoing a major transformation. Current ethylene production in Belgium is approximately 2,2 million tonnes per year, dominated by BASF (1080 kton/yr[16]) and TotalEnergies (1060 kton/yr[16]). TotalEnergies plans to shut down its older steam cracker (550 kt/yr[16]) at the Antwerp petrochemical complex by the end of 2027[45]. At the same time, INEOS is building a new, large-scale ethane cracker in the Port of Antwerp[46]. The plant will produce around 1.5 million tonnes of ethylene per year and is expected to start up in 2026.

Ethylene is produced in steam crackers by heating naphtha with steam at very high temperatures (around 800–875 °C) for a short time to break large hydrocarbons into smaller molecules, then rapidly cooling and separating the resulting gases to recover ethylene. To make this technology climate-neutral, two key strategies exist: using lower-carbon feedstocks like ethane and electrifying the fossil-fired furnaces. The first strategy is already put in place with INEOS's Project ONE cracker, while the second strategy is still in a research and development stage with projects ongoing such as the 'cracker of the future consortium'[47].

3.4.1.2 Downstream markets and trade

Belgium currently has a combined ethylene production capacity of approximately 2260 kt/yr. At present, INEOS imports on the order of 1000 kt/yr to supply its polymer production operations. This imported volume almost entirely covers Belgium's import capacity of around 1180 kt/yr (Table 9) as reported in 2023[48]. With an export volume of some 139kt/yr Belgium is a net importer of ethylene despite domestic production. The Netherlands was Belgium's largest supplier, accounting for roughly 28 % of total imports (≈333 kt), followed by the United States (263 kt), Norway (206 kt), and the United Kingdom (185 kt). In contrast, the Netherlands is a net exporter with a similar trade volume[49,50], highlighting that Belgium is more active downstream the value chain where chemical compounds and plastics are produced[51]. (e.g. TEPF producing polyethylene and polypropylene for applications in packaging or automotive industry[52], BASF[53] and INEOS[54] producing ethylene oxide and derivatives for chemicals such as antifreeze or detergents.)

While TotalEnergies plans to shut down its older steam cracker (550 kt/yr) by the end of 2027, the upcoming INEOS Project ONE cracker facility, with a planned capacity of approximately 1500 kt/yr[46],

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45 https://totalenergies.com/news/press-releases/antwerp-platform-adapts-energy-transition-challenges-and-market-trends
46 https://project-one.ineos.com/en/about-project-one/
47 https://www.brightlands.com/en/chemelot-campus/nieuws/accelerating-electrification-cracker-future-consortium
48 https://wits.worldbank.org/trade/comtrade/en/country/BEL/year/2023/tradeflow/Imports/partner/ALL/product/290121
49 https://wits.worldbank.org/trade/comtrade/en/country/NLD/year/2023/tradeflow/Imports/partner/ALL/product/290121
50 https://wits.worldbank.org/trade/comtrade/en/country/NLD/year/2023/tradeflow/Imports/partner/ALL/product/290121
51 https://www.afpm.org/newsroom/blog/ethylene-worlds-most-important-chemical
52 https://corporate.totalenergies.be/nl/nieuws/belgium-totalenergies-increases-its-production-high-performance-polymers-specialty-markets
53 https://www.basf.com/global/en/media/news-releases/2023/10/p-23-335
54 https://www.ineos.com/businesses/ineos-oxide/

could strengthen Belgium's current import dependency. Yet, looking at the total sector for chemicals and plastics, Belgium is a large exporter, with 87% of total production exported, covering 1/3rd of total Belgian exports with a positive trade balance of 36 billion euro (Essencia, 2024).

Table 9: Ethylene import to and export from Belgium in 2023. Data obtained from World Integrated Trade Solution by Worldbank[4848].

Belgian ethylene import 2023		**Belgian ethylene export 2023**	
Exporting country	**kton**	**Importing country**	**kton**
Netherlands	332.65	Germany	84.25
United States	262.62	Netherlands	38.58
United Kingdom	185.32	France	8.71
Norway	206.23	Morocco	2.90
Germany	128.68	Portugal	2.86
France	42.60	Sweden	1.17
Austria	9.77	Czech Republic	0.03
Sweden	6.79	Denmark	0.86
Finland	4.57	Poland	0.00
Italy	0.87	United Kingdom	0.00
Other	0.01	Italy	0.00
Total import BE	**1180.11**	**Total export BE**	**139.37**

3.4.1.3 Recent developments and challenges

Belgium's ethylene industry is undergoing a period of significant transformation. Historically, the country has been a major hub for petrochemical production since the 1960s and 1970s. The sector is now facing a risk of de-industrialization in Belgium and Europe due to multiple reasons (Cefic & Advancy, 2025). Firstly, over the decades, many of the older units became less efficient and more costly to operate. Secondly, energy-intensive industries in Europe, especially basic chemicals, face severe competitiveness pressures due to increased energy and feedstock prices. Feedstock and energy account for a disproportionately large share of production costs - for ethylene, up to 90% of total costs, compared to ~25% for steel (Girardin, Valee, & Correa Laguna, 2023). Lastly, global overcapacity is reducing the overall competitiveness of the European assets, as only the most innovative and cost-competitive plants will remain. Moreover, the Advancy report (Cefic & Advancy, 2025) described how Europe has been suffering from weak domestic demand, lowering utilisation rates since 2022. All of these effects are prompting recent closures or phased shutdowns in Europe and in Belgium as well[74]. Furthermore, increasing costs are even affecting downstream production sites, as demonstrated by Dow's recent decision to close its polyol production facility in Tertre[55].

TotalEnergies plans to shut down its older steam cracker (550 kt/yr) at the Antwerp petrochemical complex by the end of 2027[56]. The company made this decision because of oversupply in the European market, high energy costs, and the end of a key ethylene supply contract. Its newest cracker remains operational with a production capacity of 610 kton ethylene per year. This closure will reduce total capacity but could help improve the performance of the remaining plants.

[55] https://www.industrielings.nl/chemie/2025/10/dow-sluit-belgische-polyolenfabriek-vanwege-hoge-kosten/
[56] https://totalenergies.com/news/press-releases/antwerp-platform-adapts-energy-transition-challenges-and-market-trends

The upcoming **INEOS** Project ONE cracker facility is not without concerns under the current investment climate. While Project ONE is strategically important for INEOS, the combination of high upfront costs, legal and regulatory hurdles, debt pressures and market uncertainty due to global overcapacity makes the business case difficult under current economic conditions[57].

BASF has also expanded its ethylene oxide and derivatives capacity in Antwerp by about 400,000 tonnes per year[58]. While this expansion does not increase ethylene output directly (1080 kt/yr from BASF), it strengthens BASF's downstream production network and local integration.

3.4.2 Industrial Transformation Cases

Table 10: Overview of ITCs and insights from interviews for ethylene.

	ITC	Impact	Uncertainty
Carbon-neutral & circular production	Py-naphtha (pyrolysis naphtha from chemical recycling of plastic waste) becomes a viable technology.	**Medium** In the Carbon Managers report (CEFIC, 2025), py-naphtha covers more than 25% of the steam cracker feedstock. When targets for alternative feedstocks are put in place, this share increases to almost 50%. In the base case scenario, chemical recycling represents 14.6% of the overall feedstock consumption in 2050. This percentage remains the same in the "high recycling" scenario where further reduction for virgin feedstock is achieved through increased mechanical recycling.	**Medium** Interview respondents underline that py-naphta can only replace ~10-15% of plastics due to additional investments that are needed when increasing the pyrolysis oil share in the input above 10% and the limited availability of quality plastics in Belgium. Demonstration plants exists (e.g. Plastics2Chemicals by Indaver[59] and the SABIC demonstration in Hasselt[60]) and future commercial projects are being announced, such as the SynPet initiative[61] in the port of Antwerp. However, further roll-out of the technology needs further support, such as investment facilitation and energy and waste-sector cooperation, as highlighted in the recent UNITY report (Cefic & UNITY, 2025). Moreover, interviews highlight higher cost and weaker product profiles vs. virgin plastics.
	CCS/CCUS becomes a viable technology.	**Medium** Central in scenarios to keep EU production. The PATHS2050 study (VITO/EnergyVille, 2025) on climate neutral scenarios in Belgium estimates that approximately 20Mton/yr of CCS is needed to cover remaining emissions in industry by 2050.	**High** According to the interview, CCS will be costly, energy-intensive, and complex to monitor, which makes the adoption highly uncertain. The Kairos@C[62] CCS project in Antwerp, has faced delays[63], highlighting the broader difficulties for deploying large-scale CCS in Belgium. Some innovative projects, such as the D-CRBN[28] pilot project in ArcelorMittal Ghent, have started operations successfully[29]. However, the future scalability of these innovative technologies, remain uncertain at this point in time.

57 https://www.youtube.com/watch?v=PidB3JOALG8
58 https://www.basf.com/global/en/media/news-releases/2023/10/p-23-335
59 https://indaver.com/services/plastics2chemicals
60 https://www.specialchem.com/plastics/news/sabic-repurposes-medical-plastic-via-advanced-recycling-000233531?utm_source=chatgpt.com
61 https://synpet.com/synpet-brings-emerging-technology-in-plastics-recycling-to-the-port-of-antwerp-bruges/
62 https://kairosatc.eu/
63 https://www.flows.be/chemie/2025/03/basf-antwerpen-schuift-miljardeninvestering-in-ccs-op-lange-baan/?gdpr=accept

	Methanol-to-olefins becomes a viable technology.	**Medium** The recent Carbon Managers report (CEFIC, 2025) shows how MTO is not selected in the base case scenario and only becomes a viable investment when alternative feedstock targets are put in place. This suggests the need for policy support for such a technology to materialize in practice. When it is selected, MTO covers approximately 25% of the EU olefins production in 2050.	**High** Interview respondents mention that MTO works in China; Antwerp pilots failed[72]. In 2024, a pilot project 'Power to Methanol' failed in Antwerp due to escalating costs[64]. Methanol import could improve the feasibility of MTO in Belgium[73]. More recently, the start-up Blue Circle[65] announced its plans to build Europe's first commercial MTO plant in the port of Rotterdam[66].
Downstream market developments	Mechanical plastics recycling reduces ethylene demand.	**Medium** Interview suggests that mechanically recycled plastics are useful in some applications, but quality limitations remain. In a 2023 study, Lopez at a. estimate that increased plastics recycling could reduce primary ethylene demand with 12%[67].	**Medium** The interviews underlined that we will always need virgin ethylene plastics in certain high-end applications (medical, food, etc.); no high quality substitutes expected.
	Rise of biodegradable plastics reduce ethylene demand.	**Low** A study by Wood Mackenzie projects that in a scenario aligned with limiting global warming to 1.5°C, global ethylene production could decline by 35% by 2050 compared to their base case[68]. This reduction is attributed to a combination of factors, including enhanced recycling rates, regulatory measures, and material substitution.	**Low** Not considered "real plastics"; insufficient quality to compete at scale. Biobased options limited by resources and lack of market pull.
	Market pull for green ethylene emerges.	**High** According to the interviews, this is a core barrier: consumers unwilling to pay premium for recycled/bio-based. However, if chemicals business models evolve towards a more local, circular approach, Europe's smaller facilities might actually have an advantage[69].	**High** EU investments stalled; even flagship projects struggle, according to correspondents. However, European chemical companies are moving towards more specialised or low carbon-intensity chemical production to safeguard their businesses[70] such as BASF, Sabic, and Linde's 2024 launch of an electric steam cracker in Germany[71].

64 https://www.hydrogeninsight.com/production/government-backed-green-hydrogen-to-methanol-pilot-in-belgium-scrapped-due-to-escalating-costs/2-1-1592857
65 https://bluecircle-olefins.com/
66 https://www.industrielings.nl/innovatie/2025/11/blue-circle-olefins-kiest-rotterdam-voor-eerste-100-circulaire-olefinenfabriek/
67 https://pubs.rsc.org/en/content/articlelanding/2023/ee/d3ee00478c
68 https://www.woodmac.com/news/opinion/Plastic-demand-reduce-30-energy-transition-scenario/
69 https://www.icis.com/explore/resources/cracker-closures-europe/
70 https://www.icis.com/explore/resources/cracker-closures-europe/
71 https://cefic.org/case-study/electrifying-the-future-breakthrough-in-sustainable-chemical-production/

Industrial relocation	Import of methanol for MTO.	**Medium** A paper by Verpoort et al. indicates the potential cost reductions in green olefins production through MTO by importing methanol (Verpoort et al., 2024). Importing methanol could reduce production costs of green olefins between 20% to 70%, depending on the assumptions. Importing the green olefins themselves shows to have a marginal further contribution to cost reductions.	**High** In 2024, a pilot project 'Power to Methanol' failed in Antwerp due to escalating costs[72]. In 2025, another pilot project on Methanol to Olefins (MTO) in Antwerp was launched in 2025[73] as well as the plans to build the first commercial MTO plant in the port of Rotterdam[66]. This suggests that MTO could still be viable in Belgium or Europe, while the domestic production of the methanol could be more challenging.
	Import of ethylene from China/US.	**High** The interviews indicated that Chinese dumping prices and lower US costs erode EU competitiveness. Verpoort et al. present marginal cost benefits from importing green olefins versus local production (Verpoort et al., 2024). This suggests that the cost savings from importing ethylene likely do not outweigh the loss of industrial assets in Europe or Belgium. Ethylene is currently excluded from CBAM, limiting protection from carbon leakage, but being considered for inclusion in 2026. However, the experts pointed out that naphtha crackers also produce essential co-products (e.g. C4s, propylene, and benzene). Consequently, relying more heavily on imported ethylene - while technically feasible - could disrupt interconnected downstream value chains. Shipping ethylene is always more expensive than shipping solid polyethylene. Therefore, if ethylene imports by ship are considered in future modelling, the wider effects on integrated product and value chains should also be considered.	**Medium** Interviews highlight the large number of announced closures. An overview by petrochemicals Europe indicates 5,660 Mt of cracker capacity to be closed or mothballed by 2027 in Europe[74]. Europe's aging capacity and high production costs make it particularly vulnerable to further closures considering current global overcapacity[75], as is outlined in greater detail in the recent Advancy report (Cefic & Advancy, 2025).

3.4.2.1 *Climate neutral and circular production*

In Belgium's chemical industry, progress toward carbon-neutral and circular production depends on several emerging but uncertain technologies. (Wyns et al., 2025) distinguish various forms of feedstock shift (biomass, carbon, hydrogen), electrification & alternative heating options, CCUS technologies, and different technologies for chemical recycling and few new chemical production processes. Chemical recycling via pyrolysis naphtha from plastic waste could replace 10–15% of virgin feedstock, although its deployment will likely require EU policy support through targets as high costs and product-quality limitations remain barriers. CCS/CCUS is viewed as essential for achieving net-zero emissions, but large-scale deployment faces technical, financial, and coordination challenges. Feedstock shift with

[72] https://www.hydrogeninsight.com/production/government-backed-green-hydrogen-to-methanol-pilot-in-belgium-scrapped-due-to-escalating-costs/2-1-1592857
[73] https://www.honeywell.com/us/en/press/2025/01/honeywell-technology-chosen-by-vioneo-for-its-planned-european-production-of-fossil-feedstock-free-plastics
[74] https://www.petrochemistry.eu/about-petrochemistry/petrochemicals-facts-and-figures/cracker-capacity/
[75] https://www.icis.com/explore/resources/cracker-closures-europe/

Methanol-to-olefins (MTO) offers another pathway for low-carbon feedstock diversification, yet its commercial viability remains uncertain. Overall, while these technologies are pivotal to decarbonization and pilot projects are underway, their economic feasibility and scalability remain uncertain, delaying widespread industrial uptake.

3.4.2.2 Downstream market developments

Biodegradable plastics and notably mechanical recycling could partially reduce primary ethylene demand, although limitations apply. On the other hand, new demand niches could increase demand to a limited extent. Specialized low-carbon projects like BASF and Linde's electric steam cracker could provide a European advantage regarding green ethylene production. However, for EU or Belgian green ethylene production to become competitive, a market pull for green ethylene is needed, as adoption is constrained by consumer reluctance to pay premiums for clean products without policy intervention.

3.4.2.3 Industrial relocation

According to our respondents, Belgium's chemical sector faces significant relocation risks. Firstly, relocation risks emerge due to an overall loss of competitiveness due to high energy prices, regulatory barriers, aging plants and global overcapacity. In particular, cheap ethylene import from China or the US – currently excluded from CBAM - threatens local and EU competitiveness potentially leading to carbon leakage. Secondly, relocation risks emerge because of production cost increase due to green production targets in the EU. Pilot projects highlight challenges in local methanol supply and cost escalation for MTO, but research (Verpoort et al., 2024) suggests importing methanol for MTO could significantly reduce green olefin production costs.

3.5 Cement

The cement industry is a key pillar of the construction sector, with cement being the main component of concrete. However, cement production is highly carbon-intensive and is classified as a "hard-to-abate" sector. Indeed, cement manufacturing accounts for around 7% of global CO_2 emissions[76]. In Belgium, the industry is represented by the federation Febelcem[77], which includes all the major players in the market. At the European level, the representative organization of the cement sector is Cembureau[78].

3.5.1 Current cement production landscape

3.5.1.1 Production in Belgium

The key processes of cement production are well described in the literature (Gailani et al., 2024; Wyns et al., 2025). Clinker formation is the most energy intensive step. Clinker is obtained by heating a mixture of limestone and other minerals in a kiln at about 1,450°C. This transformation, known as calcination, releases CO_2: approximately 60–65% of total cement industry emissions are linked to this process, while the remaining share comes from fuel combustion in the kiln (Cembureau, 2024).

Cement production in Belgium is strongly shaped by the availability of raw materials, particularly limestone and chalk, which are the key inputs in clinker manufacturing. Cement plants are therefore located close to large deposits of these materials. As illustrated Figure 9, cement production in Belgium is spread across several sites, while clinker production is concentrated in Wallonia, where limestone

[76] https://www.dnv.com/article/why-is-the-cement-industry-labelled-hard-to-abate--241192/
[77] https://www.febelcem.be/fr/
[78] https://cembureau.eu/

quarries are located. Two companies, VV/M and Cemminerals, do not operate their own kilns and instead source clinker directly from other producers.

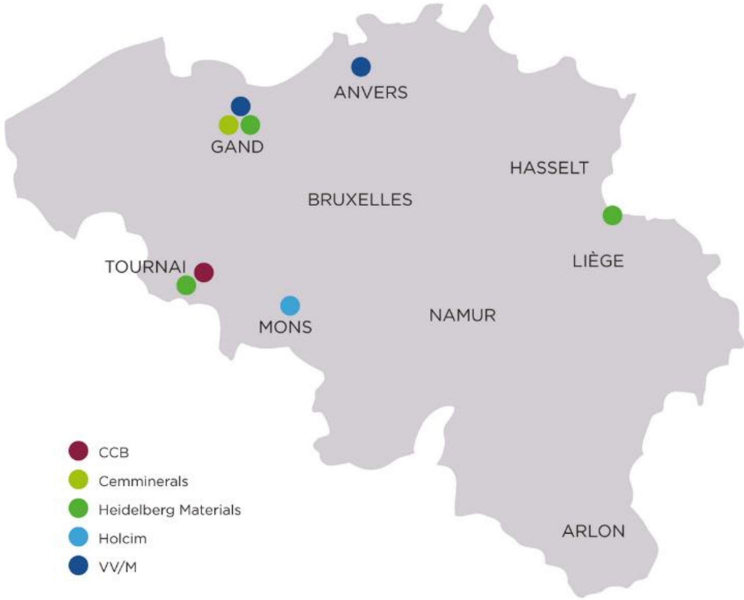


Figure 9: Cement production sites in Belgium (Febelcem, 2025a)

Figure 10 shows the evolution of grey cement consumption in Belgium[79] with an estimated 5,400 kton consumed in 2024. The total grey cement production in Belgium in 2024 amounts to 6,873 kilotons, meaning that Belgium produces more cement than it consumes (Febelcem, 2025a). It is worth noting that the term grey cement, as used in Febelcem's statistics, primarily designates Portland cement, which constitutes the main type of cement produced and consumed in Belgium. The clinker-to-cement ratio in Belgium currently stands at 61%[80], which is above the European average of 77% in 2021 (Febelcem, 2024).

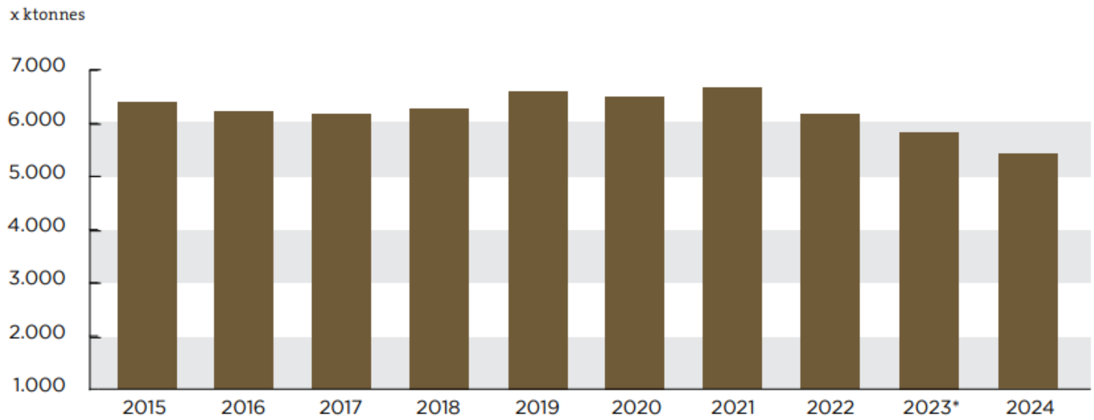


Figure 10: Grey cement consumption in Belgium (Febelcem, 2025a)

[79] It is important to note that in 2023 and 2024, two new members joined Febelcem, increasing the federation's membership from three to five companies. As a result, the 2022 figures are based on data consolidated from three cement producers, while figures from 2023 and 2024 are based on five producers.
[80] https://febelcem.be/fr/ciment-et-beton/chiffres/

3.5.1.2 Downstream markets and trade

The Belgian cement market is mainly oriented towards construction materials and infrastructure, with the following distribution of end uses (Table 11).

Table 11: Cement sector downstream market distribution (Febelcem, 2025a)

Downstream market	***[%]***
Ready-mixed concrete	58 %
Concrete and fibre-cement products: Concrete blocks, urban furniture, Fibre-cement façade panels, …	19 %
Direct deliveries to construction sites	18 %
Deliveries to distributors	5 %

Belgium is both an exporter and an importer of cement. 71% of Belgian production is delivered directly to the domestic market. Exports are around 29% of its production, going mainly to the Netherlands and France. On the import side, about 10% of the Belgian market (approximately 500 kilotons) is covered by imports, primarily from Germany and Luxembourg. These trade flows are influenced more by geographical proximity and logistical convenience than by cost competitiveness (Febelcem, 2025a).

It is also essential to consider clinker imports and exports, since clinker production represents the most carbon-intensive stage of the production process. However, precise data on clinker trade is difficult to obtain, as such information is often confidential or not fully disclosed. Beyond the elements detailed bellow, no further details on clinker import and export volumes are available, as only limited information has been shared by industry stakeholders. At the European level, Cembureau data also aggregate cement and clinker, without distinguishing between the two materials, which further limits the precision of available trade statistics.

For Belgium, clinker imports often take place within the same industrial groups as part of intra-company trade. The main sources of imported clinker include Turkey, which is the leading supplier, as well as North African countries such as Egypt, Algeria, Tunisia, and Morocco, and Luxembourg. These imports are generally transported in bulk, with shipment volumes typically ranging between 30 and 60 kilotons (CEEP-IT interviews).

3.5.1.3 Recent developments and challenges

Towards Net Zero production

Regarding the carbon intensity of cement production, Belgium already performs well compared to the global average. In fact, the country has reduced its emissions from 752 kg CO_2 per ton of cement in 1990 to 552 kg CO_2 per ton in 2023 (Febelcem, 2025b), while the global average stood at 580 kg CO_2 per ton of cement in 2022[81]. In recent years, several pilot projects and new developments have emerged with the aim of decarbonizing the cement sector. Examples are:

- LEILAC-1 in Lixhe - Heidelberg Materials[82] (LEILAC Technology Roadmap to 2050, 2021):
    - Indirect heating for calcination to efficiently separate unavoidable CO_2 process emissions for use or storage

[81] https://www.iea.org/energy-system/industry/cement
[82] https://www.leilac.com/project-leilac-1/

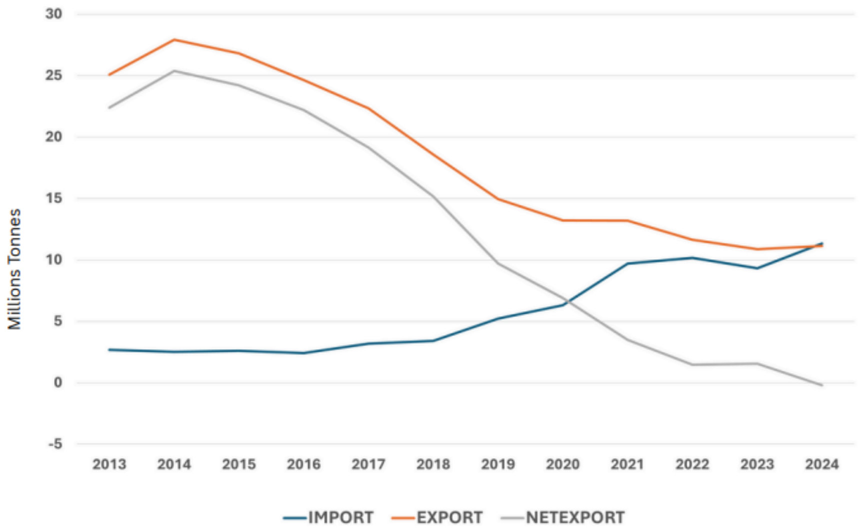
- Operating since 2019
- Proof of concept for the Leilac decarbonization technology with a capacity of 25 kton of CO_2 per year.

- Groupe Heidelberg Materials – Benelux
  - More than 60% of the fuels used are already alternative fuels that replace traditional sources such as oil, gas, or coal[83]. For example, Heidelberg Materials Benelux sources secondary products from other industries that can be recovered as fuel. This can be done thanks to Recyfuel that is a pre-treatment platform for industrial and household waste, designed to produce substitute fuels for use in cement production[84].
- The GO4ZERO project – Holcim
  - Holcim's flagship CCS project at its Obourg cement plant in Belgium, aiming to capture around 1.1 $MtCO_2$ per year[85] using oxyfuel combustion and transport the CO_2 for offshore geological storage, with construction underway and full operation targeted by the end of the decade.

Further reduction in the combustion-related emissions are foreseen in the coming years due to the various decarbonization pathways being implemented in the cement sector (Febelcem, 2025b). The process emissions represent a major challenge for the cement sector, as they are inherent to the chemical reaction required for clinker production. Unlike emissions from fuel combustion, which can be mitigated through fuel switching or energy efficiency measures, process emissions cannot be easily avoided, since they result directly from the decarbonation of limestone during clinker production. Climate-neutral cement production therefore critically relies on CCS.

A shifting trade balance

The EU27 has historically been a net exporter of cement; however, export volumes have fallen steadily since 2014 as illustrated in Figure 11. At that time, the EU27 exported roughly 28 million tonnes of cement while importing only around 3 million tonnes, resulting in a net export balance of approximately 25 million tonnes. By 2024, this situation had shifted significantly, with import and export volumes reaching similar levels, at roughly 11 million tonnes each (Cembureau, 2025). The increase in imports around 2021 can be related to the rising price of CO_2 emission allowances in Europe (CEEP-IT interviews).



83 https://www.heidelbergmaterials-benelux.com/fr/belgique-ciment/combustibles-alternatifs
84 https://www.recyfuel.be/fr/
85 https://www.holcim.com/what-we-do/green-operations/ccus/go4zero

Figure 11: Cement and clinker import/export at EU27 border (Cembureau, 2025)

3.5.2 Industrial Transformation Cases

Table 12 lists the ITCs discussed with the cement sector representatives in Belgium.

Table 12: Overview of ITCs and insights from interviews for cement.

	ITC	Impact	Uncertainty
Carbon-neutral & circular production	CCS	**High** Essential to capture process emissions from cement. Would significantly increase energy demand (gas or electricity).	**Medium** Implementation will require major infrastructure such as the CO_2 Backbone pipeline, which is planned but not yet decided[86]. The first injection is expected by 2029[87]. CCS will be an essential part of cement decarbonisation due to the high process emissions, relatively high TRL[88] and mitigation costs are not very high compared to other breakthrough technologies (Wyns et al., 2025).
	Clinker substitution with granulated blast furnace slag (GBFS)	**Low** Limited overall impact since it only partially reduces clinker use rather than transforming the production process.	**Low** GBFS is the dominant substitute today and the use is maximal. But supply is expected to decline as the steel industry transitions away from blast furnaces, the availability is expected to decrease by 80% in 2050 (expert interviews).
	Clinker substitution with limestone calcined clay (LC3)	**Medium** Partial mitigation measure and thus limited impact, reducing clinker-related emissions but not fundamentally altering the process (Girardin, Valee, & Correa Laguna, 2023). (JRC, 2025) mentions that 43% of clinker could be substitute with calcined clay or fly ash.	**Medium** Being investigated as an alternative. Projects are underway to validate its technical performance in concrete. While compressive strength is not an issue, durability (especially in marine or salted environments) is still a challenge (Islam M. Shariful et al., 2025).

86 https://www.fluxys.com/en/projects/carbon-preparing-to-build-the-network
87 https://neven.wallonie.be/home/communiques-de-presse/presses/la-wallonie-designe-l-operateur-de-son-futur-reseau-co2.html
88 https://en.wikipedia.org/wiki/Technology_readiness_level

	Clinker substitution with geopolymers	**Medium** Geopolymers could provide low CO_2 cement for some applications and contribute to CO_2 storage (Freire et al., 2022).	**Medium** Rely on activating industrial waste materials chemically. Although known since the 1950s, they remain niche and are unlikely to become a mainstream solution due to performance and standardization challenges. According to the expert interviews, some geopolymers are based on the activation of GBFS, that are already scarce.
	Electrification of processes	**Medium** Targets only combustion emissions (≈1/3 of total), leaving process emissions untouched. Impact lower than CCS but still significant for fuel-related decarbonization.	**Medium** Partial electrification (e.g., Holcim's plasma torch pilot[89]) is being tested. Full electrification before 2040–2050 remains unlikely given energy demand and infrastructure needs. There are also doubts about the availability of the necessary electrical power.
	Hydrogen combustion	**Medium** Targets only combustion emissions (≈1/3 of total), leaving process emissions untouched. Impact lower than CCS but still significant for fuel-related decarbonization.	**High** Hydrogen remains technically possible, but economically and energetically unrealistic in the current Belgian context Hydrogen is seen as a long-term possibility.
	Biogas combustion	**Low** Minor contribution limited to partial replacement of fossil fuels in combustion, with low overall emission impact.	**Low** Biogas is expected to play a supportive role in partial fuel substitution.
Downstream market developments	Expected slight gradual decline in cement and concrete demand	**Medium** A potential change of cement and concrete demand would translate to a decline of production with potentially significant impact on the energy-economy system. Yet, no such changes are foreseen by the cement sector in the short term.	**Low** According to sector experts, cement and concrete consumption in Belgium is considered to have plateaued, with no change in demand expected in the short term. In the medium to long term, however, a gradual decline can be anticipated due to increasing emphasis on renovation rather than new construction, as well as a lack of investment in infrastructure.

89 https://www.holcim.com/media/company-news/investment-saltx-plasma-technology

	Longer term increase in cement and concrete demand	**Medium** A potential change of cement and concrete demand would translate to a decline of production with potentially significant impact on the energy-economy system. Over time, infrastructure investment and potential demolition-rebuild activity could increase the demand.	**High** Future demand is highly policy-dependent. If governments sustain public infrastructure spending and support low-carbon construction through stable incentives, cement and concrete consumption could recover on a greener basis. Conversely, if investment caps and affordability concerns persist, demand may continue to shrink. According to CEEP-IT interviews, climate adaptation can play a significant role in demand for concrete.
	Alternative concretes	**High** Potentially transformative in the long term, as they can avoid the use of clinker-based cement altogether. However, current maturity and standardization remain low.	**High** Their development depends on new design standards, durability validation, scale, availability and acceptance by the construction sector.
	Concrete reuse or repurposing	**High** Avoids entirely the production of new materials for equivalent functions. (JRC, 2025) mentions that 15-20% of precast concrete éléments of buildings at other sites could be reuse by selective demolition.	**High** There are many uncertainties: technical constraints, logistic and economic feasibility (disassembly, transport, storage), normative and safety barriers, compatibility with new utilisation, local market limitations in term of availability. However, some projects are already happening (Küpfer et al., 2022).

	Concrete recycling, use of recycled aggregates, fines, valorisation of demolition waste	**Medium** Reduces extraction of virgin aggregates, lowers resource demand and CO2 savings (JRC, 2023).	**Medium** Further quality improvement of recycled aggregates and dedicated policies and legislations are essential for their market development (Cerchione et al., 2023). Standardization barriers apply. Engagement, training and awareness from stakeholders are needed (JRC, 2023). Some applications in Belgium are already happening[90] [91]. Innovative recycling technologies necessary to recycle concrete into cement fines, to be used either as raw material for clinker or as a replacement of cement (JRC, 2025).
	Biobased building materials	**High** Potentially transformative in the long term, as biobased building materials can decrease CO2 impacts significantly. However, current maturity and standardization remain low and rebound effects on other environmental impact indicators should be taken into account (e.g. land occupation and water consumption).	**Medium** Biobased building materials have been the standard for centuries, and there is no high technical risk involved.
Industrial relocation	Increased clinker import	**Medium** Structural impact on production geography and carbon leakage risks rather than direct emission reductions.	**Medium** Feasible but would require new infrastructures (terminals). Already happening with a sharp rise between 2019 and 2023 triggered by the rising price of CO_2 emission in Europe. Will be impacted by CBAM mechanism. According to the interviews, EU Taxonomy[92] may play a role requiring low carbon clinker which could affect imported volumes of clinker and cement (expected after 2035).
	Increased cement import	**High** Structural impact on production geography and carbon leakage risks rather than direct emission reductions.	**High** Feasible but would require new infrastructures (terminals).

90 https://circularconcretecenter.be/fr
91 https://www.betonakkoord-vlaanderen.be/
92 https://ec.europa.eu/sustainable-finance-taxonomy/home

3.5.2.1 Climate neutral and circular production

As illustrated in Figure 12 and discussed in (Wyns et al., 2025), the transition toward climate-neutral and circular cement production can be grouped into four main technological pathways:

- CCS to capture process-related CO_2 emissions from clinker production and either store or reuse them in other industrial applications.
- Clinker substitution reduces the share of high-emission clinker by replacing it with alternative materials such as calcined clay, slag, or other supplementary cementitious materials.
- Electrification seeks to replace fossil-fuel combustion in kilns with electric systems, including plasma torches or other high-temperature solutions powered by renewable electricity.
- Fuel switching introduces low-carbon fuels, such as hydrogen or biogas, to decarbonize the thermal energy demand of kilns.

Each option addresses a different part of the emission profile of cement manufacturing and contributes to decarbonization through complementary mechanisms. These pathways are mutually reinforcing and can be combined to maximize impact (except in the case of full electrification, which would render a fuel switch unnecessary).

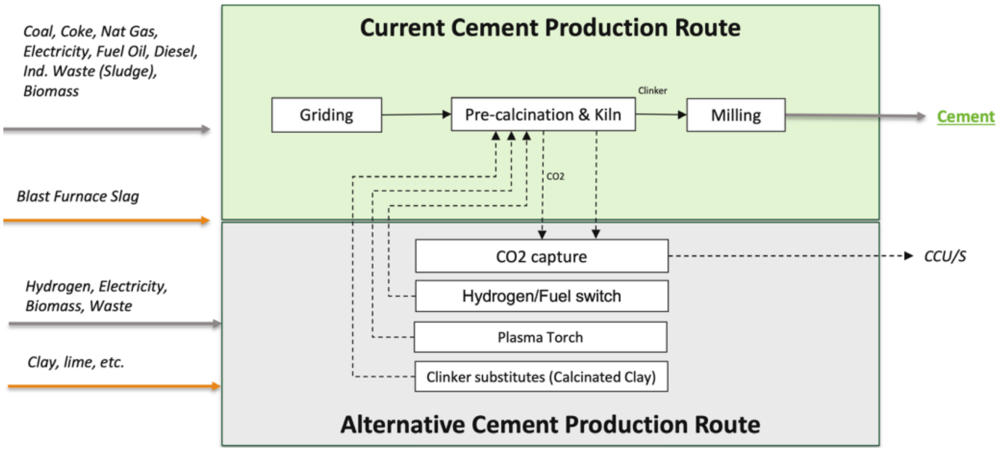


Figure 12: Current and alternative production routes in TIMES for the cement sector (simplied view) (Correa Laguna et al., 2023).

3.5.2.2 Downstream market developments

In the short to medium term, cement and concrete demand is expected to remain relatively low. The decline in residential permits since 2021 and a slowdown in new private investment have constrained volumes. Rising interest rates, elevated material costs, and regulatory delays have dampened developer activity. Moreover, renovation, now the dominant growth driver, has a limited direct impact on cement and concrete consumption, since most energy retrofits focus on insulation, glazing, and HVAC rather than structural replacement.

Over the long term (2040–2050 horizon), the net effect on cement and concrete demand is more uncertain and will depend on how the balance evolves between:

- New construction, which sustains baseline demand but is currently constrained by affordability and land-use policy;

- Deep renovation and demolition-rebuild, which could partially offset the decline in new builds if regulatory and fiscal conditions allow for it;
- Infrastructure renewal, which may become the main growth driver as climate adaptation and mobility investments accelerate.

A further source of uncertainty lies in the transition toward low-carbon cement and concrete, as well as more downstream circularity and bio-based materials. While the sector is investing in green cement and carbon capture technologies, these alternatives are more expensive and not yet scaled. Their adoption will depend on regulatory incentives, carbon pricing, and clients' willingness to pay. If policy ambition outpaces affordability, demand could shift toward lighter or bio-based materials in certain segments, reducing cement's share in total material volumes.

3.5.2.3 Industrial relocation

Relocation of clinker or cement production outside EU could lead to carbon leakage, rather than genuine emissions reductions, as production would simply shift to regions outside the EU where carbon constraints are lower. Such a scenario is precisely what the CBAM aims to address: from January 2026 onwards, clinker and cement imports will be subject to carbon cost adjustments at the EU border, which should, in principle, equalize the carbon costs between EU and non-EU producers. This should prevent carbon leakage by ensuring imported cement and clinker face similar carbon pricing as domestically produced goods under the ETS. Beyond carbon pricing, the practical feasibility of relocating production outside Europe remains limited by substantial logistical constraints and infrastructure investments.

Relocation within the EU is also highly constrained. Large-scale clinker production requires a rare combination of conditions: access to limestone deposits and nearby CO_2 transport and storage options to enable future CCS deployment. Such geographical alignments exist only in a few specific regions, making intra-EU relocation of production unlikely in practice.

3.6 Lime

Lime is produced from limestone with important applications in for steel production, environmental protection and construction. In Belgium, the lime industry is represented by the federation Fediex[93], which includes all extractive industries. At the European level, the representative organization of the lime sector is the European Lime Association (EuLA)[94].

3.6.1 Current lime production landscape

3.6.1.1 Production in Belgium

The production route of lime is similar to the production route of cement (Gailani et al., 2024) and is characterized by significant process emissions from the calcination of limestone. The process of turning limestone (CaCO3) into lime (CaO) requires heat and emits CO_2. The chemical equation for this process is:

$$\underset{1{,}79\ \text{tonne}}{CaCO_3} \xrightarrow{\text{Heat (~950°C)}} \underset{1\ \text{tonne}}{CaO} + \underset{0{,}79\ \text{tonne}}{CO_2}$$

[93] https://www.fediex.be/
[94] https://eula.eu/

For every tonne of lime created, a similar amount (0,79 tonne) of carbon-dioxide is thus inevitably released to the atmosphere. These emissions alone, account for roughly 70% of the total CO2-emissions of the sector (The European Lime Association, 2022). The calcination step is also the most energy-intensive step of lime production. As shown in Table 13, this energy consumption can vary from 3.2 to 7 GJ/t of lime produced.

Table 13: Overview of minimum and maximum heat consumption per kiln type for quicklime production (The European Lime Association, 2019)

Kiln orientation	***Kiln type:***	***Heat use / consumption of quicklime production (GJ/tonne):***
Vertical	Parallel flow regenerative kilns	3.2 – 4.2
	Annular shaft Kilns	3.3 – 4.9
	Mixed feed shaft kilns	3.3 – 4.7
Horizontal	Long rotary kilns	6.0 – 9.2
	Rotary kilns with preheater	5.1 – 7.8
Other kilns		3.5 – 7.0

The lime production industry in Belgium is highly concentrated, with only two companies, Carmeuse and Lhoist (including Carrières et Fours à Chaux Dumont-Wautier), actively producing lime. Each of these firms operates three production units. According to (Fediex, 2023), total production in Belgium was around 1200 kt of lime in 2022. In 2019, the majority of the fuel used in the lime production in Europe was fossil fuel (Figure 13).

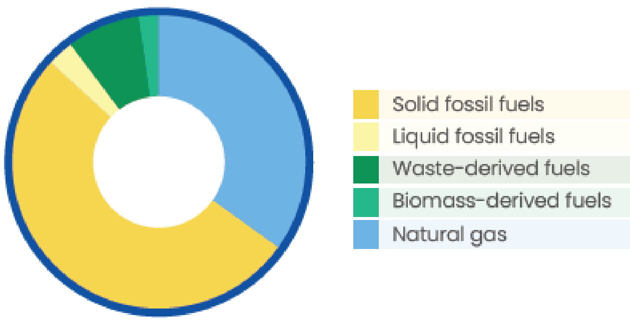


Figure 13: Average fuel mix of the European lime (EuLA, 2023)

According to CEEP-IT interviews, since 2008, lime production and consumption in both Belgium and the EU have shown a steady and continuous decline. This mirrors the broader peak in global industrial output observed around 2008, after which lime demand has contracted. Between 2008 and 2018, volumes decreased by approximately 30% in Belgium. Since then, annual consumption has continued to erode slightly, driven by multiple structural factors such as the absence of demographic growth, increased process efficiency, and reduced input needs in downstream industries. Today, the sector in Belgium operates with a significant overcapacity estimated at 35–40%.

Beyond its industrial footprint, the lime sector plays a significant role in the Belgian economy according to CEEP-IT interviews. Indeed, the two main companies employ approximately 500 people at Carmeuse and around 1,000 at Lhoist. Despite the relatively small number of actors, the sector generates substantial turnover and maintains its decision-making centres in Belgium, with Belgian ownership and global operations.

Lime production also constitutes the first link in a broad and essential value chain. A wide range of industrial activities depend on lime as a key input, making the sector a universal and indispensable supplier to numerous downstream industries as detailed in the next sections.

3.6.1.2 Downstream markets and trade

Figure 14 shows the life cycle of the limestone and the different products they can be turned into:

1. **Limestone fines**: produced after crushing and grinding the stone slabs, it is then sorted based on size and further processed for the removal of heavy metals or unwanted clay (Mitraki, 2024).
2. **Lime or quicklime:** using a rotary kiln the limestone is transformed into quicklime and carbon dioxide. It can be used in steel manufacturing to remove impurities but also in the construction sector to produce lime-based mortars and plasters[95].
3. **Hydrated or slaked lime:** or Calcium Hydroxide is produced by adding water to the quicklime. This can be used as a soil-fertilizer or at water- and wastewater treatment plants to de-acidify the water[96].
4. **Milk of lime or hydraulic lime:** slaked lime is lightly soluble in water, when large amounts of water are added limewater is created. By adding carbon dioxide to the solution, calcium carbonate (the main component of limestone) is created again, and the cycle is closed.

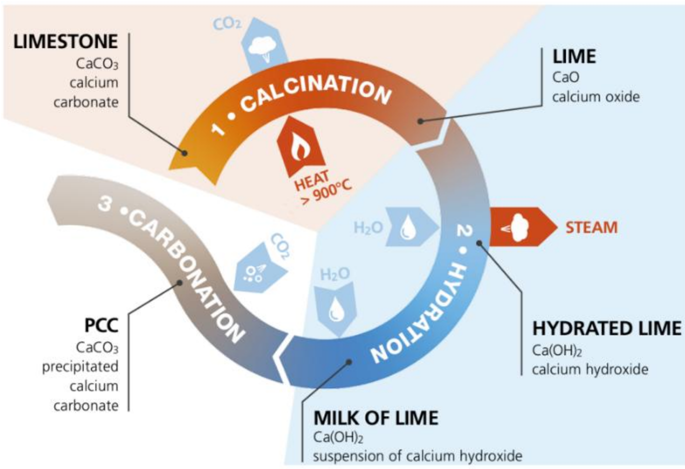


Figure 14: Lifecycle of limestone (The European Lime Association, 2022)

The main three downstream markets for these lime products (Figure 15) are:

- Steel (39%): According to Calcinor[97], lime is essential to the steel industry. It is used throughout the whole steel-making process and is necessary in electric arc furnaces, AOD converters, refining ladles, etc. It is used for three main functions:

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95 https://htmcgroup.com/understanding-quick-lime-types-properties-and-applications

96 https://www.products.pcc.eu/en/blog/what-are-the-properties-and-applications-of-slaked-lime/

97 https://www.calcinor.com/en/news/product-reviews/lime-an-essential-component-in-the-steel-industry

- Formation of slag: protects the metal from elements in the atmosphere such as nitrogen and hydrogen.
- Phosphorus removal: quicklime added to the metal-making process extracts the phosphorus in the steel, lowering its proportion to levels where its ductility is not affected.
- Sulphur removal: sulphur can cause damage to steel by making it more fragile, causing cracks to form. Quicklime is added to lower the percentage rate of the sulphur which minimizes its negative effects.

- Environmental protection (15%): like the steel industry, the environmental sector uses the lime's absorbent nature. In this case it is used to remove acidic pollutants from flue gas, but also to avoid acid rain and to reduce the environmental air emission impact of all industries by more than 98%. This can be achieved thanks to the final step in the limestone's lifecycle: absorbing carbon dioxide to turn limewater back into calcium carbonate[98].

- Construction materials (12%): lime has been used for centuries as a binding agent in plasters and mortars. Mining sector representatives highlight that process emissions from lime production are to some extent retrieved after reacting with oxygen, and advocate for this decarbonation to be officially recognized and counted as a form of CO_2 removal under climate policy frameworks. Participants stressed that acknowledging this natural recapture would more accurately reflect the climate performance of lime products[99].

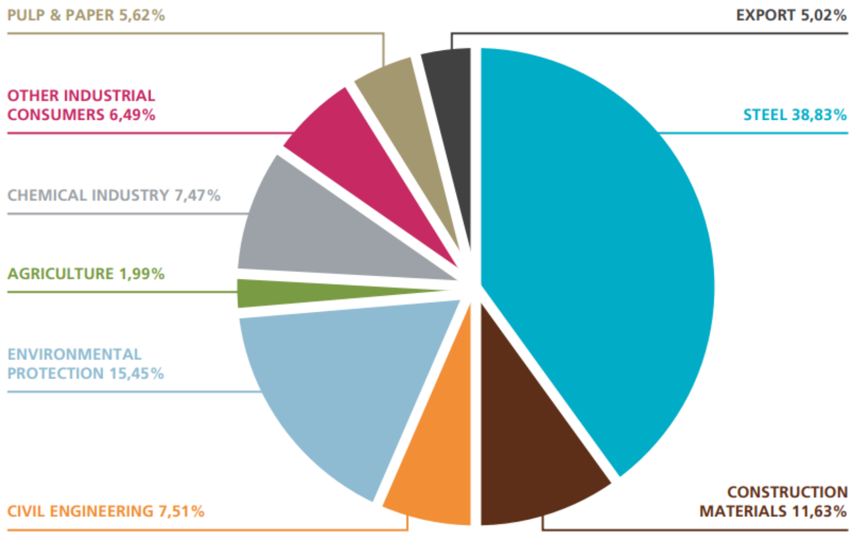

Figure 15: Overview of lime customer markets in 2018 for EuLA members (The European Lime Association, 2022)

Regarding trade, Belgian lime production in 2016 corresponded to 6% of the total European production as shown in (Figure 16), based on quick- and slaked lime production share of 6 and 5% respectively. According to the sector federation, exports are geographically limited given the low value-density rate of the product. Belgium exports its products only to neighbouring countries such as the Netherlands, Germany, Luxembourg and France. There are also some limited long-distance exports, particularly to Scandinavian countries. Belgium does not import limestone for lime production but is importing sand from the Netherlands.

98 https://eula.eu/benefits-of-lime/
99 https://www.calcinor.com/en/news/product-reviews/lime-an-essential-component-in-the-steel-industry

3.6.1.3 *Recent developments and challenges*

A main recent development has been piloting CCS. Carmeuse has launched "Butterfly" [100,101], a pilot project at its historic Andenne site (Wallonia, Belgium), aiming to capture and concentrate CO_2 emissions from lime production (process and energy emissions). Initiated in 2022, it represents a world-first step in industrial decarbonization for the lime sector. The process relies on recirculating furnace flue gases to increase CO_2 concentration from about 20% to 75%. A dedicated CO_2 purification step will still be necessary to further purify this enriched stream to a concentration compatible with CO_2 transport and storage/usage requirements (typically around 99 %) but achieving 75% is already an important step.

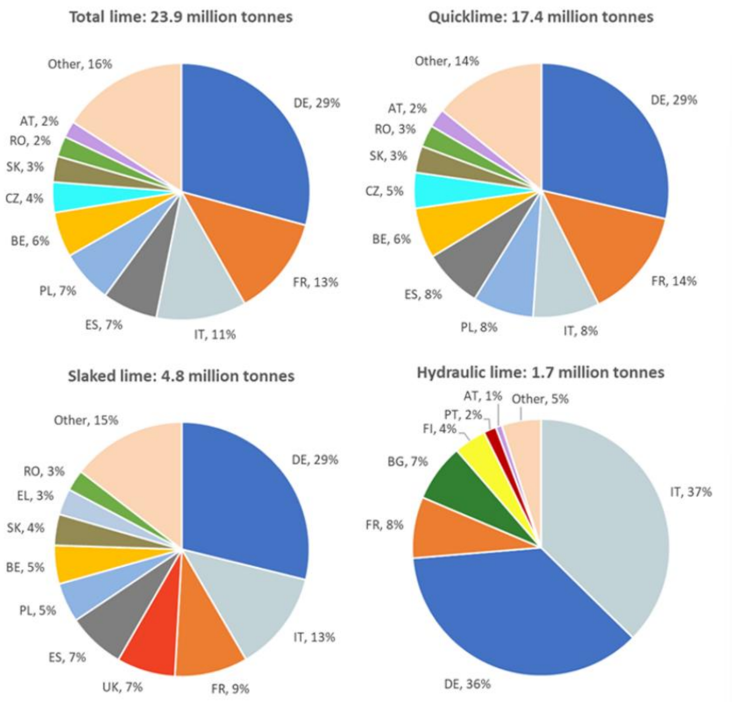

Figure 16: Production of lime-based products in Europe in 2016

Following promising test phases, Carmeuse plans to deploy CO_2 capture technologies across all its industrial sites by the end of 2028. While the CO_2 captured at the pilot site is currently released, Carmeuse stresses the urgent need for large-scale CO_2 transport and geological storage infrastructure to achieve complete industrial decarbonization.

100 https://www.lecho.be/entreprises/industries-de-base/carmeuse-pourra-decarboner-tous-ses-sites-industriels-d-ici-fin-2028/10624292.html

101 https://www.carmeuse.com/na-en/insights/evolution-project-butterfly

Figure 17: The CO_2 buffer installed on Carmeuse's Butterfly unit makes it possible to convert intermittent CO_2 flow into a continuous one, enabling transport and integration into CO_2 networks

3.6.2 Industrial Transformation Cases

Table 14 lists main relevant ITCs, discussed with the lime sector in Belgium.

Table 14: Overview of ITCs and insights from interviews for lime.

ITC	Impact	Uncertainty
Hydrogen combustion	**Medium** Offers potential for fossil-free heat generation but targets only combustion emissions (≈1/3 of total).	**High** Hydrogen combustion does not provide the same control and uniformity in the calcination process, which is critical for lime production.
Biomass combustion	**Medium** Offers potential for fossil-free heat generation but targets only combustion emissions (≈1/3 of total).	**Medium** The use of biomass as a fuel is currently preferred over hydrogen by the sector.
Electrification	**Low** By 2050, 5 to 10% of total lime production will be switched to fully electrified kilns.	**High** The technology is not yet fully ready at this stage. There are also doubts about the availability of the necessary electrical power.
Shift/upgrade to vertical kiln technologies	**Low** CO2 emission mitigation through kiln shift/upgrade to vertical kiln technologies is estimated to be ca. 4,5% of total direct CO2 emissions (EuLA, 2023).	**Medium** The kilns must be replaced at the end of their lifespan anyway. However, it is very rare for industrial actors to switch kiln before the end of life, given the significant investments required.

	CCS	**High** Major decarbonization potential but would significantly increase energy demand (gas or electricity) and infrastructure costs.	**Medium** Implementation will require major infrastructure such as the CO_2 Backbone pipeline, which is planned but not yet decided[102]. The first injection is expected by 2029[103]. CCS will be an essential part of lime decarbonisation due to the high process emissions, relatively high TRL and mitigation costs are not very high (Wyns et al., 2025).
	Recognition of recarbonation	**Medium** Scientific studies have shown that around 33% of process-related CO_2 emissions are naturally reabsorbed during the first year of the product's use phase. In some applications, such as soil treatment, additional CO_2 removal of up to 12% could be achieved by optimizing product use—enhancing contact between lime and atmospheric CO_2 through better surface exposure, pressure, and time. Despite a major impact on carbon accounting of process emissions, this doesn't fundamentally change the reality and CO_2 emissions.	**Medium** Although there is no uncertainty regarding its technical feasibility, the discussions are primarily political and regulatory. It is therefore difficult to predict precisely how it will evolve, despite some pressure from the industry to push things forward.
Downstream market developments	Lime consumption further gradual decline	**Medium** Since 2008, lime production in Belgium has been gradually declining (slow contraction). The prospects for future growth remain limited, with no strong signals of a reversal in trend.	**Medium** Lime consumption spans across a wide range of sectors, meaning that demand evolution is influenced by multiple factors. As a result, significant uncertainties remain despite the current slight downward trend.
	Relocation of lime's industrial clients	**High** Potential impacts on local demand and thus shutdown of some industries.	**Medium** If downstream industries (steel or chemicals) relocate abroad, domestic lime demand could fall. Although delocalisation of lime plants themselves is unlikely.
	Reduction of the calcined fraction in blended products	**High** This approach is particularly promising for applications such as soil stabilization, where lime is blended with clay to improve structural integrity. In this way, the CO_2 emissions linked to lime production can be cut significantly, by as much as 60% in some cases according to the sector experts.	**Medium** Although these innovative products are still under development, most of the lime currently sold on the market remains 100% calcined.

102 https://www.fluxys.com/en/projects/carbon-preparing-to-build-the-network

103 https://neven.wallonie.be/home/communiques-de-presse/presses/la-wallonie-designe-l-operateur-de-son-futur-reseau-co2.html

Relocation	Import of lime	**Low** Imports of lime could, in theory, have a significant structural impact on domestic production geography. However, trade mostly occurs at a regional scale (typically within a radius of about 350 km), which limits the real impact. Today, there is no import from outside EU.	**High** Relocation of production out of Belgium to neighbouring countries (France, Germany, the Netherlands, and Luxembourg) remains unlikely. Transport costs and the material's low value-to-weight ratio make long-distance trade economically unattractive. Furthermore, Belgium has abundant limestone resources and existing quarrying sites, but expanding or opening new quarrying sites is increasingly challenging due to stringent permitting procedures. There are also uncertainties around CO2 cost and CBAM for instance.

3.6.2.1 Climate neutral and circular production

Achieving climate-neutral lime production requires a holistic approach because of the combustion and process emissions. Substituting fossil fuels with hydrogen, biomass, or fully electrifying kilns can drastically reduce combustion-related emissions. At the same time, shift/upgrade to vertical kiln technologies (Table 14) maximizes thermal efficiency (EuLA, 2023). Process-related CO_2 emissions, inherent to the calcination of limestone, can be mitigated through carbon capture and storage (CCS) solutions. Additionally, the natural recarbonation of lime products could offer a significant contribution to the carbon accounting of the lime sector. These different decarbonization pathways are confirmed by EuLA's roadmap (EuLA, 2023) as shown in Figure 18.

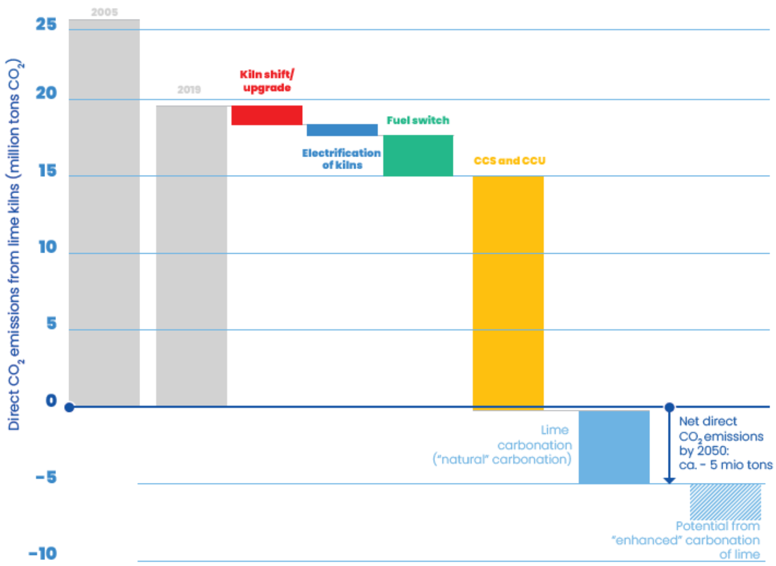

Figure 18: Pathway to negative emissions by 2050 (baseline 2019)

3.6.2.2 Downstream markets

The last few years, the European market for quicklime has been declining at a rate of around 0.5% annually[104]. Since 2018, lime production in Belgium has been gradually declining. This is not seen as a collapse of the industry, but rather as a slow contraction. The prospects for future growth remain limited, with no strong signals of a reversal in the trend. Considering these events, the lime industry in Belgium is currently facing an overcapacity of 30%. Finaly, there's the risk that the clients of the lime sector would relocate abroad, which could cause domestic lime demand to fall.

In this context, one innovation trajectory is the reduction of the calcined fraction in blended products.

3.6.2.3 Industry relocation

Lime imports could influence domestic production geography, but regional trade patterns restrict large-scale impacts. Relocation of production to neighbouring countries is unlikely, as Belgium has abundant limestone resources and established quarrying sites. Overall, industry relocation risks for the Belgian lime industry are low.

3.7 Bricks

The Belgian brick industry remains a cornerstone of the construction sector, offering a wide range of products adapted to both new-build and renovation markets. In 2024, total production volumes highlight the diversity of product categories, from masonry blocks to facing bricks, as well as the growing share of eco-formats (bricks with reduced thickness).

3.7.1 Current brick production landscape

3.7.1.1 Production in Belgium

The Belgian brick industry, from an energy and emissions perspective, is relatively small compared to cement or steel, but is significant for cultural and architectural reasons. It consists of 22 production sites owned by 12 companies, with one controlling around half of output and the remainder supplied by smaller family-owned bricks manufacturers. Most plants are located adjacent to clay quarries mostly in Flanders, ensuring short supply chains and limited transport emissions. Operating capacity has been high in recent years (around 85% in 2022), and additional production lines could be added without major technical barriers. However, output is not determined by capacity but by market demand, which has stagnated as new-build activity contracts (CEEP-IT interviews).

As shown in Figure 19, total brick production in Belgium remained stable until 2008, with annual volumes around 3 million tonnes. The economic crisis of 2008 led to a decline in production. After this downturn, production levels stabilised over the following decade. However, production started to decline after 2022, reaching approximately 1,611 kt in 2024, according to (CEEP-IT interviews). This second downward trend is closely linked to broader market dynamics. Construction and renovation costs have risen much faster than inflation, which has significantly slowed down demand for new buildings and renovation projects. In addition to higher interest rates and increased material costs, the decline in energy prices has also contributed to a cooling of the renovation market (Fédération Belge de la Brique asbl, 2024). Nevertheless, structural needs in the Belgian housing market remain substantial. To prevent a housing crisis driven by demographic changes—such as the growth in single-parent families, single-person households, and an ageing population—over 400,000 affordable homes must be built by 2030 (CEEP-IT interviews).

[104] https://www.zkg.de/en/artikel/latest-trends-in-the-hydrated-lime-market-4100561.html

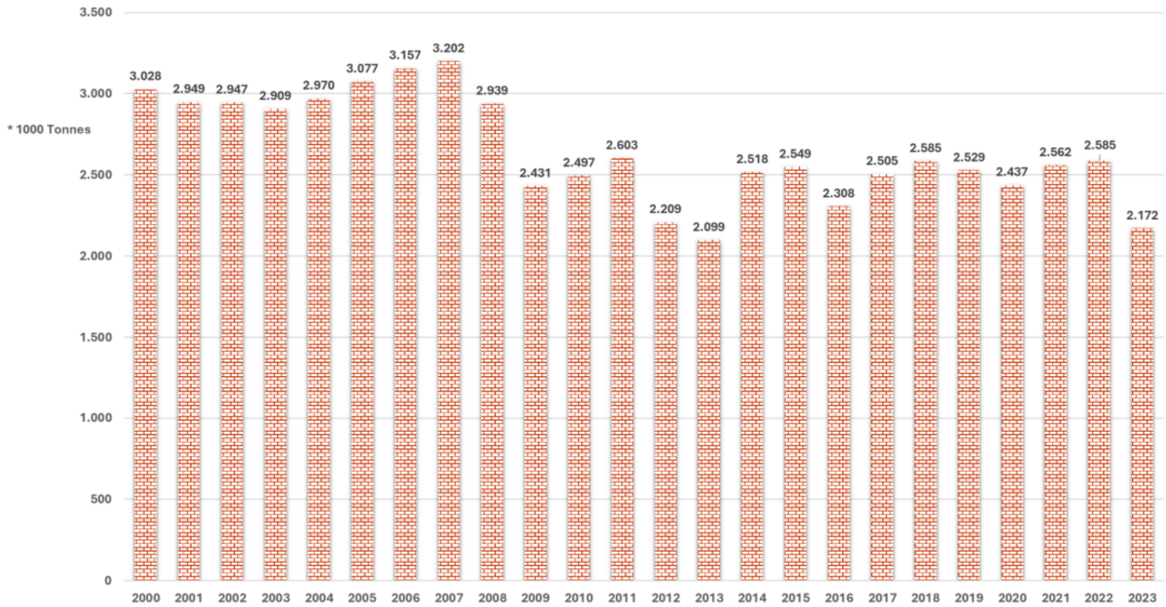

Figure 19: Total production of bricks in Belgium (Fédération Belge de la Brique asbl, 2024)

Total brick production can be split into three main types:

- Ordinary masonry bricks include both solid and perforated formats, used primarily in interior (load bearing) wall construction. In 2024, production amounted to 630,000 tons.
- Facing bricks remain the largest segment, with total production reaching 981,000 tons in 2024. This category is split between extruded facing bricks (185,000 tons) and traditional "hand-moulded" bricks, which continue to dominate with 796,000 tons.
- In line with sectoral commitments to reduce material use and environmental footprint, manufacturers have increasingly introduced narrower eco-format facing bricks alongside traditional formats. In 2024, production of eco-formats reached 1,013,719 m², confirming their consolidation as a mainstream product in the Belgian market (Fédération Belge de la Brique asbl, 2025).

The sector's emissions stem from two main sources: combustion emissions from fuel use in drying and firing, indirect emissions and process emissions from mineral decarbonation (e.g. Wyns et al., 2025). For structural blocks, process emissions account for 50–60% of total emissions, while for facing bricks they are only marginal. This makes structural products especially hard to decarbonize. Average sites produce 5–50 kt CO_2 per year, putting them above ETS thresholds, and carbon costs weigh directly on profitability. Energy price shocks, as seen during the 2021–22 energy crisis, highlighted the sensitivity of margins to fuel costs.

Total emissions in ceramics[105] (Figure 20) remained broadly stable between 2013 and 2022 but have started to decline from 2023 onwards. This downward trend reflects the contraction in new housing permits, the impact of higher mortgage rates, and the broader market pressures on construction activity.

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105 The brick industry is classified under the ceramic products sector within the EU ETS, alongside roofing tiles, porcelain, refractory bricks and related fired products.

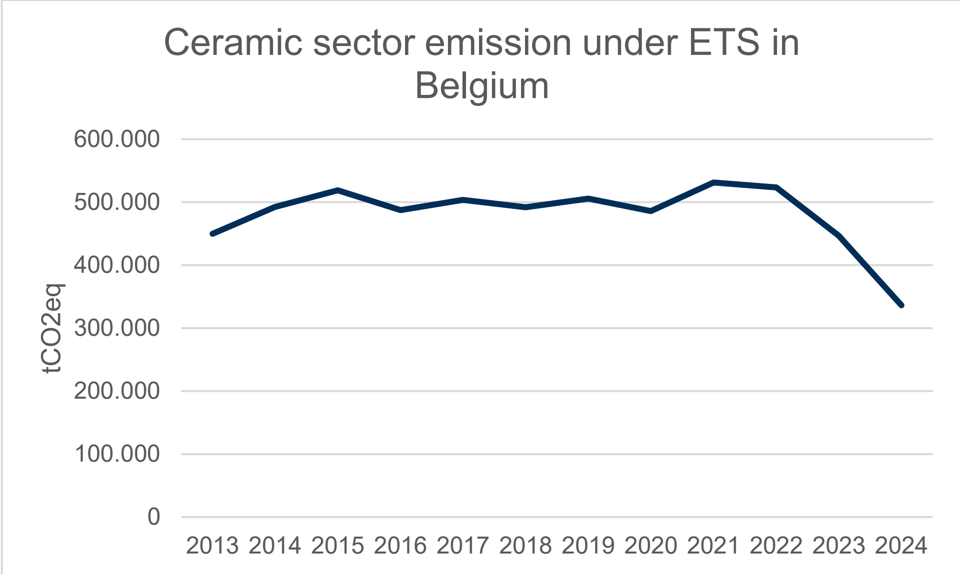

Figure 20 : Ceramic sector emission under ETS in Belgium between 2013 and 2024 (European Commission, 2025b)

3.7.1.2 Downstream markets and trade

For the brick industry, the shift from new-built to renovation presents both a challenge and a limit: renovation alone will not compensate for the persistent decline in new housing, which remains the core driver of brick demand. Unlike insulation or glass, bricks are more tied to new-build and demolition-reconstruction projects, meaning that the long-term contraction in residential permits weighs considerably on the sector's outlook. This exposure is partly offset by growing renovation demand, notably through façade insulation systems using brick slips and the replacement of facing bricks during building retrofits.

Brick exports and imports are naturally constrained by the material's weight and bulk, which make long-distance transport economically and environmentally inefficient. As a result, trade flows are concentrated primarily with neighbouring countries. In 2024, exports totalled 671,213 tons, representing 42% of total production. The United Kingdom continues to be the primary destination, followed by the Netherlands, Germany and France. Imports remain limited, amounting to 134,667 tons, or 8.4% of Belgian production (Fédération Belge de la Brique asbl, 2025).

3.7.1.3 Recent developments and challenges

In recent years, the brick sector in Belgium has begun a gradual shift towards electrification and circular-process innovation. A notable initiative is the pilot project at Wienerberger Belgium's Kortemark site, where an electric kiln and fully electric dryer were installed to produce brick slips. 25% of the electricity required is generated by an on-site photovoltaic installation, supplemented by 100% renewable grid electricity[106]. Building on the experience gained in Kortemark, Wienerberger launched the "GreenBricks" project in Austria, which represents the first industrial-scale electric kiln inaugurated in 2024[107].

106 https://www.wienerberger.com/en/media/press-releases/2022/20220211-Wienerberger-launches-first-CO2-neutral-brick-production-line.html
107 https://www.wienerberger.com/en/stories/2024/20241204-GreenBricks-Electric-Kiln-Revolutionizes-Brick-Production.html

However, several key challenges remain before full-scale electrification becomes viable for full-format brick production (e.g., 9-10 cm thick bricks) or for blocks. First, the integration of kiln-waste-heat recovery systems complicates the accounting of energy flows between dryer and kiln; this makes techno-economic assessments and system design more complex. Second, product quality demands (e.g., thermal stability, firing uniformity, dimensional stability) remain critical enablers: lighter, slip and facing-brick formats are currently more amenable to electric kiln conversion than heavy format blocks. Third, investment costs and electricity cost/availability remain significant hurdles, especially given the heavy nature of brick products and the relatively low value-density transport constraints (CEEP-IT interviews).

3.7.2 Industrial Transformation Cases

Table 15: Overview of ITCs and insights from interviews for bricks.

	ITC	Impact	Uncertainty
Carbon-neutral & circular production	Furnace electrification	**Medium** Electric kilns could significantly cut emissions if powered by renewables but would require massive quantity of electricity. No impact on the process emissions. A pilot electric kiln in Flanders has shown potential for thin products such as slips[108].	**Medium** Currently at the pilot stage, full-format bricks (9–10 cm) remain more difficult due to energy intensity and quality requirements but technologically feasible. TRL of 5-8 (Wyns et al., 2025).
	Dryer electrification	**Medium** Electric Dryer could significantly cut emissions if powered by renewables but would require massive quantity of electricity.	**Low** Electrification of the dryer is actively being explored by the sector and is already implemented in several sites. The sector expects a large deployment by 2030/2040.
	Hydrogen furnace	**Medium** Hydrogen combustion could significantly cut emissions but no impact on the process emissions.	**High** That's a long-term solution, this is still an early-stage technology. (Net Zero Associates, 2023) mentions that additional hydrogen trials would be required before a full-scale fuel switch to hydrogen, due to the challenge of meeting specific technical requirements. The sector also highlights the fact availability and accessibility of H2 can be a problem.

[108] https://www.wienerberger.com/en/media/press-releases/2022/20220211-Wienerberger-launches-first-CO2-neutral-brick-production-line.html

	Biogas furnace	**Medium** Biogas combustion could significantly cut emission but no impact on the process emissions.	**High** Uncertainty on the biogas availability.
	CCS	**Medium** High potential for large plants (and thus a limited number of sites in Belgium) to capture process emissions	**High** Highly uncertain for medium and small-sized sites (majority of sites in Belgium) because of high investment cost required and need a connexion to the CO2 network. Site dispersion and low flue gas concentrations make CCS generally impractical (Wyns et al., 2025)
	Efficiency upgrades with waste heat recovery	**Medium** The actual configuration is a coupled dryer/kiln system, where waste heat from the kiln is used to remove excess moisture from the bricks in the drying phase.	**Low** According to experts of the sector, waste heat recovery is already in place at all facilities.
	CO2 absorbing brick	**Medium** CO2-negative facing brick thanks to 100% renewable electricity and carbonation. Not intended for all applications (e.g. load-bearing performance).	**Low** Already available on the market, see Vandersanden's Pirrouet® brick[109]. Current deployments are early and limited.
	Eco-format bricks	**Medium** These eco-format bricks can offer a 30% reduction in weight for the same output in m². This reduced the amount of raw material required but also the energy needed for production. Unfortunately, these thinner bricks do not represent a 30% energy saving as well because some constraints in stacking in the kiln and airflow do not allow to have 30% more product per kiln load.	**Medium** Current brick formats (9 à 10 cm) are the result of a long tradition in the construction sector, but they are not technically needed. The width can be reduced by 2 à 3 cm and still perfectly fulfil technical requirements. However, the sector is facing limited market acceptance with adoption rates close to 10% or less. This is even more difficult for the export markets in the neighbouring countries.

[109] https://www.vandersanden.com/en-uk/pirrouet

	Circular economy - recycling	**Low** Use of recycled aggregates from demolished masonry reduces raw material extraction (sand). The energy required for recycling bricks in aggregates is about the same order of magnitude than the energy needed for the extraction of raw materials. Also, bricks with recycled content may show inconsistent strength and appearance, limiting their potential[110] given that technical and aesthetic quality check is a must for all new products.	**Medium** Brick recycling faces several uncertainties related to process efficiency and secondary raw material quality. Masonry waste may contain contaminants (e.g. plaster, mortar) that hinder recycling in 'clean' ceramic aggregates. Economic feasibility also remains uncertain due to high labour and processing costs, compared to primary raw materials. Experts from the sector point out that most end-of-life bricks are recycled as backfill material, not reinserted into the production process[Error! Bookmark not defined.].
	Circular economy – urban mining and reuse	**Medium** Selective deconstruction and reuse of intact bricks can substantially lower embodied emissions by avoiding new clay extraction and emission from brick production.	**Medium** The reuse of bricks faces several uncertainties related to process efficiency and material quality. The removal of mortar is labour-intensive and technically challenging, while masonry waste often contains contaminants (e.g. plaster, paint) that hinder the reuse. Economic feasibility also remains uncertain due to high labour and processing costs, compared to new bricks. According to the sector's experts, the reuse of bricks remains a niche market, representing approximately 2% of material recovery. Knoth et al. (2022) highlight some important barriers for the reuse of construction products: the way buildings are designed and constructed rarely considers deconstructible systems, legal and economic frameworks require modifications and the lack of available information and collaboration and exchange in the value chain for reused building materials, especially towards production and manufacturing industries, architects and construction companies.

110 https://www.azobuild.com/article.aspx?ArticleID=8123&

	Use of industrial by-products and end-of-waste materials	**Medium** Partial clay substitution with end-of-waste materials reduces embodied carbon; industrial symbiosis potential	**Medium** In the brick industry in Belgium end-of-waste materials and by-products are used (see inventory[111]). Uncertainty regarding future availability of these by-products.
Downstream market developments	Changes in the brick consumption	**Medium** A potential change of brick demand could translate to a decline of production with potentially significant impact on the energy-economy system.	**Medium** The future of the Belgian brick sector is uncertain. Without stronger incentives for demolition–reconstruction, brick demand may remain subdued, and long-term trends such as stricter embodied-carbon rules or competition from low-carbon alternatives could lead to a decline. Yet several dynamics pull in the opposite direction. Demographic growth implies a continued need for new housing (about 400.000 new residential units according to Embuild[112]), and the renovation wave could increase cases where demolition–reconstruction becomes the most effective option. Bricks (including low-carbon bricks, eco-bricks or brick slips used on insulation) can play a role in the energy transition. Keeping local production of bricks will remain a major advantage as production is not at risk of geopolitical influencing factors.
	Raw Clay Blocks (Unfired Bricks)	**Low** These blocks are not fired, which avoid emissions but they require additional binder and their use is limited to niche applications (e.g., interior non-load-bearing walls).	**Medium** They have lower mechanical performance, particularly in terms of load-bearing capacity and acoustic performance. They cannot currently meet regulatory standards.

[111] https://www.omgeving.vlaanderen.be/nl/monitoringsysteem-duurzaam-oppervlaktedelfstoffenbeleid-mdo

[112] https://embuild.be/fr/la-construction-sous-pression-le-nombre-d%E2%80%99entreprises-stagne#:~:text=Niko%20Demeester%2C%20CEO%20d'Embuild,Actualit%C3%A9s

Industrial relocation	Some relocation outside EU	**High** Could have a structural impact on production geography and carbon leakage risks rather than direct emission reductions. Relocation outside EU would increase the total amount of emissions due to transport to Belgium and the production in countries where best available technologies are maybe not applied.	**High** Relocation outside EU is unlikely to happen because of heavy/low-value product. The brick sector is a local market. This is also due to the availability of raw materials.
	Some regional relocation intra EU in neighbouring countries	**Medium** Impacts on the economy and energy system if some industries are leaving Belgium for neighbouring countries. Relocation in (neighbouring) EU countries would increase the total amount of emissions due to transport to Belgium.	**Medium** SMEs tied to local clay so massive relocation is not viable but regional relocation within the EU might emerge with varying electricity price and labour cost. Transporting raw materials over 150 km is generally avoided due to the high environmental impact and logistical and economic inefficiency.

3.7.2.1 Climate neutral and circular production

Various options are available for climate-neutral production (e.g. Wyns et al., 2025) and incremental progress is already underway. Among our selection of ITCs (Table 15), waste heat recovery from kilns is standard practice, and electrification of dryers is advancing. A pilot electric kiln in Flanders has shown potential for thin products such as slips, but full-format bricks (9–10 cm) and blocks remain far more difficult due to energy intensity and quality requirements.

Future energy options remain open: biogas is technically compatible, hydrogen is not a near-term option given infrastructure distance, and green electricity could gradually substitute fossil fuels. Yet none of these pathways fully address process CO_2, which remains the structural obstacle to climate neutrality, mainly for blocks.

The sector cannot rely on a single solution. A realistic pathway, according to sector experts, involves:

- **By 2030/2040:** broad deployment of electric dryers, selective pilots of electric kilns for thin products, and wider adoption of eco-formats to reduce material intensity. Transitional use of biogas and green electricity certificates will be essential to contain ETS costs.
- **By 2040:** partial electrification of kilns where feasible, cluster-based trials of carbon capture and utilization/storage (CCUS) at larger sites, and scaling of reuse channels supported by regulatory frameworks and certification.
- **By 2050:** either widespread adoption of CCUS for structural brick plants, alternative raw materials (low(er) process emissions) keeping the same structural and acoustic performance.

The sector's ability to follow this trajectory will depend less on technology, which is gradually becoming available, than on coherent policy alignment, financing support for pilot projects, and a demand-side framework that accepts higher-cost for low-carbon bricks. As with the construction sector overall, the challenge will be balancing ambition with affordability: if building costs rise too sharply, demand risks collapsing before the transition can take root.

The sector is pursuing eco-design by reducing material thickness, particularly for facing bricks. Belgium is ahead of its neighbours in requiring eco-formats for all new products, with up to 30% weight reduction possible for equivalent wall surface coverage. However, thinner bricks do not deliver proportional energy savings, as kiln stacking and airflow constraints limit load efficiency. Recycling and reuse remain marginal (≈2% of recovered material) and at the end-of-life, bricks are generally downcycled into backfill rather than reincorporated into production.

3.7.2.2 Downstream market developments

The outlook for the Belgian brick sector is neither purely negative nor clearly optimistic. On the one hand, limited incentives for demolition–reconstruction and rising pressure to reduce embodied carbon could constrain future brick demand, especially if low-carbon alternative materials are gaining market share. On the other hand, demographic projections still indicate a substantial need for new housing, and the renovation wave to achieve new EPB requirements will request a higher rate of demolition-reconstruction. The role of bricks in the Belgian (energy) transition of the building sector can be multifaceted: eco-bricks or brick slips on thermal insulation and new facing bricks in insulated external walls. These mixed signals suggest that the sector is entering a transition. Local production, supply security and familiarity within the Belgian market remain strong assets, but sustained demand will hinge on the sector's ability to align with evolving regulatory, environmental and architectural expectations.

Alternative products, such as unfired raw clay blocks, remain limited to non-structural or experimental applications due to performance constraints.

3.7.2.3 Industrial relocation

Relocation of brick production outside the EU would have a high systemic impact on production geography and carbon leakage risks, but remains highly unlikely due to the heavy, low-value nature of bricks and their dependence on local markets. Regional relocation within the EU, especially to neighbouring countries, is less unlikely to happen. While such moves could influence the Belgian economy and energy system, massive relocation is not viable given the sector's reliance on locally sourced clay and the high environmental and economic costs of transporting raw materials over long distances. Nonetheless, limited intra-EU relocation could emerge in response to differences in electricity prices and labour costs across countries.

3.8 Glass

The strong dependency of the glass industry on natural gas (NG) emphasises the need for low-emission alternatives. The glass sector is divided into many federations in Europe, depending on the glass type. We can cite the FEVE (the European Container Glass Federation)[113], Glass for Europe (the European flat glass federation)[114], the APFE (European Glass Fibre Manufacturers)[115]. These three federations outline the progress in the decarbonisation of plants across Europe, through ecodesign, recycling, breakthrough furnaces and renewable energy, which will be developed in this section.

113 https://feve.org/
114 https://glassforeurope.com/
115 https://glassfibreeurope.eu/

3.8.1 Current glass production landscape

3.8.1.1 Production in Belgium

The glass industry in Belgium is diverse, producing several categories of glass that serve different markets and functions (Zier et al., 2021):

- **Flat Glass** – Manufactured mainly through the float process, its value lies in optical clarity, uniform thickness, and mechanical strength.
- **Container Glass (Hollow Glass)** – This segment is characterised by its recyclability, chemical resistance, and durability.
- **Glass Fibre** – Produced by drawing molten glass into thin filaments, glass fibre offers strength, lightweight properties, and thermal resistance.

Table 16: Existing glass types and applications.

Glass type	Application
Flat	Windows, façades, automotive glazing, and solar panels.
Hollow	Bottles & Jars, flacon in food or pharmaceutical sectors
Fibres	Insulation materials, composites for wind turbines, automotive parts and electronics.
Special	Laboratory glassware, electronics, optics, etc.

Among the different glass types and applications (Table 14), flat glass was the dominant segment in Belgium (notably AGC and Saint-Gobain). Until 2014, 75% of production (in ton) was flat glass, with the rest evenly split between container glass and other types. In 2014, total glass production reached 1.6 million tons. After 2014 (following the closure of Saint-Gobain), the distribution changed while total annual glass production remained similar (around 1.5 million tonnes in 2022). Flat glass then accounted for roughly 60%, container glass 15–20%, and glass fibre increased its share (CEEP-IT interviews).

The current glass production process is well described in (Wyns et al., 2025). All glass production begins with a mixture of raw materials—mainly silica sand, soda ash, limestone, and recycled glass (cullet). Adding cullet reduces energy consumption and CO_2 emissions, since recycled glass melts more easily than raw minerals. The critical stage common to both flat glass, container glass and fibre glass is melting. Raw materials are heated in furnaces at 1200–1600°C until they form a homogeneous molten glass. This process is highly energy-intensive, accounting for up to 50–95% of total energy use in a glass plant, and relies predominantly on natural gas, though electrification and hybrid technologies are emerging. Around 25% of the sector's emissions are process emissions (from raw materials carbonates) and the rest of the emissions come from the combustion of natural gas in the furnace (Wyns et al., 2025).

From this shared melting stage, three main glass sectors diverge:

- Flat Glass (Glass for Europe, 2020)

Flat glass is produced almost exclusively using the float process, where molten glass is poured onto a bath of molten tin. The glass floats and spreads evenly, forming a perfectly flat ribbon. It is then gradually cooled and annealed before cutting into sheets for applications in buildings, vehicles, and solar panels. Flat glass requires extreme precision: high optical quality and transparency are essential.

- Container Glass (FEVE, 2024)

Container glass is shaped into bottles, jars, and other hollow products. After melting, the glass passes through feeders that cut it into gobs, which are then molded using blow-and-blow or press-and-blow techniques. The containers are cooled in annealing ovens to remove internal stresses, and then often treated for surface strength and inspected. Container glass can incorporate much higher cullet rates—sometimes exceeding 70–80%—making recycling central to its decarbonisation strategy.

- Fibre Glass[116]

Glass fibre manufacturing is a continuous industrial process, whereby the furnace runs without interruption for seven to ten years. The molten glass is extruded through a bushing into filaments, the filaments are cooled with water and a chemical sizing is applied before final fabrication. The continuous filament glass fibres products include glass fibre reinforcements (i.e. chopped strand, rovings and mat / veil) and yarns.

3.8.1.2 Downstream markets and trade

With flat glass being a dominant segment, main downstream sectors are construction, automotive and energy. Exports are primarily to neighbouring countries, with only a small portion going beyond Europe (inDUfed, 2024a). This means that the Belgian market is more influenced by the European context than by international factors. For reasons of market competition, data such as the share of Belgian glass production that is used in Belgium vs the share that is exported are not published.

The main clients in the sector are European: Germany leads, followed by France, the Netherlands, the United Kingdom, and Italy. These five countries alone account for 70% of Belgium's foreign sales, with the European Union representing 85% overall. Similarly, Belgium's main competitors are German, followed by Dutch, French, and other European firms. Regarding insulating glass, the Netherlands is by far the largest client, accounting for 80% of Belgian exports in 2024 (inDUfed, 2024a). Nevertheless, Belgium is not particularly competitive in terms of industrial support (labour costs, investment aid, energy prices, etc.). In a context of overcapacity, this creates complications and risks (CEEP-IT interviews).

3.8.1.3 Recent developments and challenges

In recent years, the Belgian glass sector has implemented various measures to reduce CO_2 emissions, particularly within the framework of the 2014–2023 branch agreement[117]. This agreement enabled significant progress in energy efficiency and decarbonization.

Container Glass

- Partial furnace electrification: Pilot projects have integrated electricity into glass melting processes, reducing reliance on fossil fuels.
- Ecodesign: efforts were made to make thinner container glass without compromising product quality.

Flat Glass

- Partial furnace electrification: Pilot projects have integrated electricity into glass melting processes, reducing reliance on fossil fuels.

[116] https://glassfibreeurope.eu/our-industry-products/#the-manufacturing-process
[117] https://energie.wallonie.be/fr/les-accords-2014-2020-2023.html?IDC=7863

- Emission reduction efforts: Improvements in the energy efficiency of existing installations have contributed to lowering CO_2 emissions.

Technical Glass (automotive, electronics)

- Process optimization: Measures to improve energy efficiency in manufacturing processes have helped reduce CO_2 emissions.

Cross-Cutting Initiatives

- Electrical boosting: Tests have increased the electrical input in furnaces to improve energy efficiency without compromising product quality.
- Increased cullet usage: Using more recycled glass reduces energy consumption and associated emissions.
- Renewable energy: By 2023, 10 GWh of renewable electricity was produced under branch agreement (therefore only in Wallonia), contributing directly to CO_2 reduction.
- Carbon capture and storage (CCS): Feasibility studies are ongoing to integrate CCS in suitable furnaces, with large-scale implementation expected in the future.

Particularly, FEVE (2024) specifies that manufacturers are redesigning containers to be lighter, stronger, and made with alternative raw materials, while also optimising collection and sorting technologies. Transport systems are being streamlined with shorter supply chains and low-carbon logistics options such as rail, multimodal systems, and alternative-fuel vehicles. In the flat glass subsector, major investments have already been done across Europe in terms of furnace design and energy mix. Efforts are made in recycling more flat glass and pre-demolition audits.

In line with the above developments, emissions (Figure 21) have declined significantly from around 1.3–1.4 $MtCO_2eq$ in 2005 to just above 0.5 $MtCO_2eq$ in 2024. This represents a reduction of more than 50% over two decades, showing the effectiveness of efficiency measures, recycling (cullet use), fuel switching, and other decarbonisation initiatives in the Belgian glass sector. But still, the Saint-Gobain Glass Group shut down its last furnace in 2013. This is reflected in the figure, where one can see a decline in CO_2 emissions between 2011 and 2014. The closure of this major facility clearly contributed to the significant reduction in emissions in the Belgian glass sector during that period.

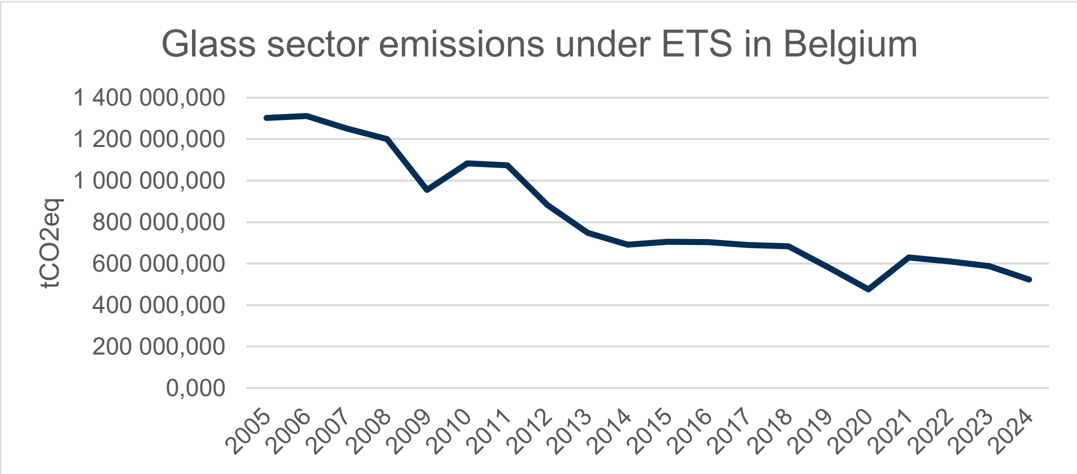

Figure 21 : ETS emissions in the glass sector in Belgium. Source : European Commission, 2025.

To accelerate progress, the industries are calling on public authorities and customers to create enabling conditions, including access to clean, reliable energy, stronger glass collection systems and removal of recycling barriers, as well as targeted financing—such as R&D support, infrastructure investment, and compensation under the EU ETS. These measures are crucial to enable breakthrough technologies, sustain the transition, and maintain EU competitiveness while securing domestic glass production. Additionally, politics needs to make carbon-avoiding products mainstream.

3.8.2 Industrial Transformation Cases

Table 17 lists various ITCs, discussed with the glass sector in Belgium.

Table 17: Overview of ITCs for glass

	Glass Type	ITC	Impact	Uncertainty
Carbon-neutral & circular production	Flat	Hybrid furnace combining electrofusion and oxygen-gas combustion (50-50)	**Medium** This could cut emission because half of the energy would come from electricity but need to be powered by renewables and would require more electricity.	**Medium** Electrification of furnaces is promising but faces technical and durability barriers. There are no 100% electric furnaces in Europe because there is still a lot of uncertainty for the glass quality and furnace lifetime. The Volta project in the Czech Republic, which started operations in February 2025, is a pilot hybrid furnace operating at 100 tonnes per day and producing printed glass for shower doors. It combines 50% electrification with oxy-gas combustion and aims to serve as a proof of concept before scaling to larger furnaces.
	Container	Hybrid furnace combining electrofusion and oxygen-gas combustion (70-30)	**High** This could cut emission because half of the energy would come from electricity but need to be powered by renewables and would require more electricity.	**Low** Electrification of furnaces is promising but faces technical and durability barriers. There are no 100% electric furnaces in Europe because there is still a lot of uncertainty for the glass quality and furnace lifetime. Electrification is easier for container glass furnaces.

	All	Hydrogen furnaces	**High** Could drastically cut emissions if powered by green hydrogen.	**High** Hydrogen combustion is not the main decarbonization pathway selected by the sector in Belgium. It is not out of the table but hydrogen combustion creates water vapor that will impact the refractories. The TRL is still low (3-4) (Wyns et al., 2025)
	All	Increase of cullet shares in the production	**High** Circularity is a key decarbonization pillar. Adding cullet reduces melting temperature, lowering both natural gas use and CO_2 from raw materials.	**Medium** One of the challenges is ensuring sufficient cullet supply with the right quality.
	All	Carbon capture and storage	**High** The glass industry views CCS as important to achieving net-zero because of process emissions.	**High** Currently, only three furnaces in Europe, including one in Belgium, are well placed for their proximity to future CO_2 transport networks, underscoring the importance of timely infrastructure development.
Downstream market developments	Flat and fibre	The demand of flat and fibre glass increases	**Medium** Can have a non-negligeable impact since some industries are producing flat glass for windows replacement and also fibre glass for insulation.	**Low** Energy renovation targets are expected to drive demand for flat and fibre glass used in buildings.
	Container	The Directive on single use plastic increases the demand in container glass.	**Low** For packaging, Belgium's container glass production is not affected by plastic reduction efforts. Indeed, there are only two container glass plants in the country: one serves the luxury spirits market, while the other focuses more on perfume and cosmetics.	**Low** Unless a new production unit is set up, we do not produce container glass for packaging in Belgium.
	Container	Eco-design of bottles	**Medium** Reduces the amount of raw material needed per unit, thereby lowering energy and raw material consumption per product.	**High** The level of adoption remains uncertain.

Relocation	All	Intra-European relocation of glass production	**High** Structural impact on production geography and energy consumption.	**Medium** Glass is rarely traded over long distances, but high prices of electricity and labour could lead to some relocation. However, glassmaking remains a highly capital-intensive and specialized industry; for instance, AGC's Belgian plant is the only one in the world producing a specific type of automotive glass, serving a global market.

3.8.2.1 Climate neutral and circular production

The glass industry faces a similarly complex landscape of decarbonisation options as heavy industries like steel. Recent reviews (Bataille et al., 2018), (Zier et al., 2021), (Salman et al., 2025) and (Wyns et al., 2025) identify key approaches such as electrification, fuel switching (hydrogen / biofuels / oxy-fuel), CCUS, waste heat recovery, and deeper use of recycled glass (cullet).

Electrification of glass furnaces is increasingly recognised as one of the most promising routes to reduce process emissions, although several technical and durability challenges remain. Small fully electric furnaces already exist, but their performance is still limited, particularly due to lower glass quality resulting from bubble formation and degassing issues. A typical industrial furnace operates at around 50 MW of installed capacity, and different strategies are being tested to increase the share of electricity in the energy mix. Electroboosting, which adds roughly 3 MW of electricity via electrodes, has shown no significant impact on furnace lifetime if properly managed. Superboosting, currently under evaluation through the Eco² consortium in Wallonia, has tested up to 7 MW of additional input, reaching a total of 10 MW, although the long-term effect on furnace lifetime remains to be fully assessed. In parallel, hybrid furnaces are emerging as a key transitional solution. In the longer term, hybrid solutions are expected to achieve between 50 and 70% electrification. Fully electric large-scale furnaces, however, are still limited by shorter lifetimes, which remains a significant obstacle to wider deployment.

Alongside electrification, circularity represents an essential pillar of decarbonisation in the sector. Increasing the share of cullet—recycled glass—directly reduces energy consumption, since cullet melts at lower temperatures than virgin raw materials, while also cutting process emissions from carbonate decomposition. This dual effect makes circularity one of the most immediate and reliable levers to lower emissions across all glass segments. Glass is an endlessly recyclable material. In 2023 in Belgium, 92% of glass packaging on the market is collected for recycling (FEVE, 2023). A concrete example is provided by AGC through its "Recycle Glass" service, dedicated to collecting flat glass waste from industrial offcuts and deconstruction projects, including end-of-life glazing from both commercial and residential buildings. This glass waste is processed by a network of specialised partners to produce high-quality cullet suitable for circular recycling, thus avoiding both landfilling and the "downcycling" of material quality. Building on this approach, AGC Energypane, based in Hannut, Belgium, has launched a pilot project for the recovery of end-of-life insulating glazing units. The collected materials are remelted and reintegrated into new production cycles, contributing to AGC Glass Europe's ambition of reducing carbon emissions and expanding the production of low-carbon glass under its "AGC Low-Carbon Glass" initiative (AGC, 2025).

Another major component of the industry's decarbonisation strategy lies in addressing Scope 2 emissions, which account for roughly 10% of the sector's carbon footprint. The glass industry is actively pursuing onsite and offsite power purchase agreements and securing Guarantees of Origin to ensure that electricity demand is met by renewable sources. The goal is to achieve 100% renewable electricity by 2030. Progress has already been significant, with emissions reduced by 30% compared to the 2019 baseline. Renewable electricity alone is expected to deliver nearly one-third of the targeted reductions by 2030, highlighting the importance of decarbonising electricity supply for the sector.

Carbon Capture and Storage (CCS) is also being actively studied as a large-scale solution, especially for process emissions that cannot be abated through electrification or circularity. At present, only three furnaces in Europe, including one located in Belgium, are geographically well-positioned near planned CO_2 transport networks, making them suitable for integration with CCS technologies. The success of this pathway will depend heavily on the timely deployment of European CO_2 transport and storage infrastructure. Nevertheless, CCS is widely regarded as essential if the glass industry is to achieve net-zero emissions in the coming decades.

Other decarbonisation options, such as hydrogen and biomethane, are considered more distant or supplementary rather than priority solutions. Hydrogen combustion, for example, presents several technical barriers: the production of water vapour leads to foam formation in molten glass and hampers heat transfer, while also altering the colour of the final product by imparting a bluish tint. It further requires specially designed refractories to withstand the altered flame and atmosphere conditions. Beyond these technical constraints, hydrogen remains the most expensive decarbonisation pathway, with marginal abatement costs far higher than other options. Biomethane is also recognised, but its limited availability and high costs prevent it from being a central component of current decarbonisation strategies. Decarbonisation strategies in the glass industry must be tailored to each production site, as local conditions play a decisive role in determining feasible solutions. Electricity grid capacity, for instance, varies significantly across regions, with Belgium facing particular constraints that limit the potential for rapid electrification. Similarly, access to CO_2 transport and storage infrastructure differs from site to site, directly influencing the viability of carbon capture solutions. These disparities mean that each facility requires a customised decarbonisation "toolkit," and the associated costs can fluctuate widely depending on local infrastructure and energy availability.

3.8.2.2 Downstream market developments

For future demand, inDUfed expects production levels to remain similar to those of 2022, as the slight decline observed in 2023 and 2024 is anticipated to be offset in the coming years. Glass production in Belgium is expected to remain stable through 2030, with no plans for furnace shutdowns or construction of new large-scale furnaces in the country.

Demand is expected to remain steady, supported in part by energy renovation in the building sector, which sustains the use of both glazing and glass fibre. In packaging, Belgium's container glass production is relatively insulated from plastic reduction policies, as the country hosts only two specialised plants: one serving the niche luxury spirits market and the other supplying perfume and cosmetics brands. External shocks such as the COVID-19 pandemic and foreign trade tariffs have had a greater impact, though most of the sector's output continues to serve European markets.

Despite this resilience, there is currently no established market for low-emission glass. The higher cost of green electricity and decarbonised gas, combined with the absence of a legal framework to incentivise sustainable products, has limited production capacity. While it is technically possible to trace and certify "green" batches of glass, sites are calling for recognition and valorisation of these decarbonisation efforts to make low-carbon glass a viable market segment.

3.8.2.3 Industrial relocation

The glass sector is firmly established in Belgium, with most raw materials, such as sand from local quarries, sourced domestically. In container glass, both supply and recycling loops largely operate within the European market, particularly within Belgium, complemented by some imports from neighbouring countries to secure recycled glass. Because glass is rarely traded over long distances, measures like the Carbon Border Adjustment Mechanism (CBAM) could generate unintended impacts. Glass processors are especially exposed, as a large share of glazing products is imported from Eastern Europe. Manufacturers, by contrast, are dominated by major groups such as AGC, which also operates sites in northern France, creating intra-European competition. While relocating production within Belgium may be feasible, replicating such moves across the EU would be far more challenging. The sector has ruled out any relocation of its Belgian operations, underlining the long-term stability of its domestic production base[118] .

3.9 Paper, pulp & printing

The Belgian paper industry, like the European sector at large, is deeply integrated into international markets, with substantial import and export flows. This is due to the high specialization of the sector, capital-intensive technologies for production and long investment cycles[119]. The pulp and paper sector accounts for approximately 2% of industrial CO_2 emissions in Belgium and around 0.8 % of total CO_2 emissions in Europe (Wyns et al., 2025). In Belgium, the sector is represented by the federation inDUfed[120], while at the European level, it is represented by the Confederation of European Paper Industries (Cepi)[121].

3.9.1 Current paper production landscape

3.9.1.1 Production in Belgium

The pulp and paper industry can be divided into three main stages: pulp production, paper manufacturing, and finishing. Belgium has six pulp and paper producers, all members of inDUfed, with three sites located in Flanders and three in Wallonia. Two of the Flemish sites and one Walloon site are integrated facilities, producing both pulp and paper on the same site. The remaining producers operate paper machines using imported pulp, sourced either domestically or internationally (CEEP-IT interviews) . The installed capacity in Belgium could absorb a slight increase in production but could not absorb a 50% increase without the installation of new production lines (CEEP-IT interviews). A similar observation can be made at the European level, where pulp production has operated between 81% and 93% of its full capacity over the past 30 years (Confederation of European Paper Industries, 2025).

Pulp production itself can be categorized into chemical, mechanical, and recycled pulps as follows (Cobelpa, 2012):

- Chemical pulp is produced by cooking wood chips in an alkaline (sulfate) solution to remove lignin, leaving mainly cellulose fibres, with a mass yield of approximately 50%. During the Kraft process, lignin is dissolved into a by-product known as black liquor. The black liquor is then burned in a recovery boiler, allowing both energy recovery (they generate high-pressure steam

[118] https://www.agc-glass.eu/fr/news/sustainability/recuperation-des-vitrages-en-fin-de-vie-chez-agc-energypane
[119] https://single-market-economy.ec.europa.eu/sectors/raw-materials/related-industries/forest-based-industries/pulp-and-paper-industry_en
[120] https://www.indufed.be/fr/
[121] https://www.cepi.org/

that is first used for electricity production and then as process heat across the mill) and chemical reuse.
Chemical pulp is primarily used for high-quality, long-life papers, such as book paper, notebooks, and durable packaging materials, due to its high fiber purity and strength.

- Mechanical pulp is produced by grinding or refining wood to separate fibers without removing lignin, with a much higher mass yield of around 95%. Mechanical pulps are used for short-lived paper products such as magazines, catalogues, and newsprints. The presence of lignin, however, causes the paper to yellow and become brittle over time, limiting its use to non-durable applications.
- Recycled pulp is made by reprocessing recovered paper. The fibers are re-suspended in water, with repeated washing or screening steps to remove fibers that are too short to be reused effectively. For graphic or sanitary papers, a de-inking stage is usually required, which is typically done by flotation, where air bubbles lift ink particles out of the pulp. Recycled pulp is mainly used to produce newsprint, office papers, tissues, and packaging papers, depending on the fiber quality and the number of times the fibers have been reused.

The pulp production phase accounts for some 50%-60% of the energy consumption (Correa Laguna et al., 2023; Wyns et al., 2025), with the remainder for paper manufacturing, and finishing. Biomass and biofuels represent the highest share in consumption (50%), alongside natural gas (24%), electricity[122] (16%), and other fuels (10%) (CEEP-IT interviews). There are various future options for changing this energy consumption mix, depending on the type of mill (integrated or not) and the type of pulp produced (Figure 22).

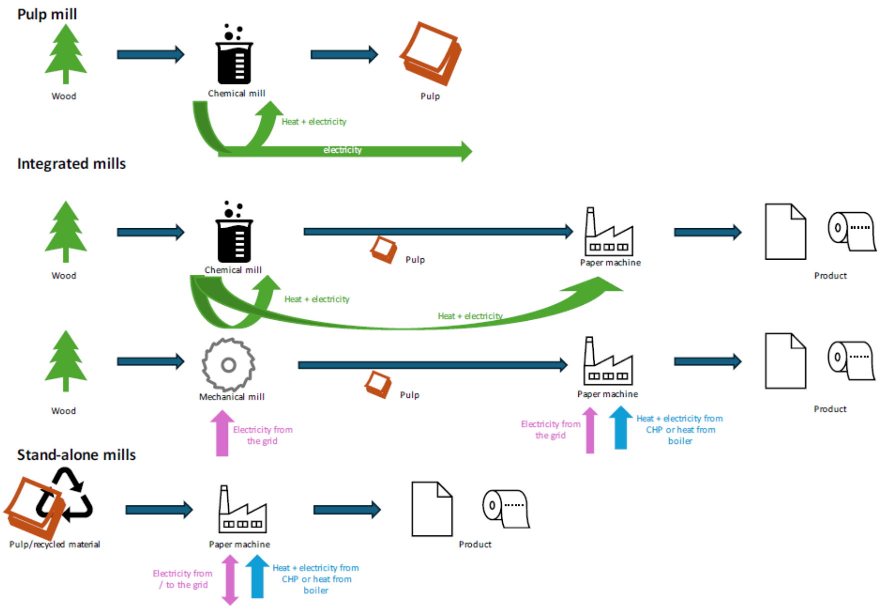

Figure 22: Energy consumption outlook depending on a mill type (Cepi, 2025a)

The recycling rate in Belgium reached 86% for paper and cardboard in 2022[123], which is relatively high compared to 75% for Europe in 2024 and 62% globally in 2023 (European Paper Recycling Council

[122] Specifically for total electricity consumption, 41% is purchased, 30% is self-produced from biomass/biofuels in cogeneration units and 30% is self-produced from other fuels in cogeneration units (waste and fossil fuels).
[123] https://statbel.fgov.be/fr/themes/environnement/dechets-et-pollution/dechets-demballages

(EPRC), 2024). Two-thirds of the fibers used originate from recovered paper (Cobelpa, 2012) as confirmed by CEEP-IT interviews.

Nonetheless, there are several limitations to (further) recycling. First, not all paper products are recyclable, for instance, contaminated paper or sanitary paper are excluded. Moreover, wood fibers degrade each time they undergo the recycling process (Cobelpa, 2012) with declining paper strength and fiber yield with each cycle (Jirarotepinyo et al., 2025; van Ewijk et al., 2020). Furthermore, recycled paper is not suitable for certain applications, such as food packaging in which the paper comes into direct contact with food. In such cases, a layer of virgin fibres is often required to ensure food safety (CEEP-IT interviews). Van Ewijk et al. (2020) also warn that energy requirements could be higher for recycling than for virgin paper production as it lacks the intrinsic use of the renewable by-product (black liquor) virgin paper production benefits from, and note that the growing global demand for materials exceeds the waste available from past consumption.

3.9.1.2 Downstream markets and trade

The evolution of paper and board consumption in Europe[124] is illustrated in Figure 23. The consumption of paper and board for packaging and tissue products has increased since 1991, while consumption of graphic paper (newsprint, printing, and writing paper) has declined roughly from the year 2000 onwards. This European trend is also observed in Belgium, where the decline in graphic paper is linked to digitalisation, while the demand for paper-based packaging has increased as plastic packaging use has decreased (CEEP-IT interviews). The digital transition, expansion of e-commerce, the reduction in plastic use in packaging are generally considered main drivers of future paper demand (ADEME, 2024).

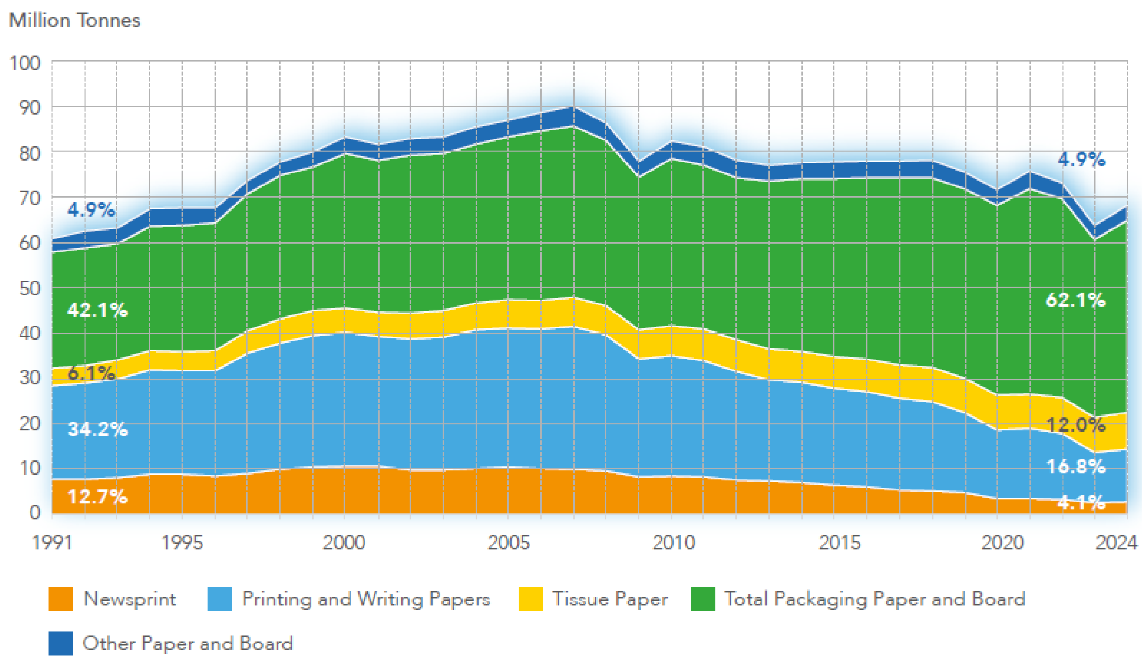

Figure 23: Evolution of the consumption of paper and board in Cepi EU countries (Confederation of European Paper Industries, 2025)

The Belgian and European paper industry are deeply integrated into international markets, with high specialization, capital-intensive technologies and long investment cycles. A single paper machine can

[124] Data presented cover European countries represented by Cepi, accounting for over 75% of paper and board consumption in Europe.

produce up to 400,000 tonnes per year of a single grade of paper, which typically exceeds domestic demand for Belgium. This trend is also evident at the European level, where the number of pulp mills has continuously decreased since 1991 (from some 300 to 120 mills) while production levels in 1991 and 2024 are almost identical (Confederation of European Paper Industries, 2025). As a result, significant volumes of paper and board are exported and imported to meet specific product needs (CEEP-IT interviews). The majority (~80%) of Belgium's pulp, paper, and board production is exported (inDUfed, 2024b), mainly to France, The Netherlands and Germany[125] (Figure 24). It is difficult to obtain more detailed figures on the breakdown between different product categories due to competitiveness constraints in Belgium (CEEP-IT interviews). Taken together, European Cepi countries have historically been a net importer of pulp, and a net exporter for finished paper and board products[126] (Confederation of European Paper Industries, 2025).

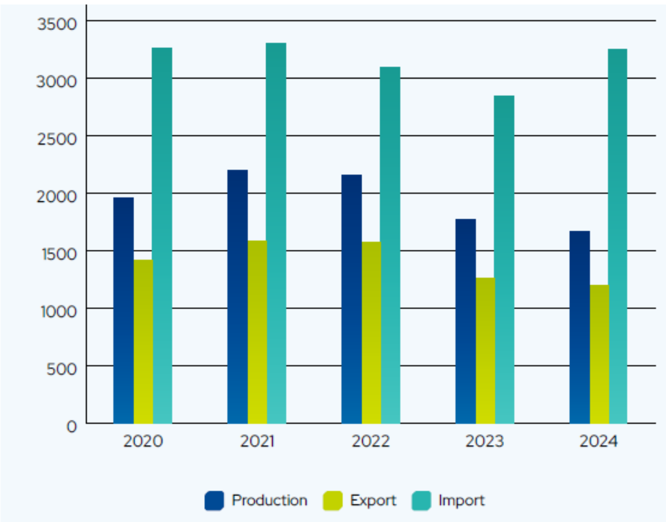

Figure 24: Production, export and import of pulp, paper and board for Belgium in kton (inDUfed, 2024b)

3.9.1.3 Recent developments and challenges

Recently, the Sappi paper mill in Lanaken (Limburg) stopped production in March 2024. While the company referred to an increasingly tense market and a strategic shift in its European operations[127]., the closure also reflects broader structural pressures faced by the graphic paper segment. Lanaken was specialised in graphic papers, a market that has been structurally declining for more than a decade due to digitalisation and shrinking demand.

This underlines that the difficulties observed in 2023, driven by high energy prices, eroding competitiveness compared to neighbouring countries, and weak consumer demand, persisted and even slightly intensified in 2024. The recurring weak performance signals deeper structural issues: Belgian paper and board manufacturers, especially those oriented towards export markets, face increasing competitiveness challenges in a context of shrinking European demand (inDUfed, 2024a).

In Belgium, a notable example of decarbonization is the Stora Enso Langerbrugge paper mill in Ghent, which is equipped with two biomass cogeneration units supplying 100% of the steam required for

[125] https://www.indexbox.io/store/belgium-paper-and-paperboard-market-analysis-forecast-size-trends-and-insights/

[126] Pulp: 8.2 million tonnes imported and 6.4 million tonnes exported. Finished paper and board products: 5.2 million tonnes imported and 15.8 million tonnes exported. Figures for the year 2024.

[127] https://www.lemaitrepapetier.ca/nouvelles/internationales/sappi-se-separe-de-son-site-historique-de-lanaken.html

production, as well as three wind turbines that enable approximately 75% self-sufficiency in electricity consumption[128]. In 2016, the site also inaugurated a 4 km pipeline connecting the mill to the Volvo Cars plant, allowing hot water at 125°C to be transferred from Stora Enso's mill to heat buildings and paint booths at the Volvo Cars facility[129]. This resonates with similar low-carbon innovation initiatives in Europe, covering renewable electricity via PV or wind, circularity, renewable fuels, demand-side flexibility and new types of packaging, see Box 2 (Cepi, 2025b).

Box 2: Low-carbon innovation initiatives of the pulp and paper sector in Europe Source: (Cepi, 2025b)

Renewable electricity via PV or wind

- Company: Arctic Paper, Poland
- Project: Solar farm provides renewable power
- Description: Expansion of a pilot PV farm at the Kostrzyn mill from 0.9 MW to 18 MW by early 2025 with an additional +10 MW planned by mid-2025.

Circular economy

- Company: Essity, Netherlands
- Project: Converting paper sludge into Circular Calcium Carbonate (CCC), pyrolysis oil, and gas.
- Description: Construction of a large-scale demonstration plant with the capacity of treating19.700 tonnes of paper sludge per year to produce 7000 tonnes of CCC, 2000 tonnes of pyrolysis and 5230 MWh of energy.

Other renewable fuel

- Company: Sofidel, Sweden
- Project: Innovative bio-syngas generation plant
- Description: On-site gasification of wood residues to produce 32 GWh per year of bio-syngas with a generation capacity of 4.2 MW. The project aims to demonstrate this potential to energy stakeholders, including governments.

Demand-side flexibility

- Company: Sappi Maastricht, The Netherlands
- Project: Demand-side flexibility with an e-boiler and CHP unit
- Description: Combination of a new e-boiler and an existing CHP unit allows the mill to switch between renewable electricity and natural gas to produce steam. The old gas-fired backup boiler was replaced by the e-boiler, which, alongside the CHP, provides the automated frequency restoration reserve (aFRR) balancing service to the transmission system operator. during the start-up year, the flexible capacity reached 68 MW.

New types of packaging

- Company: Metsä, Finland
- Project: Muoto™ packaging from wood
- Description: PFAS-free moulded fibre packaging made from renewable wood fibres using an innovative, integrated process at a demo plant in Äänekoski.

[128] https://www.storaenso.com/en/newsroom/news/2024/5/langerbrugge-paper-site-today
[129] https://www.storaenso.com/en/newsroom/news/2016/11/renewable-energy-in-the-pipeline

3.9.2 Industrial Transformation Cases

Table 16 lists the ITCs that were discussed with the paper sector in Belgium.

Table 18: Overview of ITCs for paper.

	ITC	Impact	Uncertainty
Carbon-neutral & circular production	Electrification of the dryer	**High** Electrification could cut emissions if powered by renewables but would require more electricity.	**Low** The sector sees the electrification as one the key decarbonization pathway and TRLs of solutions such as electric air heating of electric boiler are already at 9. Heat pump is still under development with a TRL of 7 (Wyns et al., 2025).
	Fuel switch to increased use of biomass or biofuels	**Medium** This could cut emissions compared to fossil fuels.	**Medium** The sector is already highly dependent on biomass or biofuels since this represents around 50% of the energy consumption in Belgium. There are uncertainties on biomass and biofuels availability.
	BECCS (Bioenergy with Carbon Capture and Storage)	**High** Bio-based Kraft mills emit large amounts of biogenic CO_2, making them ideal for BECCS retrofits. This could lead the sector to carbon sinks but would require an increase in electricity and heat consumption.	**High** Lack of economic incentives and clear policy framework for this technology to develop (Lipiäinen et al., 2023). Even if this technology could be promising, in Belgium, no company in the sector is currently considering it (CEEP-IT interviews). The technology is still developing with a TRL of 5 (Wyns et al., 2025). Other barriers are the infrastructures needed (transport and storage) as well as the important cost (Joyo et al., 2025).
	Efficiency-Improving Technologies	**Medium** Electricity generation in modern recovery boilers increased by 20% (while still providing the required heat for the pulp mill) within 10 years (Lipiäinen et al., 2023). They are also other technologies that are emerging to improve the efficiency of pulp and paper production processes, such as deep eutectic solvent (Lipiäinen et al., 2023), (Wyns et al., 2025).	**Low** Typical technical lifetime of a mill is between 30 and 50 years, and thus, the renewal rate in Europe is roughly 2–3% of the capacity per year (Lipiäinen et al., 2023).

	Enhanced utilization of by-products such as black liquor	**Low** Replacing traditional recovery boilers with advanced installation converting black liquor to chemicals and fuels via synthesis gas could achieve CO_2 reductions of 85-94% (Wyns et al., 2025). However, black liquor availability from chemical pulp production is a limiting factor, especially with enhanced recycling rates.	**Low** The TRL already at 9 (Wyns et al., 2025) and this technology is already deployed in some industries.
	Increase the recycling rate	**Low** In Belgium the recycling rate is already high, and the remaining potential is limited.	**Medium** Since the system is mature in Belgium, further increases may face diminishing returns and higher marginal costs.
Downstream market developments	Decrease in the graphic paper consumption	**Medium** Ongoing digitalisation will continue to expand, further reducing the demand for graphic papers.	**Low** Projections (van Ewijk et al., 2020) and sector expectations (CEEP-IT interviews) support this trend. Unless there is a major reversal in digitalisation, a continued decline in graphic paper demand is expected.
	Increase in the packaging paper and board consumption	**High** Reduction in plastic use for packaging and the growth of e-commerce will increase the demand for packaging paper and board.	**Low** Unless there are significant changes in consumer behaviour or strong government incentives, e-commerce is expected to keep expanding in the coming years.
Relocation	Relocation of some paper production within EU	**Medium** Structural impact on production geography and thus impacts on the Belgian energy system and economy.	**High** Some companies could relocate their operation within Europe due to combined energy and labour cost consideration. The paper sector is a regional market thus important relocation movements are not a major concern for the sector.
	Import of pulp from outside EU	**Low** Pulp represents about 50%-60% of total energy consumption. Structural impact on production geography and thus impacts on the Belgian energy system and economy. Carbon leakage risks if relocation outside EU rather than direct emission reductions.	**Medium** The pulp market is highly globalized, with major producers located in countries such as Brazil. Some Belgian paper producers already rely on imported virgin wood pulp from international.

3.9.2.1 Climate neutral and circular production

The path to decarbonising the pulp and paper industry can differ from other energy-intensive industries since the key challenge lies in eliminating the remaining use of fossil fuels in heat and steam generation (no process emissions). Biogenic carbon capture could lead the sector to carbon sinks. According to sectoral experts, the sector faces no major technical barriers to reach full decarbonisation, but progress is constrained by long investment cycles, as the typical lifetime of a mill ranges from 30 to 50 years, resulting in a renewal rate of only 2–3% of capacity per year (Lipiäinen et al., 2023).

As highlighted in (Wyns et al., 2025), the main decarbonisation solutions fall into three main categories, as reflect in ITCs of Table 16:

- Valorisation of papermaking by-products, such as black-liquor
- Electrification and carbon-capture solutions, such as dryer electrification and BECCS
- Efficiency-improving technologies.

Electrification of drying processes, deployment of heat pumps, and increased recovery of residual biomass streams are seen as key levers, provided that sufficient renewable electricity is available at competitive prices. In addition, increasing the share of biomass or biofuels in the energy mix, as well as further improving recycling rates, can also contribute to reducing the sector's carbon footprint. Hydrogen is not considered a priority option, given the relatively moderate temperature needs, between 60°C and 170°C (Correa Laguna et al., 2023).

3.9.2.2 Downstream market developments

For Belgium and EU, the future market dynamics in the pulp and paper sector will be shaped by diverging trends across product categories. Long-term projections indicate a continued decline in graphic paper consumption due to digitalisation, a trend confirmed by industrial experts. Conversely, demand for packaging papers and boards is expected to grow, driven by the expansion of e-commerce, increasing pressure for more sustainable packaging, and regulatory initiatives aimed at reducing plastic use. (van Ewijk et al., 2020) highlight that global paper demand is expected to increase especially driven by non-OECD countries demand. Indeed, the consumption of paper in non-OECD countries is expected to increase or stabilize for all types of paper.

3.9.2.3 Industrial relocation

Relocation dynamics in the pulp and paper industry are expected to remain moderate, as the sector is structurally linked to regional markets and bulky products. While rising energy prices and labour costs in Europe may encourage some companies to reconsider their production location, significant delocalisation outside the EU is not seen as a major risk. Instead, relocation within Europe could occur as firms adjust to regional differences in energy availability, cost or policy incentives. At the same time, industry representatives stress that further erosion of carbon-leakage protection must be avoided, and that secure access to abundant, affordable fossil-free energy remains essential for maintaining global competitiveness (Cepi, 2025b).

3.10 Data centres

In 1796, the steam engine was patented by James Watt, which sparked the beginning of the industrial revolution and caused an explosion of technological advancements. More than two centuries later, a similar change is occurring across the industries, in which virtual and physical systems of manufacturing cooperate with each other. In this process, artificial intelligence (AI) is considered one of the key technologies[130]. To support this transition, large data centres are being built across the globe.

[130] https://www.iberdrola.com/about-us/our-innovation-model/fourth-industrial-revolution

These centres are essentially facilities with powerful servers, where data is stored, managed and disseminated across the grid. Construction of these sites exerts pressure on communities, ecosystems and critical resources. Some of the ecological challenges this sector faces are water consumption (cooling installations), electronic and toxic waste management (life cycle of components) and finally energy demand and greenhouse gas (GHG) emissions. The latter will be disclosed in more detail in this section.

3.10.1 Current and future global landscape

It is important to distinguish different types of data centres categorized based on their size and use[131]. From an energy system perspective, the main ones are (Boston Consulting Group, 2025b):

- **Hyperscale** – large facilities operated by tech giants like Amazon, Microsoft and Google
- **Enterprise** – generally used to handle a company's data and IT workload internally, they are owned by a single organization with predictable usage and limited scalability requirements
- **Colocation** – facilities where several organisations share the physical space while managing their own computing infrastructure. The facility is owned and operated by a third-party or vendor

Essentially, each centre has the same function, storing data, but the scale at which the infrastructure runs differs. Another difference between data centres types lies in their performance, reliability and redundancy requirements. Typically, the large hyperscale data centres will be subject to higher requirements (so-called 'Tier 1') than smaller data centres. The presence of redundancy, in particular, may lead to an increase in installed capacity, physical infrastructure, and embodied energy (materials, manufacturing, and installation), slightly influencing auxiliary energy consumption and overall resource demand over the system's lifetime. However, the direct increase in the operational power consumption generally remains low.

Around 415 TWh of electricity is globally consumed by data centres which accounts for roughly 1.5% of the global electrical consumption of 2024 (IEA, 2025). The last five years, an annual rise of 12% has been measured, mainly attributed to the rise in popularity and accessibility of e.g. video streaming platforms and AI-models such as ChatGPT. Main energy consumption components are (IEA, 2025, Figure 2.2):

- The servers, powerful computers that process and store the data, accounting for around 60% of the electrical demand.
- Cooling, which is necessary to keep the installation in an optimal condition, accounting for some 30% of energy demand.
- Other power consumption, such as managing the data centre's storage systems and networking equipment and other infrastructural necessities, such as lighting and office equipment.

In the medium term (2028), power demand for mainly the hyperscale and colocation data centres is expected to grow further (Figure 25), with hyperscale data centres covering approximately 60% of total growth (Boston Consulting Group, 2025a). The demand for this global growth is mainly driven by the USA that is expected to account for close to 2/3rds of global data centre power demand (excl. China). Main reasons include: a) the U.S. is home to large cloud and tech firms, such as Amazon, Microsoft, Google, and Meta, b) high land availability and a stable connection to the grid, c) active government support for the export of cloud and digital infrastructure with programs such as the U.S. International

[131] https://www.ibm.com/think/topics/data-centers

Development Finance Corporation, and d) strong focus on domestic digital infrastructure for national security reasons[132].

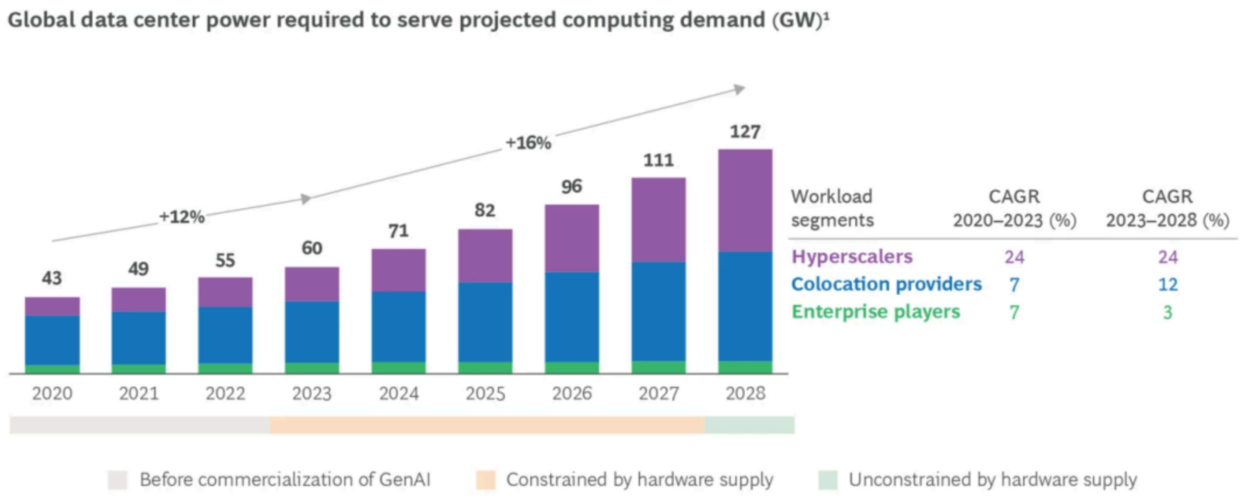

Figure 25: Growth of data centre demand per type (Boston Consulting Group, 2025a)

By 2030, according to the IEA (2025) Base scenario (Figure 26), electricity consumption is projected to double compared to 2024, reaching around 945 TWh. From 2030 to 2040, data centre's electricity consumption is anticipated to continue to grow by around 15% per year. Further sensitivity cases (Figure 27) highlight the uncertainty of future data centre electricity consumption as follows:

1. *Lift-Off scenario*: this case assumes a stronger growth in AI adoption than the base case, supported by a more resilient supply chain and greater flexibility in data centre location, powering and operations. It consists of an electricity demand that is 4.4% of global electricity demand and that is 45% higher compared to the base case in 2035.
2. *High Efficiency scenario*: this case is very similar to the base case however, it assumes a stronger progress on energy efficiency in software, hardware, and infrastructure. This means that the same level of AI can be achieved but it is met with a reduced electricity consumption footprint. This case could unlock energy savings of more than 15%, and a global electricity demand of 2.6% dedicated to data centres.
3. *Headwinds scenario*: this case goes off on an assumption that the AI adoption will go at a slower pace than currently expected. The tight supply chain and the emergence of local bottlenecks cause a delay in capacity expansion, leading to a limited total installed IT stock by 2030.

132 https://www.dfc.gov/our-work/infrastructure-and-critical-minerals

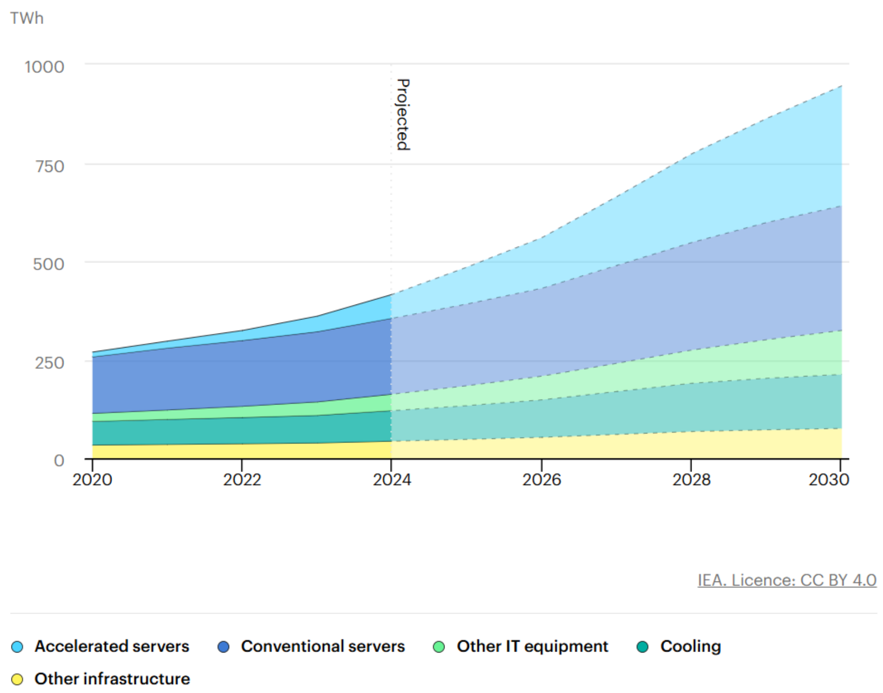

Figure 26: Projected electricity consumption per equipment for data centres in de Base scenario (IEA, 2025)

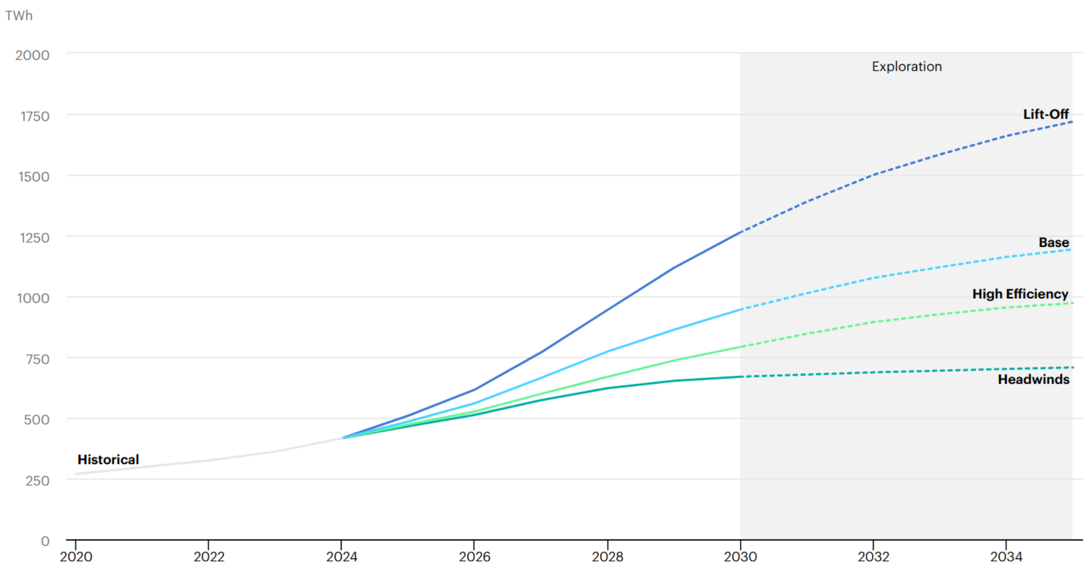

Figure 27: Global energy consumption of data centres per sensitivity case (IEA, 2025)

3.10.2 Main developments in Belgium

In Belgium, data centres consumed 3.2 TWh in 2024 (Boston Consulting Group, 2025b), or 4% or the country's electricity consumption, i.e. significantly higher than the global average. An estimated 30% of data centre sites are located in Brussels (Figure 28), with roughly 90% of those consisting of enterprise data centres (Belgian Digital Infrastructure Association, 2025). This concentration reflects the political and economic significance of Brussels both nationally and within the European Union. Taking into account their installed power capacity, Google's hyperscale site in Saint-Ghislain, Hainaut (red circle in the Figure 28) dominates the landscape, representing around 60% of the total installed data centre capacity in the country (Boston Consulting Group, 2025b). This site expanded from 51 MW to 223 MW over the last 10 years and is still expected to extend in the coming years[133, 134]. In addition, three Microsoft-operated colocation facilities are planned to be operational by autumn 2025[135]. Figure 29 shows recent growth can be attributed mainly to the hyperscale site, as well as colocation facilities to some extent.

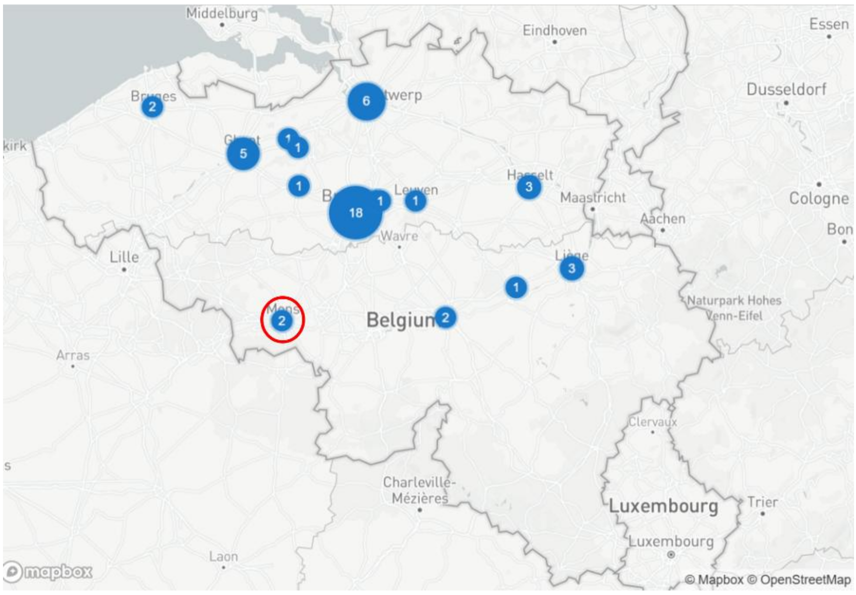

Figure 28: Data centres in Belgium[136], Google's hyperscale site in Saint-Ghislain is circled in red

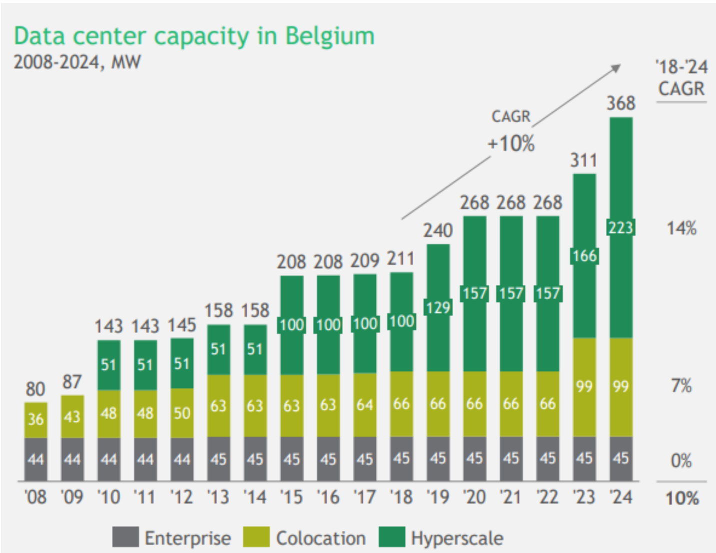

Figure 29: Growth rate of data centre capacity in Belgium (Boston Consulting Group, 2025a)

133 https://www.lecho.be/entreprises/tech-science/google-va-investir-5-milliards-supplementaires-en-belgique-dans-ses-data-centers/10630314.html
134 https://www.lesoir.be/703664/article/2025-10-08/google-et-la-wallonie-une-idylle-qui-de-lavenir
135 https://www.lecho.be/entreprises/tech-science/microsoft-ouvrira-son-premier-data-center-belge-a-l-automne-2025/10597462.html
136 https://www.datacentermap.com/belgium/

From an energy system perspective, the efficiency of a data centre is relevant to consider. This efficiency is measured using the PUE score (Power Usage Effectiveness). One challenge for lowering PUE is the lack of innovative and efficient cooling facilities for smaller data centres. As Figure 30 shows, the Belgian hyperscale centre scores better on PUE than colocation centres, which can be attributed to the use of innovative cooling systems (Google, 2025). Yet, Belgium has shown a significant drop in their average PUE score for colocation data centres in 2025, and overall Belgian PUE scores better than the global average.

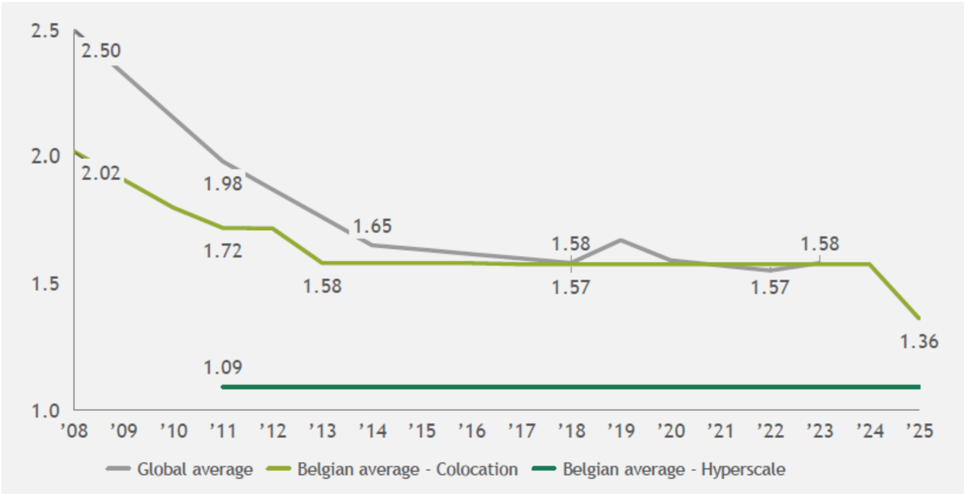

Figure 30: Evolution of the average global PUE score compared to Belgium averages (Boston Consulting Group, 2025b)

The future development of data centres in Belgium is uncertain. Geographically speaking, Belgium is in the centre of Europe, making it a perfect spot to place data centres. Although Google's new data centre is located outside of metropolitan areas, it is still within close range of Brussels, which enables it to connect to key European data hubs in London, Amsterdam, Frankfurt and Paris. The main disadvantage Belgium currently holds, is that there is an absence of a direct submarine connection to America, as Belgium relies on neighbouring countries to have intercontinental access (Belgian Digital Infrastructure Association, 2025).

According to recent projections from (Boston Consulting Group, 2025b), electricity demand from Belgian data centres could grow sharply towards 2035 and 2050. Three development scenarios are considered:

- Low case: Two-thirds of the currently announced 450 MW of projects are deployed by 2030, with the remainder by 2032. This corresponds to an estimated electricity demand of 7.0 TWh in 2035 and 10.5 TWh in 2050.
- Mid case: All announced projects are commissioned by 2030 resulting in electricity demand of 9.5 TWh in 2035 and 18.5 TWh in 2050.
- High case: All announced projects plus an additional 100 MW of new capacity are deployed by 2035. This leads to 15.5 TWh in 2035 and 34.0 TWh in 2050.

These projections thus highlight a potential two- to fivefold increase in electricity consumption by 2035, and a three- to tenfold increase in electricity consumption by 2050, depending on market development and regulatory conditions. The latest Elia adequacy and flexibility study (Elia, 2025 p. 26) anticipates an additional 2.5 TWh of demand by 2030 and an additional 5.2 TWh in 2035 compared to 2024, in between the Low and Mid cases above.

3.10.3 Industrial Transformation Cases

The following table lists various ITCs for the data centre sector in Belgium.

Table 19: Overview of ITCs for data centres.

	ITC	Impact	Uncertainty
Carbon-neutral & circular production	Enhanced cooling methods	**High** Innovative cooling technologies such as direct-to-chip liquid or immersion cooling could improve PUE with 30%[137].	**Medium** Potential safety risks could hamper uptake[138].
	Increased reuse of heat generated by data centres	**Medium** The heat recovery potential is significant, typically ranging from 20% to 80%. Values between 20% and 50% are generally considered realistic, based on data from existing industrial applications. (Yuan et al., 2023).	**Medium** Heat recovery is already implemented in current data centres (e.g. Google St. Ghislain site) and is required for data centres > 1MW (Energy Efficiency Directive (2023/955), Article 26(6)). Yet, the heat recovery potential varies significantly.
	Enhanced use of renewable electricity	**High** Reduced indirect emissions and can be more resilient to energy market if dedicated renewable production is installed (Google, 2025).	**Low** 84% of Google's energy production in Belgium is served by dedicated renewable production, with - dependent on weather conditions - possibility to fall back on alternative power sources.
	Replace fossil fuel generators with battery-based systems	**Medium** Whereas diesel generators sit idle most of the year, batteries can be better used as an asset to strengthens the electric grid[139].	**Low** Already used by Google, batteries installed with power of 2,75 MW/5,5 MWh.
	Carbon-intelligent computing	**High** Shifting the computing work to the facility that is currently working where CO_2 content of electricity is lower reduces CO_2 emissions from global operations (Google, 2025)	**Low** Innovative but proven technology

137 https://services.global.ntt/en-us/newsroom/ntt-leads-the-way-for-green-technologies-in-data-centers
138 https://www.datacenterdynamics.com/en/opinions/immersion-cooling-safety-in-a-data-center/
139 https://blog.google/inside-google/infrastructure/cleaner-data-centers-batteries-included/

	Increase recycling to limit dependency on scarce materials	**High** Direct reduced impact on the environment, eventually recycled scrap will be cheaper than virgin material (Andrews & Whitehead, 2019)	**High** The current recycling infrastructure is insufficient, and recycling is a heavy process (high cost, skills, energy and time required)[140]
Downstream market developments	Adoption of AI and streaming services leading to high demand for data centres	**High** Key factor for determining data centre power demand	**Medium** Global projections for data centre growth show that this trend will continue, but with a wide range mainly depending on AI adoption
Industrial relocation	Shifting to regions outside Belgium that are generally favourable for data centres deployment	**High** Large economical and energy system impact if data centre moves out of Belgium.	**Medium** Belgium is not favourable for all the key factors to decide where to install a data centre such as electricity price, grid connection available. But Belgium is well located in Europe with big markets for data centre deployment.
	Shifting to regions with low CO_2 content of electricity	**High** Reduced CO_2 emissions from global operations (Google, 2025).	**Medium** Data is moved across long distances which may require extra energy for transmission
	Moving data centres to outer space	**Medium** Abundance of solar power in space and a lower ambient temperature creates excellent conditions for data centres. Large amount of energy required for the implementation	**High** Discussion of feasibility of project. Risks of orbital collision, insufficient radiation shielding and cooling techniques[141]

3.10.3.1 Climate neutral and circular production

Various options for enhancing climate-neutrality and circularity of data centres can be identified in Table 19. A first aspect is energy efficiency. The European Energy Efficiency Directive[142] (EED) sets mandatory reporting obligations regarding their environmental footprint: As of 2025 data centres in EU with 500 kW of IT power or more are obligated to report on energy efficiency, renewability of energy sources, residual heat reuse and potable water usage. For Belgium the directives are implemented separately for each region (Flanders, Wallonia and Brussels). Concretely our ITCs reflect:

[140] https://www.human-i-t.org/data-center-recycling/?srsltid=AfmBOoolm3MaWM8oYDpbZJfmm095RAzSiD5fWnNsubTjVpf0JTeXPexg
[141] https://www.economist.com/science-and-technology/2025/04/09/could-data-centres-ever-be-built-in-orbit
[142] https://eur-lex.europa.eu/eli/dir/2023/1791/oj/eng

1. Enhanced cooling methods

Traditionally, data centres are cooled with water and air. Although water-based cooling is less energy intensive, water consumption tends to be a challenge and more efficient cooling methods are required to solve this problem. Direct Contact Liquid Cooling[143,144], for example, is a method in which the water is brought only to the heat dissipating parts of the server. In this way the water is used more efficiently. Another method called Liquid Immersion Cooling[144,145] uses a dielectric liquid to submerge the servers in. This type of liquid has non-conductive properties, allowing the servers to work, while absorbing large amounts of heat. Two types of immersion cooling exist: 'single phase' using only a non-conductive fluid, and 'two phase' where evaporation of the cooling fluid is used in the heat dissipation process.

2. Reuse heat produced by the data centre

Waste heat from the data centres can be distributed to district areas where it could provide heating and warm water for houses or other buildings. In Germany for example, the NTT-DATA's Berlin 2 facility was able to save approximately 6000t CO_2eq in this way. According to the EED, Article 26(6), *Member States shall ensure that data centres with a total rated power exceeding 1 MW make use of waste heat*. As a result, heat recovery will become a mandatory design consideration for new installations, influencing both site selection and technical configuration from the early planning stages.

3. Integration of renewable energy and storage

Using dedicated renewable electricity generation for data centres reduces the CO_2 footprint of their power consumption. Moreover, combining on-site renewable generation with battery storage systems enables data centres to play a more active role in supporting the electricity grid. In particular, the presence of batteries enables operators to offer transmission grid flexibility services and a reduction of the size of the grid connection. In line with its 2030 commitment to operate on Carbon-free energy (CFE) at an hourly basis, the Google data centre in Saint-Ghislain achieved an 84% hourly share of carbon-free energy (Google, 2025). This value breaks down as follows:

- 32% from carbon-free electricity directly contracted by Google (Contracted CFE), and
- 52% from carbon-free electricity already available on the local grid.

Finally, demand side flexibility or so-called "carbon-intelligent computing" is an innovative method to reduce CO2 footprints[146]. This system distributes computational workloads across a network of data centres, shifting processing tasks in real time to locations where the electricity mix is cleaner at a given moment.

4. Recycling

Currently, materials required to build data centres are often sourced from mines in Africa and Asia[147], and only limited amounts of the data centre's waste is recycled. Mining the minerals is carbon-intensive and requires large areas to produce relatively small amounts of material. Figure 30Therefore, better reuse of waste materials to create new servers, enabling a circular economy, is promising to

143 https://www.parkplacetechnologies.com/blog/direct-to-chip-cooling-how-it-works-effectiveness/#considerations
144 https://services.global.ntt/en-us/newsroom/ntt-leads-the-way-for-green-technologies-in-data-centers
145 https://www.datacenterdynamics.com/en/opinions/immersion-cooling-safety-in-a-data-center/
146 https://blog.google/outreach-initiatives/sustainability/carbon-aware-computing-location/
147 https://www.systext.org/node/1785

reduce ecological footprints. The biggest challenge this industry faces is the lack of infrastructure available and circular design thinking to start this circular strategy (Kerwin et al., 2022). This includes insufficient systems for the collection and sorting of electronic waste, limited industrial facilities for component refurbishment and advanced material recovery, and underdeveloped logistical and market structures to support the reuse of components.

3.10.3.2 Downstream markets

AI adoption is the key determining factor for driving future demand for data centres. This extent to which AI develops is highly uncertain, as reflected in the wide range of projections of future data centre demand (Figure 27).

3.10.3.3 Industry relocation

Deciding in which country a new data centre will be located is a key factor in ensuring efficient operation and in determining its overall carbon footprint. This is particularly critical for hyperscale data centres, given their size and high energy demand. Our ITCs reflect geographical decisions, both on general considerations, as well as on climate-neutrality specifically.

According to (Boston Consulting Group, 2025b), the decision is based on two essential prerequisites:

- **Power reliability:** Can the country deliver electricity supply with minimal outage risk?
- **Data connectivity**: is there sufficient high-speed data infrastructure?

Once these baseline conditions are met, the location decision generally depends on five key factors:

- **Power cost:** Is the cost of electricity competitively priced and stable in this location?
- **Grid connection:** is there sufficient grid capacity to connect withing reasonable timelines?
- **Carbon intensity:** is there sufficient green power available to meet corporate sustainability targets?
- **Local support:** does the country offer political and local support?
- **Physical and political risk:** is there a risk of political instability or physical disruptions?

Also data sovereignty and national regulatory frameworks may influence the choice of location (Boston Consulting Group, 2025b), since these can limit where data generated in a specific country may be stored or processed, particularly in sensitive sectors. Finally, according to (Boston Consulting Group, 2025b), latency considerations are also important: the further data are stored from the end user, the higher the latency, which can negatively affect user experience or real-time digital services. For this reason, companies often prefer data centres located close to major population or business hubs, depending on the purpose of the data centre.

From a Belgian perspective, grid-related constraints have recently become a challenge. Grid capacity is limited in several regions, which can delay or restrict the connection of large new facilities. In 2025, announced plans to limit new grid connections for data centres in certain zones due to capacity saturation[148].

Finally, moving data centres to outer space is included as an 'out-of-the-box' ITC that already attracts investment and may become relevant over the longer term.

148 https://www.lecho.be/economie-politique/belgique/federal/elia-veut-limiter-les-raccordements-des-data-centers-au-reseau/10632275.html

3.11 Future of construction

The construction sector is a relevant downstream sector to various energy intensive industries, such as cement, lime, bricks, steel and glass. Therefore, we address similar main developments for this sector, looking at the recent history, the short-term trends and long-term future. This section is based primarily on the interview with the expert panel member on construction.

3.11.1 Buildings

Recent trends since 2021 diverge between buildings and infrastructure. For buildings, residential construction in Belgium enjoyed a post-COVID boom in 2020–21 but ran into a 'perfect storm' from mid-2021 onward: rapidly rising interest rates, historically high material prices and heightened macro-political uncertainty (energy shock, inflation, geopolitics) pushed many household and developer projects to the sidelines. New residential permits fell in 2022–24 across all Belgian Regions, signalling a contraction in new-build projects. This decline reflects lower affordability (mortgage rates higher than the decade average), accumulated regulatory friction (permit delays, legal recourses) and the removal of some fiscal incentives for demolition-rebuild, producing a clear shift from greenfield/new-build solutions toward renovation and more cautious developer behaviour (L'Echo, 2025).

At the same time, since 2018 the EU has adopted increasingly strict renovation policy. Under the recast EPBD (Directive (EU) 2024/1275), member states must currently prepare national renovation plans to transform the housing stock to near-zero emissions by 2050. For comparison, today the renovation rate is just below 1% whilst rates of 3% and 5% are needed to reach the climate targets. This tighter legal framework reframes the sector: renovation is no longer optional but a structural obligation that will reshape demand for labour, insulation, glazing, cement and bricks.

This strong energy renovation effort will radically alter material demand.

- Glass is a key growth segment: out of 4.5 million housing units, 80–90% still fall short of 2050 energy standards. Meeting these goals implies tripling the current renovation rate within five years and maintaining it to mid-century.
- Bricks and cement, by contrast, remain tied to new construction and civil engineering. While renovation boosts demand for insulation, glazing, and prefabricated retrofits, it does not fully compensate for the loss of traditional new-build volumes. For the brick and cement industries, maintaining a certain level of demolition-rebuild activity remains critical to keeping production viable.

Even with slower population growth, the number of households continues to rise due to smaller household sizes. This generates persistent new housing demand, despite a stable population. The housing market is also diversifying with student housing, expat accommodation, second homes, all contributing to structural pressure on housing needs. Hence, even as renovation dominates policy, new construction remains indispensable to maintain market balance and address social needs.

Most viable office-to-housing conversions have already been achieved, leaving limited remaining potential. Belgium's The next challenge comes from an upcoming influx of large homes (e.g., four-façade villas from the 1970s-80s) that become available, but no longer fit contemporary household needs. The sector faces a strategic choice between re-dividing existing homes into multiple smaller ones (a low-material, low-cost path) or demolition and rebuilding, which sustains demand for bricks and new materials.

3.11.2 Civil engineering and infrastructure

Beyond buildings, civil engineering investment is emerging as a defining factor for the sector's trajectory. Belgium's investment in civil engineering and infrastructure has fallen from 5% of GDP in the 1980s to around 2-3% today, which is lower than in neighbouring countries. A return to 5% of GDP would be necessary to address accumulated maintenance and to meet future adaptation needs. For example, climate change impacts (e.g., floods, rising sea levels) will necessitate major infrastructure adaptations such as stormwater basins, sewer systems, coastal protections, and updated transport systems. While the De Croo government had aimed for 4% of GDP by 2030, the current De Wever administration has capped spending at 3%, which is below what's required for a genuine modal shift in transport and infrastructure resilience.

3.11.3 Costs of (green) materials and labour

Timber, bio-based insulation and prefabricated façade systems are gaining share regionally (notably in Wallonia), and lower-carbon cements and concrete are increasingly discussed. Yet, their higher costs create a trade-off between low-carbon ambition and renovation take-up (Conseil Central de l'Economie, 2025). Indeed, about half of total construction costs come from labour and the other half from materials (roughly 40% each, plus 20% for other expenses). The introduction of greener materials, such as low-carbon cement, will push costs higher unless offset by policy support. Regulations will drive uptake, but if costs rise too far, renovation activity could stall.

A growing wave of innovation is reshaping the materials used in construction. These new materials go beyond merely reducing emissions, they aim to turn buildings into long-term carbon storage assets, closing the loop between industry, construction, and climate mitigation. One notable example is CO2ncreat[149], a Belgian initiative that utilizes captured CO_2 and secondary raw materials such as aggregates to produce eco-friendly masonry blocks. This approach not only reduces reliance on virgin materials but also permanently embeds carbon within the product, resulting in a negative-emission material with standard structural performance. Similarly, Paebbl[150] is pioneering a technology that captures CO_2 and mineralizes it into solid, stable compounds that can serve as inputs for concrete, plaster, or other building components. This process effectively stores carbon for centuries while delivering a versatile and scalable alternative to conventional cementitious materials.

Energy renovations often remain financially challenging for households, as the payback from energy savings is slow. The sector warns that the balance between environmental ambition and affordability must be carefully managed to avoid a collapse in demand. So, scaling a deep-renovation program at national level requires parallel investments in workforce training, material supply chains and financing mechanisms to avoid price spikes that would cut demand.

3.11.4 Policy and implementation challenges

Meeting 2050 climate and renovation goals in the construction sector will depend less on technology than on policy coherence and financial capacity. Industry experts underline several priorities:

- Harmonize regional policies and ensure coordination of regulation, subsidies, financing, training, and legislation.
- Simplify procedures and reduce delays in permits and subsidy access.
- Strengthen household-level support, particularly for co-owned buildings, where collective decision-making hampers renovation.
- Improve public communication and guidance, as lack of information remains a barrier.
- Reduce uncertainty surrounding the *Renolution* bonus: amount, eligibility, and the fact that it's a reimbursement model requiring upfront payment are key barriers.

In short, the Belgian construction sector is moving toward a structural transformation driven by renovation obligations and public investment choices. For buildings, the renovation speed, strategies

149 https://co2ncreat.com/
150 https://paebbl.com/

for meeting the increasing housing demand, the costs and uptake of alternative building materials, labour costs, and supporting policies are crucial factors. Infrastructure activity is largely policy-dependent, more than tech-dependent (CEEP-IT interviews).

3.12 Clean tech in Belgium

3.12.1 Current batteries production and recycling landscape

Belgium's battery recycling network is anchored by three major facilities. Umicore's Hoboken plant processes up to 7,000 tonnes[151] of Li-ion and NiMH batteries per year, using high-temperature melting and hydrometallurgical refining to recover cobalt, nickel, and lithium with >95 % metal yield. Bebat's Sortbat facility in Tienen sorts over 3,000 tonnes[152] of portable batteries annually into chemical fractions with >98 % sorting accuracy. Moreover, Watt4Ever, established in 2020, repurposes second-life EV batteries for stationary storage and recently partnered with Sortbat[153]. RecupBat, based in the port of Antwerp, provides secure storage and pre-treatment capacity for ~150 tonnes[154] of EV and HEV batteries per year, including lithium-ion vaults and automated discharge systems.

Umicore's 2025 strategic review announced a reduction in capital expenditure by approximately €1.4 billion in battery-materials between 2025-2028, shifting focus toward recycling and more profitable segments[155]. Reasons for lower revenues in 2024 were lower-than-expected demand for electric vehicles and competition from cheaper lithium-based batteries. At the same time, investment continues in core, high return- segments (refining, recycling) where the company already has strong competitive advantage, such as the Hoboken facility in Belgium. Umicore also secured a €350 million European Investment Bank (EIB) loan for battery-materials RDI (research, development, innovation) in Belgium among other places[156]. Consequently, in March 2025, Umicore has announced a €400 million investment at its Hoboken site (Belgium) by 2030 to upgrade its refining of metals (to refine 18 metals) and improve fine dust collection/air quality[157]. In addition to Umicore's investments, Avesta Battery & Energy Engineering (ABEE), which was founded in 2019[158], operates a €27 million battery R&D and recycling centre and plans a 3 GWh battery production factory in Wallonia[159, 160]. Beyond Belgium, in Europe: the project by Cylib (Germany) is building a largescale battery- recycling plant with a capacity of ~30,000 tons per year, demonstrating how Europe is scaling up the circular battery value- -chain[161].

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151 https://www.umicore.com/en/about/battery-materials-solutions/battery-recycling-solutions/start/
152 https://2019.bebat.be/en
153 https://watt4ever.be/news/sortbat-acquires-watt4ever-febelauto-remains-on-board-belgian-collaboration-gives-ev-batteries-a-second-life
154 https://www.belganewsagency.eu/150-tonnes-of-batteries-from-old-electric-vehicles-collected-in-belgium-last-year
155 https://www.belganewsagency.eu/umicore-refocuses-on-core-businesses-amid-profit-pressure
156 https://www.eib.org/en/press/all/2024-054-belgium-eib-to-support-umicore-with-a-eur350-million-loan-for-its-european-research-and-innovation-in-electric-vehicle-battery-materials
157 https://eurotoday.org/hoboken-umicore-to-invest-e400m-to-refine-18-metals-by-2030/
158 https://www.agoria.be/en/services/expertise/green-transition/environment/take-back-obligations/batteries/abee-opens-state-of-the-art-rd-facility-and-upscaling-center-for-next-generation-batteries-in-ninove
159 https://www.belganewsagency.eu/abee-invests-27-million-euros-in-battery-research-centre
160 https://www.avestaholding.com/news/be-volt-battery-system---giga-factory
161 https://www.reuters.com/technology/porsche-backed-german-start-up-cylib-breaks-ground-battery-recycling-plant-2024-09-09/

3.12.2 Current plastics and metals recycling landscape

Belgium is actively expanding its material recycling infrastructure across metals, plastics, and chemical streams. Recently, SynPet Technologies[162] further strengthens this expansion with a €300 million facility at the Port of Antwerp-Bruges, designed to convert ~250 kton/year of mixed hard-to-recycle plastics into circular feedstocks, expected to begin operations in 2028. Moreover, Freepoint -Eco-Systems[163] announced plans for an 80 kton/year chemical recycling plant in Ghent (with potential expansion to ~160 kton/year). Moreover, Morssinkhof- -Rymoplast[164] is developing a PET recycling plant in Neufchâteau (~40 kt/year), while Indaver's Plastics2Chemicals initiative[165] in Antwerp targets 26 kt/year of chemical feedstock from end-of--life- plastics (€105 million).

For metals recycling, Aurubis operates major plants in Olen (135 kton/year[166]) and Beerse (250 kton/year[167]), processing complex multimetal scrap, including copper, nickel, and anode sludge, with the recently inaugurated ASPA hydrometallurgical facility extracting tin and precious metals. Other key players include REVATECH, which recycles approximately 50 kton/year[168] of non-ferrous metals such as zinc, lead, copper, tin, nickel, and cobalt, and Galloo, which maintains a network of 40+ collection and recycling sites across Belgium for non-ferrous metals including copper and aluminium. More recently, HYDROMETAL Belgium[169] inaugurated a pilot plasma furnace in Engis for recycling non-ferrous metals in 2024, including rare earth elements and battery residues. The furnace is part of a broader R&D pilot programme ("Reverse Metallurgy" / plasma metal recovery) meaning its commercial scale-up (if any) is still to be confirmed.

3.12.3 Regulations and outlook

Under the 2023 new EU Batteries Regulation[170] (which governs battery design, production, waste and recycling), there are specific collection & recycling targets (e.g., for portable batteries, light-transport batteries) and minimum levels of recycled critical materials (lithium, nickel, cobalt) for new batteries. Initially, from eight years after the regulation's entry into force, new batteries must contain at least 16% cobalt, 6% lithium, 6% nickel, and 85% lead from recycled sources. These minimum levels increase after thirteen years to 26% cobalt, 12% lithium, 15% nickel, and 85% lead. Additionally, the regulation specifies material recovery targets from waste batteries: by 2027, recyclers must recover 90% of cobalt, copper, lead, and nickel and 50% of lithium. By 2031, these recovery targets rise to 95% for cobalt, copper, lead, and nickel and 80% for lithium[171]. However, according to a 2024 article[172], Europe's actual battery materials recycling capacity is currently only about one- tenth of what will be needed by 2030 to meet demand and the regulation's ambitions, mainly due to energy costs and a lack of technical expertise- and financial support.

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162 https://synpet.com
163 https://www.icis.com/explore/resources/news/2024/05/31/11004337/freepoint-eco-systems-to-build-80-000-tonne-year-chemical-recycling-plant-in-belgium
164 https://www.packaging-gateway.com/projects/mopet-belgium-pet-recycling-facility-neufchateau-belgium
165 https://belgashare.be/newsrooms/118/press-releases/11999
166 https://www.recyclingtoday.com/news/aurubis-inaugurates-recycling-plant-olen-belgium
167 https://www.aurubis.com/en/media/press-releases/press-releases-2022/aurubis-builds-facility-to-recycle-more-nickel-and-copper-in-belgium
168 https://www.revatech.be/en/operations/recycling
169 https://www.jgi-hydrometal.be/en/inauguration-of-europes-unique-plasma-furnace-at-hydrometal-belgium
170 https://www.europarl.europa.eu/news/en/press-room/20221205IPR60614/batteries-deal-on-new-eu-rules-for-design-production-and-waste-treatment
171 https://www.europarl.europa.eu/news/en/press-room/20230609IPR96210/making-batteries-more-sustainable-more-durable-and-better-performing
172 https://www.reuters.com/world/europe/europe-set-miss-potential-battery-material-recycling-2024-12-11

The 2024 Net-Zero Industry Act (NZIA) prescribes that by 2030 at least 40% of its annual deployment needs for net-zero technologies are met by domestic manufacturing[173]. It covers final products, components, and machinery for technologies such as solar, wind, batteries, heat pumps, and geothermal energy[174]. Initial implementation steps are underway: for example, the European Commission launched consultations on draft secondary legislation in early 2025 to define how the NZIA will be applied in practice (e.g., which projects qualify as "net-zero strategic projects", faster permitting -rules)[175].

The 2025 Clean Industrial Deal (EC, 2025b) incentivizes clean-technology investments, aiming to create predictable markets for batteries, hydrogen, renewables, and energy-efficient machinery, encouraging companies to scale production and innovate. The CID also introduces a State Aid Framework and financing tools, mobilizing over €100 billion to support EU-made clean technologies[176]. Moreover, from 2026, EU will introduce sustainability, resilience and "European preference" (Made in Europe) criteria in public procurement for strategic sectors, which is a concrete step toward boosting domestic demand for clean technologies[177].

173 https://commission.europa.eu/topics/competitiveness/green-deal-industrial-plan/net-zero-industry-act_en

174 https://single-market-economy.ec.europa.eu/industry/sustainability/net-zero-industry-act_en

175 https://single-market-economy.ec.europa.eu/news/commission-seeks-views-provisions-implement-net-zero-industry-act-2025-01-27_en

176 https://eaccnl.eu/european-commission-a-clean-industrial-deal-for-competitiveness-and-decarbonisation-in-the-eu

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4 Towards industry transformation scenarios

4.1 Results from the expert panel workshop

4.1.1 Qualitative storylines

As explained in Section 2, based on the expert panel workshop, the pre-defined scenarios have been refined taking the feedback from experts into account. Several guiding principles shaped the scenario development:

- Scenarios must be sufficiently differentiated and contrasted. Otherwise, the exercise becomes a sensitivity analysis on a limited set of parameters rather than an exploration of distinct futures.
- Comparability between scenarios results must be achievable. Indeed, if scenarios vary simultaneously across too many modelling parameters and assumptions, results become difficult to interpret and compare. For this reason, an example is that all scenarios are designed to achieve carbon neutrality by 2050.
- Each scenario must remain realistic and credible from both a technological and policy perspective, even when describing more extreme or disruptive futures.

Table 20 presents a general overview on the three storylines, followed by a detailed description of each scenario. The minutes of the expert panel workshop are included in Appendix 2.

4.1.1.1 GREEN-IT scenario

The GREEN-IT scenario focusses on **achieving a climate neutral and circular production for current process industry** in Belgium. Production levels remain largely stable with limited relocation, and potentially some opportunity for growth. Expected demand side trends, for example for data centres, paper, and construction materials are taken into account. The different sectors undergo a profound transformation towards climate neutrality and circularity, with enhanced supply side circularity based on recycled commodities being a defining characteristic of this storyline.

Further defining characteristics of this storyline are:

- Core commodities continue to be produced in Belgium, but production processes shift towards climate-neutral technologies.
- EU ETS price trajectories follow a strongly increasing pathway.
- Circular economy principles are widely implemented
- CO_2 pipeline and storage infrastructure are deployed at scale, making CCS available where needed.
- Adequate grid expansion and reinforcement, ensuring electricity availability for electrification
- Lower and more predictable renewable energy costs, with no additional OPEX burden on industry.
- CBAM and other protective mechanisms to ensure fair competition
- Development of markets for green products (demand pull).
- Investment support for emerging technologies (CAPEX subsidies).

Table 20: Overview of the three storylines

	GREEN-IT	SHIFT-IT	LEAVE-IT
Climate-neutral and circular production	Via full scale transformation to climate-neutral and circular production.	Via large scale transformation with somewhat smaller volumes of energy-intensive production.	Via relatively limited transformation and loss of domestic production (risk of carbon leakage).
Energy availability and policy support	Favourable conditions and strong policy support.	Fairly favourable conditions with targeted policy support.	Unfavourable conditions with limited policy support.
Relocation of energy-intensive production	No or limited relocation.	Partial relocation. High value added processes remain, others may relocate, mostly within EU.	Maximum relocation. Import of (semi) finished products, mostly from outside EU.
Demand for energy-intensive commodities	Status quo, but taking into account expected trends.	Some change, following innovations in downstream sectors.	Some decline, economic stagnation of downstream sectors.
Circularity logic	Enhanced supply side circularity based on recycled commodities.	Downstream markets tend towards alternative less energy-intensive products.	Downstream efficiency and circularity reducing the need for energy-intensive production or import.
Economic shift	Limited.	Towards new innovative sectors such as AI / datacentres, green tech, innovative construction materials.	Towards services.

4.1.1.2 SHIFT-IT scenario

This scenario describes a **selective transformation of Belgian industry characterised by strong innovation.** High value added activities develop domestically while lower value added / energy-intensive production steps may progressively relocate. To compensate, emerging demands from innovative sectors such as AI / datacentres, green tech, innovative construction materials feature under this scenario, reflecting a high innovative capacity of Belgium in the EU context. The outcome is a restructured industrial base that is less carbon- and energy-intensive, more exposed to import dependencies, but still strong from an economic point of view.

Further defining characteristics of this storyline are:

- Energy-intensive production considered of high added value or strategic importance remains in Belgium. Others may relocate, but preferably within the EU.
- Emerging sectors (such as data centres, battery recycling, chips…) expand, along with industries linked to the energy transition (e.g., stainless steel).
- Downstream markets tend towards adopting innovative less energy-intensive products, such as alternative concretes or bio-based materials in construction
- Strategic autonomy could be compromised, but in a limited way
- Climate neutrality by 2050 is achieved through a combination of large-scale green transition with somewhat lower reliance on energy-intensive production.

- CCS transport and storage infrastructure remains indispensable for specific sectors (cement in particular) to avoid full relocation but is delayed compared to GREEN-IT scenario.
- ETS prices follows a moderately increasing path due to reduced domestic emissions.
- CBAM and other protective mechanisms to ensure fair competition. Relocation is generally 'green' with limited carbon leakage.
- Development of markets for green products (demand pull).
- Strategic and targeted industrial policy to promote specialisation and support high-value industries (CAPEX subsidies).
- Policy and societal discussion about which industries are to be considered of highest strategic importance.
- Education and workforce reskilling to accompany restructuring towards innovation.

4.1.1.3 LEAVE-IT scenario

This scenario represents a pathway of **progressive deindustrialization of Belgium**, where many energy-intensive activities relocate abroad and the economy relies increasingly on services. Industrial production contracts sharply, while domestic demand is covered predominantly through imports of semi-finished and finished products. Under this storyline, the risks of carbon leakage and loss of strategic autonomy are high. Yet, it may offer opportunities in the form of downstream efficiency and circularity reducing the need for importing energy-intensive products.

Further defining characteristics of this storyline are:

- Large-scale relocation of steel, cement, chemicals, and other energy-intensive activities to other global regions, thus creating higher risks for strategic autonomy and dependency on foreign supply.
- Remaining industrial production is concentrated in locally bound or niche competitive sectors.
- National climate targets are achieved, partly due to the loss of domestic production. However, relocation is not necessarily based on climate-neutral production elsewhere, hence a high risk of carbon leakage
- Supply chains become dominated by imports, requiring significant expansion of logistics and port infrastructure (e.g., new clinker import terminals).
- High risk of economic recession and stagnation. Services cannot substitute for industrial decline given their dependence on manufacturing. Highly connected value chains are impacted as a whole.
- Unsuccessful policies on various accounts: weak or ineffective CBAM enforcement, lack of coordination on energy infrastructure deployment, absence of a coherent industrial policy.
- Competitiveness further eroded by persistently high energy and labour costs.
- Political and societal debate becomes necessary on which sectors to retain and which to let go, raising strategic questions about autonomy and resilience.
- Possibly further systemic crisis beyond CO_2 to be considered in this scenario, such as plastic pollution, raw materials availability, building renovation challenges

4.1.1.4 Key discussion points and takeaways from the expert panel

During the expert panel workshop, several issues or key elements triggered more substantial debate and are interesting to point out (see Appendix 2 for full minutes).

CCS

The availability, cost, and timing of CCS were repeatedly identified as decisive. Experts stressed that CCS cannot be treated as a temporary option: once deployed, its continuity must be ensured. Concerns were raised about over-reliance on CCS in the modelling and the need for additional sensitivity analyses.

Relocation
The prospect of industrial relocation generated intense discussion. The dynamic was considered relevant to analyse, but the importance to address impacts on the economy, carbon leakage, strategic autonomy was highlighted. Participants underlined the importance of distinguishing between intra-EU relocation and global relocation, as the implications for CBAM, competitiveness, and resilience differ strongly. EU relocation is also about current production overcapacities, which makes it relatively flexible to move production to another country if it has better conditions (energy and labour costs, but also other factors). Relocation should not be seen as a binary phenomenon but as a spectrum of partial adjustments along value chains.

In this context, experts emphasised the close link between CBAM and relocation: with a well-designed and properly implemented CBAM, the risk of major relocation is expected to remain limited. Conversely, without CBAM, carbon leakage would inevitably increase, highlighting the need for coherent policy alignment. The question of relocation also raised discussion about the importance of political and societal debate to determine which sectors to retain and which to let go.

Shift to what?
Participants generally required clearer specification of the economic shift in response to relocation. Under SHIFT-IT there are many possible innovative emerging sectors that could be included, but it is unclear which one(s) would be most relevant. The LEAVE-IT scenario presumes a general shift to services, but it is unclear which services and to what extent this can compensate for the loss of industrial activity.

Assumptions on demand and costs
Stable demand for energy-intensive commodities was considered unrealistic in scenarios where prices increase due to high CAPEX and OPEX. The risk of losing both domestic and export markets under such conditions was emphasised. Cost modelling, in particular for energy prices, breakthrough technologies, and imported molecules, was flagged as highly uncertain.

4.1.2 Mapping ITCs to scenarios

The ITCs of Section 3 can now be consistently mapped under each of the qualitative storylines as a first step to model scenarios. As such, it provides a basis to guide further model development (WP2). Depending on model developments realized, and based on further interactions with the expert panel, a sub-selection of the ITCs will be modelled under WP3 Pathways. Under each main storyline, potentially multiple sensitivity scenarios can be developed, reflecting alternative technological, economic and policy assumptions within the scope of the main storyline.

The following tables give a first proposal of how ITCs can be mapped under the different scenarios[178]. Table 21 first presents *baseline* developments. These are considered as relevant trends (high or medium impact) with relatively low uncertainty and could feature under any scenario. Tables 22-24 present ITCs that are considered as relevant trends (high or medium impact) with medium to high uncertainty. Hence, they are adopted under specific scenarios, either *GREEN-IT* (Table 22), *SHIFT-IT* (Table 23) or *LEAVE-IT* (Table 24). The uncertainty levels in the tables are a further indication of the relevance of each ITC under a scenario. As a starting point, medium uncertainty ITCs are considered somewhat more relevant to include than high uncertainty ITCs, as the latter may be insufficiently plausible (to be further assessed). Finally note that a significant number of ITCs reflecting climate-

[178] In the table, the dimensions ‘climate-neutral and circular production’, ‘downstream market developments’ and ‘industrial relocation’ are abbreviated as ‘green production’, ‘downstream markets’ and ‘relocation’.

neutral and circular production routes (see Appendix 3) were not classified *a priori* under a scenario. The uptake of these production routes under the different scenarios is rather considered an outcome of the modelling exercise. However, announced investment decisions on CCS or any other ITC will be considered baseline developments.

Table 21: ITCs selected as potential baseline developments

Sector	Product	Dimension	ITC name
Iron & Steel	Primary steel	Green production	Primary steel production is partially replaced with increased secondary steel production
Chemicals	Ammonia	Downstream markets	Ammonia-based fertiliser demand reduces (due to alternative fertilizers)
Non-metallic minerals	Cement	Downstream markets	Expected slight gradual decline in cement and concrete demand
Glass	Flat and fibre glass	Downstream markets	The demand of flat and fibre glass increases
Bricks	All	Green production	Efficiency upgrades with waste heat recovery
Bricks	Facing brick	Green production	CO2 absorbing brick
Paper, pulp & printing	Paper and pulp	Green production	Efficiency-Improving Technologies
		Downstream markets	Decrease in the graphic paper consumption
		Downstream markets	Increase in the packaging paper and board consumption
Emerging sectors	Datacentres	Green production	Enhanced use of renewable electricity
		Green production	Carbon-intelligent computing
		Green production	Replace fossil fuel generators with a battery-based systems
		Downstream markets	Moderate adoption of AI and streaming services

Table 22: ITCs selected as potential cases under the GREEN-IT scenario

Sector	Product	Dimension	ITC name	Uncertainty
Iron & Steel	Primary steel	Green production	Steelanol becomes viable and additional capacity is built.	Medium
	Primary steel	Green production	Primary steel production is strongly replaced with increased secondary steel production	Medium
Chemicals	Ethylene	Green production	Py-naphta (pyrolysis naphta from chemical recycling of plastic waste) becomes a viable technology.	Medium
Non-metallic minerals	Cement	Downstream markets	Concrete recycling, use of recycled aggregates, fines, valorisation of demolition waste	Medium
	Cement	Downstream markets	Longer term increase in cement and concrete demand	High
	Lime	Green production	Reduction of the calcined fraction in blended products	Medium
Glass	All	Green production	Increase of cullet shares in the production	Medium
Bricks	All	Green production	Use of industrial by-products (fly ash or waste materials)	Medium
Emerging sectors	Datacentres	Green production	Increased reuse of heat generated by datacentres	Medium

Table 23: ITCs selected as potential cases under the SHIFT-IT scenario

Sector	Product	Dimension	ITC name	Uncertainty
Iron & Steel	Primary steel	Relocation	Domestic DRI is replaced with import of sponge iron.	High
	Secondary steel	Downstream markets	New markets or increase in production due to clean and emerging technologies.	Medium
	Primary steel	Downstream markets	New markets or increase in production due to clean and emerging technologies.	Medium
Chemicals	Ammonia	Relocation	Additional imports of ammonia replace domestic production	Medium
	Ethylene	Green production	Methanol-to-olefins becomes a viable technology.	High
	Ethylene	Relocation	Import of methanol for MTO.	High
Non-metallic minerals	Cement	Green production	Clinker substitution with limestone calcined clay	Medium
		Green production	Clinker substitution with geopolymers	Medium
		Downstream markets	Alternative concretes	High

		Downstream markets	Biobased building materials	Medium
Bricks	All	Relocation	Some regional relocation intra EU in neighbouring countries	Medium
Emerging sectors	Datacentres	Green production	Enhanced cooling methods	Medium
		Relocation	Shifting to regions with low CO2 content of electricity	High
		Downstream markets	Strong adoption of AI and streaming services	Medium

Table 24: ITCs selected as potential cases under the LEAVE-IT scenario

Sector	Product	Dimension	ITC name	Uncertainty
Iron & Steel	Primary steel	Relocation	Domestic steel production is replaced with import of steel slabs.	High
	Primary steel	Downstream markets	A loss of competitiveness in the certain EU industries (e.g. automotive) results in a reduction of primary steel demand.	Medium
	Secondary steel	Downstream markets	A loss of competitiveness in the certain EU industries (e.g. automotive) results in a reduction of steel demand.	Medium
	Secondary steel	Relocation	International competition reduces Belgian secondary steel production.	Medium
Chemicals	Ammonia	Relocation	Additional import of fertilizer replaces domestic production	High
	Ethylene	Downstream markets	Mechanical plastics recycling reduces ethylene demand.	Medium
	Ethylene	Relocation	Import of ethylene from China/US.	Medium
Non-metallic minerals	Cement	Downstream markets	Concrete reuse or repurposing	High
	Cement	Relocation	Increased clinker import	Medium
	Cement	Relocation	Increased cement import	High
	Lime	Downstream markets	Lime consumption further gradual decline	Medium
	Lime	Downstream markets	Relocation of lime’s industrial clients	Medium
Glass	Container glass	Downstream markets	Ecodesign of bottles	High
	All	Relocation	Intra-European relocation of glass production	Medium
Bricks	All	Green production	Circular economy – urban mining and reuse	Medium
	All	Downstream markets	Decline of the brick consumption	Medium

	All	Downstream markets	Eco-format bricks	Medium
	All	Relocation	Some relocation outside EU	High
Paper, pulp & printing	Paper and pulp	Relocation	Relocation of some paper production within EU	High
Emerging sectors	Datacentres	Relocation	Shifting to regions outside Belgium where the conditions are more favourable for datacentres deployments	Medium

4.2 Implications for the CEEP-IT modelling framework

After review of the ITCs presented in this report, as well as reflection on the broader forces shaping the place of manufacturing in the economy, three main classes of economic shocks have been defined. In an CGE – ESOM setting, these shocks will initiate in the CGE model, providing an altered projection of energy services to be used in the ESOM model in order to gauge the impact of a changing industrial landscape on energy system outcomes.

We distinguish shocks emanating from a changing international environment, from a changing input structure of firms in the manufacturing sector and elsewhere (e.g. construction) and broader economic evolutions determining the relative weight of manufacturing versus services, or between different manufacturing sectors.

The methodological advisory board (AB) of the project with participation from national and international experts on CGE and ESOM was consecrated to a discussion on these economic narratives, and their translation in modelling terms. The main conclusion of this discussion, and subsequent reflection, is as follows.

Shocks in <u>international competition</u> (reflecting the dimension of industry relocation) seem to be relatively straightforward to implement as CGE model shocks, provided the necessary data can be found. CGE models share the tried-and-tested Armington assumption, translating aggregate demand into demand for imports and domestic production, as well as capturing foreign demand for exports. These demands are assumed to be imperfect substitutes and are determined by foreign and domestic prices. Foreign prices can in principle be shocked to capture a loss of competitiveness in industrial markets, or the parameters of the Armington demand system can be directly adapted. The CGE model will then endogenously calculate a new vector of imports and exports to maintain equilibrium, and corresponding new production levels.

The methodological AB also revealed that the likely challenge is in data. These challenges can be about breaking down imports by geographical scope (Intra versus extra EU, e.g.), or by product. The latter seems to be an especially important point of attention, due to the aggregate nature of national accounts data, and the specific nature of some of the ITCs. The imports of Ethylene are a case in point.

Shocks in the <u>input composition of firms</u> (reflecting the dimension of climate-neutral and circular production) also seems to be implementable. Classic CGE production functions are endowed with a factor 'material inputs', subdivided in different goods. The function governing this subdivision is called a Leontief function, dividing aggregate materials in subcomponents with fixed proportions. These proportions can be altered to reflect changing production patters.

Again, potential data-issues are likely if concepts of national accounts/supply and use tables do not match with those of the ITCs. Some conceptual issues could arise, to the extent that changing input composition of firms is preceded by investment in new processes. Also, when the use of one input is decreased exogenously, a judgment call would in principle be needed as to the factors of production that would potentially take its place.

A broader reflection on forces that could drive the relative place of manufacturing has highlighted the role of demand in driving historical deindustrialization patterns (reflecting the dimension of downstream market developments), and notably the relative income elasticity of demand of manufacturing and service goods. Other potential drivers, such as ageing, have also been touched upon. Integrating income elasticities of consumer demand in a CGE model has been done before, but it remains to be seen that such demand systems can be captured in our particular CGE model. Broader issues aside, demand – consumer, investment and government demand – can also be used to drive ITCs. The changing weight of cement in investment demand is a potential example. It was noteworthy that in the AB the growth of AI was linked to a changing demand, too, for information services. As before, a remaining conceptual issue here is in what services and goods these evolutions displace. In the case of AI, this would be a deep theoretical question related to a recent strand in the economic growth literature (Acemoglu & Restrepo, 2019).

5 Conclusion & outlook

The CEEP-IT project aims to explore climate-neutral energy-economy pathways with *industrial transformation* of energy-intensive industry. Analysing industrial transformation in a comprehensive and integrated way requires a broad understanding of the industry's value chains, alongside the variety of options for climate-neutral and circular production in Belgium. This includes the value chain *upstream* of domestic energy-intensive production, in the form of the potential imports of different forms of energy, and final or intermediate energy-intensive commodities. It also includes the *downstream* markets such as construction, automotive, plastics and fertiliser that consume energy-intensive commodities and may be in transformation themselves. Moreover, new sectors could emerge, such as data centres or a materials recycling industry, that may generate additional energy demands.

This scoping report lays the foundation for the CEEP-IT model-based analysis of industrial transformation. It takes stock of main relevant developments related to industrial transformation in Belgium as they unfold currently and possibly towards the future. To this end, we combined literature review and the perspectives from the expert panel covering industry perspectives from different sectors. Based on these insights, we derived a 'long-list' of so-called Industrial Transformation Cases: concrete cases of transformation, whether an innovative production route, a change of import of (intermediate) commodities, or a change of practice downstream altering energy-intensive product demand. The long-list was further condensed based on a qualitative evaluation (based on literature, expert interviews and own interpretation) of the impact and uncertainty, as an indicator of the relevance of each transformation case for scenario analysis. Consequently, ITCs considered of highest relevance were clustered under three main storylines, all portraying a climate-neutral Belgium in 2050, but differing in terms of the level of industrial relocation and the nature of economic shift, whether to innovative economic sectors or more traditional services.

The main value of the current report is that it lays a comprehensive basis for the further quantification of industrial transformation cases for developing modelled scenarios. We distinguished trends that have a relatively low level of uncertainty that should be adopted under each scenario as baseline trends. Increased levels of circular steel, a shift in graphic paper consumption towards packaging, increasing demand of flat and fibre glass and waste heat recovery for the production of bricks are examples under this category. Other possible developments that were considered having high uncertainty are to be adopted differently under each scenario. Main examples cover innovative circular production routes (such as the chemical recycling of plastic waste), new types of imports (such as sponge iron import as an alternative to domestic DRI), long-term demand outlooks (such as for cement and concrete), and emerging demands (for example from data centres).

In general, we find that all sectors are working towards the uptake of climate-neutral or circular production options, with innovative production routes being piloted and further investment being prepared. Yet, different barriers apply, with high energy costs as a common factor. Other barriers, such as the exposure to global competition (mainly steel, chemicals) or the reliance on CCS infrastructure (mainly cement, lime) are more sector specific. Our findings suggest that main global industry relocation risks apply for chemicals and primary steel, and to some extent for cement, with other sectors being more locally bound. Yet, for most sectors trade flows within Europe are common, making relocation intra-EU relevant to consider. Transformation cases reflecting industry relocation (i.e. shift from domestic production to imports) are potentially more disruptive than downstream market developments, which are more gradual in nature.

Considering downstream markets, we addressed the future of construction as a main potential driver of the demand for commodities like cement, steel, glass and brick. This will depend on the level of new-built versus renovation, the uptake of alternative building materials, and government infrastructure spending among other factors. With high current growth rates, datacentres are highly relevant to consider as emerging energy demands. However, their future growth rates and power consumption is highly uncertain, depending on efficiency improvements, the speed of uptake of artificial intelligence and the regional allocation of datacentres to Belgium. We also touched upon the potential role of batteries, plastics and metals recycling in the Belgian future industrial landscape. Last-but-not-least, increased defence spending in the context of NATO's recent 5% commitment could be a relevant driver of the demand for energy-intensive commodities in Europe.

The next main research step is to prepare the CEEP-IT modelling framework to cover the transformation cases and qualitative scenarios discussed in this report.

- From the perspective of the linked CGE – ESOM system, three main classes of economic shocks will be implemented: shocks in international competition, shocks in the input composition of the production processes of firms, and broader economic evolutions driving the demand of energy-intensive commodifies. To implement these shocks, important data challenges apply. Examples are breaking down the representation of imports by geographical scope (global vs. intra EU) and by product, and setting up new Input-Output structures for transformation cases not yet covered in existing supply and use tables.
- Dedicated work on energy system modelling with the TIB3R model will provide complementary work on similar levels. After a model screening, main model updates will be identified and carried out to represent (a selection of) industrial transformation cases not yet included in the model. Model updates may entail additional climate-neutral and circular production routes, enhanced data sets on import options, and alternate demand projections based on assumptions for downstream markets.
- For environmentally-extended Input-Output modelling, a methodological approach will be worked out to link with the results of the CGE and energy system models to use the changes in industrial production and associated energy demand as input. The appropriate level of disaggregation of economic sectors will be a main point of analysis.

The updated CEEP-IT modelling framework will consequently be applied to elaborate on the current qualitative storylines and analyse different modelled Climate-neutral Energy-Economy Pathways with Industry Transformation.

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Appendix 1: Stakeholder engagement

The following table lists all organisations that provided input to the analysis in this report, either via bilateral interviews, participation in the expert panel workshop, or advisory board.

Sectors	Organisation
Steel	ArcelorMittal Aperam Industeel
Chemicals & Fertiliser	Essencia INEOS
Cement & Lime	Febelcem UCLouvain Fediex Carmeuse
Bricks	Fédération Belge de la Brique
Glass	inDUfed AGC
Paper, pulp & printing	inDUfed
Construction	Embuild
Emerging sectors: data centres, clean tech in Belgium	-
Industry cross-sector	Febeliec
System operators	Fluxys Elia
Policy	FOD VVVL
NGO	BBL
Research	VITO-EnergyVille UCLouvain

Appendix 2: Minutes expert panel workshop

General setup

Agenda:

- 10:00 – 10:10 Introduction of participants
- 10:10 – 10:40 Introduction to the project and to the meeting objectives
- 10:40 – 11:50 Roundtables
- 11:50 – 12:05 Conclusion

Purpose of the meeting:

- Presentation of the CEEP-IT project
- Co-creation of scenarios narratives and storylines
- How do our Industrial Transformation Cases fit under each scenario?
- Which policies could lead to, or are needed under, each scenario?

Organization:

- The introduction and conclusion took place in plenary session with all participants in the main Teams room.
- The roundtables were held in three separate Teams rooms. Participants were divided among these three rooms and rotated approximately every 20 minutes.

Discussions / Questions and Answers / Comments

Plenary session

Economic Modelling Approach

Clarifications were given on how investment and economics are handled in the modelling frameworks:

- TIMES model: represents energy system optimization under a central planner perspective, assuming perfect foresight over the defined time horizon.
- Macro-economic models: provide complementary perspectives on economic impacts of green transition and policies. Households, industries and other economic agents optimize their choices independently of each other. They interact in labor, money and commodity markets where supply and demand define price levels endogenously.

Orange flag on costs: participants highlighted that cost modelling remains particularly difficult to capture realistically and should be critically reviewed throughout the modelling work.

Scenarios definition

Question raised on how extreme the scenarios are intended to be.

Clarification: the scenarios are designed as extreme but still plausible cases, not business-as-usual projections.

Climate Targets

Open question: are targets applied only for 2050, or also for intermediate years such as 2030 and 2040?

Decision pending: still to be determined within the project.

Relocation Drivers

Relocation of industry is considered primarily as a consequence of competitiveness issues. Current drivers: mainly energy and carbon costs, not renewable energy availability.

Scenario Naming

Suggestions were made to revisit the naming of scenarios for clarity and consistency:

- *GREEN-IT*: to highlight ambitions of climate neutrality, circularity, and the EU Green Deal.
- *SHIFT-IT*: as an alternative to "CHANGE-IT", emphasizing that GREEN-IT itself already represents a large transformation.
- *LEAVE-IT*: retained for the deindustrialization-oriented scenario.

Room 1: KEEP-IT scenario

Clarification on the name and scope of the scenario

- Several participants pointed out that the name KEEP-IT is misleading. The scenario does not represent a status quo, but rather the maintenance of industrial production in Belgium/Europe through profound transformation. Some suggested renaming it to *Keep the industry, change the conditions of production.*
- The scenario is perceived as aligned with the European Commission's "desired" pathway, but its optimistic character raises doubts about plausibility.

Technologies and trajectories

- Integrating very different technological pathways into one scenario (e.g. massive electrification vs. CCS at scale) is challenging.
- Participants stressed the need for sensitivity analyses on key assumptions (electricity prices, CCS potential, cost of imported molecules, etc.).
- CCS was highlighted as a critical assumption: if large-scale CCS is available and affordable, TIMES will choose it; if not, other technologies will dominate. Participants suggest to run sub-scenarios or sensitivity analysis on CCS.

Costs and competitiveness

- Concerns were raised regarding additional costs: breakthrough technology CAPEX, energy-related OPEX, and infrastructure requirements. Even with competitive electricity prices, the massive investments required will increase product prices, which creates problems for exports and domestic demand.
- Risks to international competitiveness and domestic demand were highlighted, especially if product prices rise due to costly investments. It should be noted that international competitiveness and its impact on domestic demand are not taken into account in the TIMES model.

- The assumption of stable demand for industrial output was considered unrealistic under these conditions.
- Uncertainty about the future ETS market is important

Industrial Transformation Cases (ITCs)

- ITCs listed (e.g. primary steel, electrification of glass furnaces, clinker substitution) were deemed broadly relevant but require sector-specific refinement.
- For cement, the assumption of CCS in 2030 but not in 2040 was flagged as incoherent – such investments cannot be temporary. In general, it is essential to ensure the consistency of the trajectories in the model (one should not invest in a technology only to abandon it later). It should be noted that, in TIMES, CCS available from 2030 means that it will also be available in 2040 (and 2050).
- In glass, full electrification and CCS were seen as mutually exclusive options.

Room 2: CHANGE-IT scenario

Scenario nature

- Defined as a deeper transformation of the industrial sector, with specialization in high value-added activities (pharma, semiconductors, data, aerospace, etc.), while relocating hard-to-abate and energy-intensive sectors.
- This relocation is an assumption and should be treated carefully. Participants stressed the need to clarify which parts of the value chain relocate, and under which conditions.
- The scenario raises risks of greater dependency on imports, and with it, concerns about strategic autonomy, supply stability, and exposure to price volatility.
- Some noted the scenario can look close to LEAVE-IT unless nuances are made clear (partial relocation, selective retention of key industries, or premium product niches).

Relocation

- Key distinction between relocation inside the EU and outside the EU, as impacts on ETS/CBAM differ strongly.
- Relocation should not automatically be seen as negative. Some industries may remain in Belgium if competitiveness and policy support are adequate.
- For cement and clinkers relocation is especially sensitive. Without CCS, the risk is full carbon leakage — effectively turning CHANGE-IT into LEAVE-IT.
    - Imports of clinker were debated: questions about how much could realistically be imported, whether this is technically and economically feasible, and whether transport emissions and costs are sufficiently captured in the model.
- It’s important to reflect relocation carefully in the report. It is a “touchy” subject:
    - Does it mean full closure of some industries, or a general decline in production across all actors?
    - To what extent relocation will impact production and demand?

Economic and social implications

- Results will need to be analysed from an economic perspective: how would the Belgian economy react to relocation and partial deindustrialisation?
- Two relocation scenarios might be too much — risks confusing the narrative. Suggestion to keep one grounded scenario that explores realistic pathways.
- Welfare risks are significant if industrial decline is not offset. The services economy alone is unlikely to offset industrial decline
- Participants asked: can the model show a stable cement production level in Belgium while increasing imports? This would be one of the hardest cases to sustain.
- Education and workforce retraining policies will be essential to accompany restructuring.
- Importance of fostering new business models / innovation and ensuring a minimum of strategic production capacity in Belgium to safeguard resilience.

CCS and technological aspects

- Participants stressed CCS remains necessary for specific sectors such as cement; otherwise, the scenario risks converging toward LEAVE-IT.
    - Cement and clinker are not highly specialized → Belgium cannot rely on comparative advantage. CCS is indispensable for avoiding full relocation.
- CCS remains a huge topic for Belgium, especially for cement, and must be operational by 2029. Without CCS, the system does not work → carbon leakage.
- CCS may be delayed, which changes the timing of relocation and demand shifts in the model.
- Green products (low-carbon cement, green steel, green glass, etc.) should be explicitly included in TIMES to test demand-side drivers and procurement policies.
- Electrified cracking was ruled out as a realistic option for Belgium in the next 10+ years.
- Debate on the clinker import hypothesis: feasibility was questioned due to transport costs, environmental impacts, and technical limitations.

Modelling concerns

- TIMES optimises on least-cost solutions, but misses social, welfare, and competitiveness aspects. TIMES results should be complemented with macroeconomic analysis, as TIMES optimises costs but does not capture distributional or social impacts.
- Calls for inclusion of transport-related costs linked to increased imports. Transport modelling (scope 3 emissions, logistics costs) is not yet captured but should be considered if imports become a defining feature of the scenario.
- Participants called for a more “patchwork” or hybrid pathways, not binary (all relocation vs. none). A pathway approach may be the only viable one.

Policy assumptions

- Several participants highlighted the unrealistic assumption of perfect CBAM protection. Current CBAM design has significant loopholes, and its effectiveness should not be taken for granted in the narrative.
- For cement specifically, public procurement policies could be a strong driver of demand for low-carbon products.

- Technology subsidies and demand-side pull measures could help keep part of the industry in Belgium while still pursuing relocation in others.

Room 3: LEAVE-IT scenario

Imports & CBAM

- Question: do we have a CBAM in this scenario (even a "small" one)?
  - The presence (even limited) of a CBAM mechanism must be considered.
- Critical to clarify whether imported products are carbonized or decarbonized.
- If imported goods' carbon prices are correctly accounted for under CBAM, the scenario becomes unlikely.
- Imports of cement and clinkers are feasible but would require new infrastructure (terminals).

Climate Targets & Carbon Leakage

- Current formulation ("climate targets are met") is misleading. Relocation reduces emissions in Belgium/EU but causes carbon leakage. More accurate: decarbonization targets for Belgian industry are met, but global climate targets are not achieved.
- In this project, TIMES modelling framework applies national level climate targets applied to all sectors as a whole.

Economic and Social Implications

- Progressive deindustrialization is already happening; the scenario is then plausible to a large extent.
- This scenario would likely lead to a recession and stagnation in Europe.
  - A transition to a services-based economy is unlikely to offset industrial decline: services are largely industry-dependent.
  - These negative impacts need to be understood

Industry Retention vs. Relocation

- It is important to avoid framing relocation only as negative. Some industries may leave while others remain strategically important. This is not necessarily negative. This scenario may serve to break these taboos and could help to explore questions that should be addressed
- Open societal debate is needed:
  - Which industries do we want to keep, and why?
  - Are they policy tools to decide?
- Paper and glass industries highlighted as essential for other sectors (insulation, packaging…). In this context we should acknowledge that this scenario would have consequences for strategic autonomy and lead to dependencies on imports of highly needed commodities.
- When speaking of relocation, it is relevant to be explicit about intra-EU relocation vs. relocation globally. EU relocation is also about current production overcapacities, which makes it relatively flexible to move production to another country if it has better conditions (energy costs, but also labor and other factors).

Other Challenges & Opportunities

- Beyond CO_2, we also have a plastics crisis. The role of reduced use of plastics could be considered under this scenario.
- Construction sector faces major barriers in addition to energy costs: renovation, availability of products and labor force. Materials substitution in construction could be relevant to consider under this scenario, for example a transition to more bio-based materials (opportunities for agricultural production). Materials recycling, upcycling rather than downcycling
- Under this scenario, value chains are likely to weaken; import dependency increases.
- Other drivers are relevant under this scenario. Besides policy failures, also consequence of global situation (energy cost, energy mix, cost of workers,…)

Policy failures and policy recommendations

- Explicit treatment of carbon leakage and intra-EU vs. global relocation.
- Clearer specification of services sector development under this scenario.
- Debate on strategic industry choices (which to retain, which to let go).
- Consider systemic crises beyond CO_2 (plastics, raw materials, construction inefficiencies).
- Acknowledge risks for strategic autonomy and dependency on imports.

Appendix 3: Modelled ITCs

The following table lists the ITCs reflecting climate-neutral and circular production routes that were not classified *a priori* under a scenario, since their uptake is rather considered an outcome of the modelling exercise.

Sector	Product	ITC
Iron & Steel	Primary steel	Investment in H2-DRI-EAF route
	Primary steel	Biomass use in primary steelmaking expands
	Primary steel	CCS becomes a viable technology
	Secondary steel	Electrification and hydrogen use.
	Secondary steel	Alternative fuels for the furnace: biogas, e-methane for the hot rolling furnace
Chemicals	Ammonia	Blue/green ammonia routes.
	Ethylene	CCS/CCUS becomes a viable technology.
Non-metallic minerals	Cement	CCS
	Cement	Electrification of processes
	Cement	Hydrogen combustion
	Cement	Biogas combustion
	Lime	CCS
	Lime	Hydrogen combustion
	Lime	Biomass combustion
Glass	Flat glass	Hybrid furnace combining electrofusion and oxygen-gas combustion (50-50)
	Container glass	Hybrid furnace combining electrofusion and oxygen-gas combustion (70-30)
	All	Hydrogen furnaces
	All	Carbon capture and storage
Bricks	All	Furnace electrification
	All	Dryer electrification
	All	Hydrogen furnace
	All	Biogas furnace
	All	CCS
Paper, pulp & printing	All	Electrification of the dryer
	All	Fuel switch to biomass or biofuels
	All	BECCS (Bioenergy with Carbon Capture and Storage)