The Power
Of Perspective

PATHS2050 Coalition

Belgian Energy System Pathways 2025

Executive Summary
d.d. 23rd of April, 2025

Purpose and content

How Belgium can become climate-neutral by 2050 while maintaining industrial resilience, is one of the most profound societal and economic challenges of the century. VITO, partner in EnergyVille, has therefore joined forces with ArcelorMittal, BASF, Elia, Fluxys and Luminus – key players in the Belgian energy system – within the PATHS2050 Coalition to jointly outline possible pathways that can serve as a compass for policymakers and industry to navigate this complex and urgent transition.

Content

1. Modelling cost-effective pathways to net-zero

VITO/ EnergyVille and the PATHS2050 Coalition have explored a wide range of pathways to achieve a Belgian energy system that leads to net-zero CO_2 emissions by 2050. Three main scenarios have been developed, with key messages derived from these and supported by insights from sensitivity scenarios.

The analysis is data-driven, using the TIMES-Be model, which optimizes cost-effective net-zero pathways based on evolving technical and economic parameters while ensuring energy service demands are met from today, all the way up to 2050. This way the model creates least-cost roadmaps, giving insights in what we should do by 2030 and 2040 to reach net-zero by 2050. Due to the long time horizon for the scenario calculations, the model uses a more aggregated temporal representation within 1 year (10 representative days, each divided in 12 2-hourly timeslices). This means the model is not suited for and is not doing an adequacy analysis of the Belgian electricity system.

The model applies a sector-wide CO_2 price (ETS and non-ETS), following a trajectory of €185 per ton in 2030, aligned with previous PATHS2050. By 2040, the price increases to €295 per ton, which is slightly lower than in previous PATHS2050 analyses but aligns with carbon values from European Commission modelling. By 2050, the price reaches €480 per ton, fully in line with European Commission projections.

All euro values in this document are expressed in 'euro 2024 constant' values.

2. The 3 main scenarios – Key input assumptions

In the three main pathways, industrial production in Belgium remains at the same level as today. This assumption allows to analyse how our energy system should evolve to sustain this production level while achieving net-zero emissions. All pathways have access to 8 GW of Belgian offshore wind and can invest up to 100 GW of PV in Belgium. Furthermore, Belgium is interconnected with its neighbour countries and the option to invest in more interconnections. The future of the neighbour countries' electricity systems is based on the ENTSO-E TYNDP 2020 Distributed Energy scenario, which projected nearly 700 GW of wind power, 750 GW of solar PV, and 90 GW of nuclear capacity across Europe.

2.1. ROTORS scenario

What could the future look like if the energy system leans heavily into renewable energy, with wind energy at the forefront?

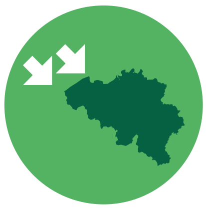
In the **ROTORS scenario**, the model is allowed to invest in up to up to 8 GW within and an additional 16 GW offshore wind energy outside the Belgian territorial waters. In addition, onshore wind energy is fully facilitated up to 20 GW, while biomass, biogas and biomethane becomes available in larger quantities (up to 43 TWh/a by 2050). Furthermore, this scenario has access to nuclear power production with a 20-year operation extension of Doel 4 and Tihange 3, together 2 GW up to 2045. From 2045 onwards the model can invest in additional Small/Advanced Modular Reactors, up to 4 GW. Carbon Capture Utilisation and Storage (CCUS) becomes available from 2030, with transport and storage costs expected to decline towards 2050. However, we assume Belgium has limited access to commercial storage, with a maximum annual storage of 10 Mton CO_2.

2.2. REACTORS scenario

What could the future look like if the energy system is bolstered by new nuclear energy capacity, ranging from large scale to small scale modular reactors?

In the **REACTORS scenario**, Belgium is allowed to invest in up to 8 GW offshore wind domestically and can access only 6 GW of far offshore wind outside the Belgian territorial waters, directly connected to its power grid, instead of 16 GW. In addition, the onshore wind potential is limited to 10 GW, half of the technical potential in Belgium, due to permitting issues. Biomass, biogas and biomethane availability is more limited (up to 29 TWh/a by 2050). The pathway explores the impact of having access to a large nuclear capacity in Belgium. Apart from the 20-year operation extension of Doel 4 and Tihange 3, a new 1,6 GW EPR Gen III+ nuclear plant was introduced into the model as a given,, operational by 2040. Furthermore, the model can invest in additional Small/Advanced Modular Reactors, which are allowed to be operational from 2045 onwards. The total new nuclear capacity can amount up to 8 GW in Belgium, as sum of the EPR and SMRs. As in the ROTORS scenario, CCUS is available from 2030 onwards, with unlimited access to commercial storage.

2.3. IMPORTS scenario



What could the future look like if the Belgian energy system relies more on electricity imports and gains access to cheaper molecules?

In the **IMPORTS scenario**, Belgium, like in the REACTORS scenario, has access to 8 GW offshore wind domestically, 6 GW of far offshore wind and 10 GW of onshore wind. Biomass, biogas and biomethane availability is in line with the ROTORS scenario and increases to 43 TWh/a by 2050. In this scenario Belgium steps out of nuclear energy after the approved 10-year extension of Doel 4 and Tihange 3. So, no 20-year operation extension of the existing plants and no new investments are allowed in large or small scale modular reactors. In the IMPORTS scenario, we assume a global expansion of the hydrogen and derivatives market, enabling molecule imports at progressively lower costs, reaching 80 €/MWh (equivalent to 2.4 €/kg H_2) by 2050. As in the REACTORS scenario, CCUS is available from 2030 onwards, with unlimited access to commercial storage.

3. Key insights from the PATHS2050 scenarios

All three modelled scenarios reduce CO_2 emissions to nearly zero by 2050. This outcome is based on how the model was set up: it assumes net-zero CO_2 emissions by 2050. Other greenhouse gases such as N_2O, CH_4 and F-gases are not included.

High CO_2 prices, assumed at 480 euro per ton by 2050, are effective in reducing emissions. However, without additional complementary policies, they are not sufficient to achieve net-zero in Belgium, with emissions reaching approximately 8–9 million tonnes per year. This conclusion is based on a near-zero sensitivity run.

3.1. Final energy demand and electrification

In all three scenarios, Belgium's final energy demand (excluding feedstock) decreases by a third, from over 350 TWh in 2023 to about 250 TWh by 2050. This is mainly due to efficiency gains and electrification of end-user demands such as buildings (use of heat pumps) and road transport.
Electricity use more than doubles in all scenarios, from 80 TWh in 2025 to 155-170 TWh in 2050. Electrification is a no-regret measure, particularly for building heating and road transport. From 2030 onwards, industry offers the highest electrification potential, although this depends strongly on the availability of CO_2 storage.
Growth in electricity demand between today and 2050 includes:

- Road transport: +8 TWh by 2030, +14 TWh by 2050

- Buildings (residential and commercial): +7 TWh by 2030, + 15 TWh by 2050
- Industry: +6 TWh by 2030, +14 TWh by 2050 (potentially more if CCS is limited)
- Data centres: from 2 TWh today to 12 TWh in 2050

3.2. Electricity generation and system needs

All scenarios require a significant increase in power generation and capacity to keep pace with rising electricity demand. Accelerated investments are needed to:

- Expand offshore wind—both in the Belgian North Sea and far offshore—to nearly full potential is a no-regret option. Grid connections to the mainland and reinforcements within Belgium are essential and at least 3,5 GW offshore wind is made available by 2030.
- Build out PV capacity at a steady, high pace, to at least 40 GW by 2050 (up from over 10 GW end of 2023)—averaging 1,2 GW per year. As a reference: in the record year 2023, Belgium added 1,8 GW of new PV capacity.

Firm capacity remains important. New gas turbines (CCGTs and CHPs) are required to accommodate the closure of nuclear capacity. These newer, more efficient turbines can support a net-zero 2050 future, running on synthetic gas, biomethane, or potentially hydrogen. Even in scenarios with flexible nuclear capacity, at least 7.5 GW fuel-based thermal capacity is needed by 2050, rising up to 9.3 GW depending on the scenario.

Belgium remains a net importer of electricity in all scenarios, with imports ranging from:

- 7 TWh/year in the ROTORS and REACTORS scenario
- Over 30 TWh/year in the IMPORTS scenario

3.3. The role of Carbon Capture and Storage (CCS)

CCS will play a crucial role in reducing hard to decarbonise CO_2 process emissions. It is not economically viable for power generation. Starting from 2030 with pilot projects, the model assumes CCS scales to 20 million tonnes per year by 2040 and stays constant through 2050.

A scenario without CCS is feasible but would be more expensive and requires much higher imports of green molecules. In the ROTORS scenario, limited access to CCS combined with locally produced hydrogen enables domestic e-molecule production.

3.4. Methane and biomethane in the energy system

Methane remains important in a net-zero system. Today, natural gas—of wich methane is the largest component—makes up over 100 TWh of the final energy demand. By 2050, this drops to 21-35 TWh, depending on the scenario. In the scenarios with unlimited access to CCS, more natural gas remains in the energy system.

Key trends include:

- Phase-out in low-temperature heating in buildings and industry
- Continued use in high-temperature industrial processes
- Peak natural gas use in power generation towards 2030, increasing from 42 to more than 50 TWh depending on the scenario. Towards 2050, gas turbines will be used as peak plants, with low operating hours.

Natural gas is gradually replaced by:

- Imported e-methane (3-8 TWh), particularly for international aviation
- Hydrogen derivatives
- Biomethane and biomass (29-43 TWh combined, domestic and import)

Biomethane is mainly used in maritime transport for dual-fuel engines, helping to mitigate the higher cost of e-methane. Solid biomass is predominantly used in industry, and for electricity and heat production (CHPs). When combined with CCS in industry, this can lead to negative emissions, which would not be possible when biomass would be converted into biofuels and used in road transport or aviation.

3.5. Demand and supply of clean molecules

Clean molecules such as hydrogen, e-methane, e-methanol, ammonia and synthetic fuels will gain in importance in a net–zero emission future. Their role in the final energy demand remains very limited due to cost, with electrification almost always the better option.

However, EU legislation (e.g. RED III, FuelEU, ReFuelEU, ETS) will push their use in:

- International aviation (70% sustainable fuels by 2050)
- Maritime transport (net-zero by 2050)

That way, international transport will account for at least 57 TWh in all scenarios.

Apart from international transport, clean molecules are also needed in:

- Remaining refinery operations
- Industrial feedstocks
- Power generation: 4 TWh (ROTORS/REACTORS), up to 20 TWh (IMPORTS)

The supply of clean molecules depends heavily on import. By 2050, the high need for clean international transport fuels such as e-methane, ammonia and e-kerosene will push the import of clean molecules to at least 69 TWh, up to more than 100 TWh in the IMPORTS scenario with lower costs for clean molecules.

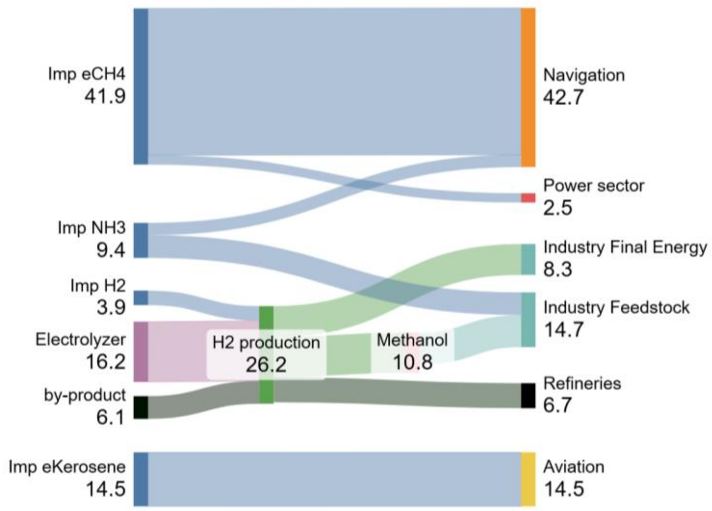


Figure 1: ROTORS scenario Supply and Demand of Clean Molecules in 2050 (hydrogen, e-methane, e-methanol, ammonia and synthetic fuels)

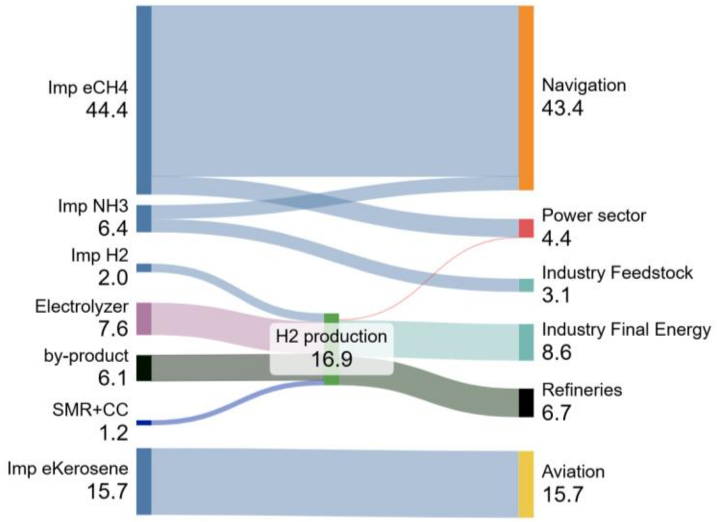


Figure 2: REACTORS scenario Supply and Demand of Clean Molecules in 2050 (hydrogen, e-methane, e-methanol, ammonia and synthetic fuels)

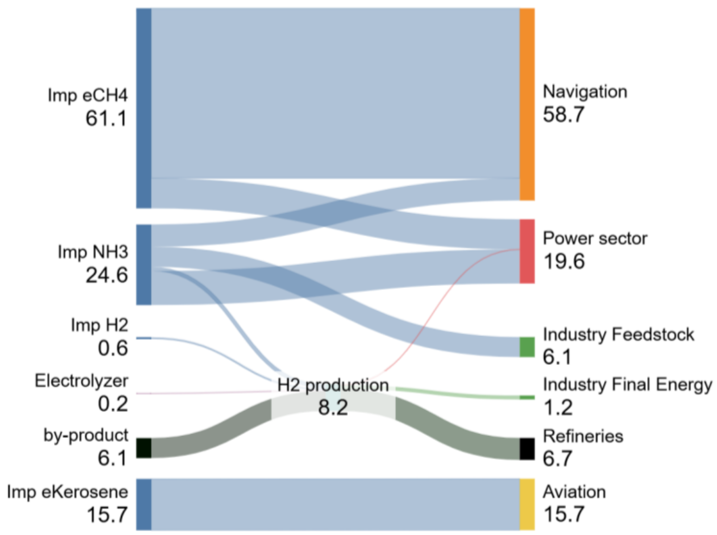


Figure 3: IMPORTS scenario Supply and Demand of Clean Molecules in 2050 (hydrogen, e-methane, e-methanol, ammonia and synthetic fuels)

3.6. Domestic hydrogen production

Domestic green hydrogen production from electrolysers linked to renewable production will be negligible. Exceptions include:

- E-hydrocarbon production can become economically viable when having access to large quantities of affordable electricity while having limited CCS storage potential (ROTORS)
- Availability of nuclear SMRs enables high-efficiency hydrogen production via Solid Oxide Electrolysis (SOE): 7-16 TWh by 2050
- Hydrogen as a by-product of refineries and chlorine production: up to 6 TWh

3.7. Investment needs and system costs

Large-scale domestic low-carbon electricity production helps reduce long-term system costs, though it requires significant upfront investment. Total system costs include capital and operational expenditures, alongside evolving fuel costs. Savings are driven by a sharp decline in fossil fuel imports.
The ROTORS and REACTORS scenarios show similar total system costs. Differences between them fall within the margin of uncertainty for technology costs. Rather than debating small cost variations, the focus should be on ensuring electricity supply and implementing a robust long-term strategy. Between 2040 and 2050, these scenarios require annual investments of around 12.5 billion euro in the electricity sector.

Even in the IMPORTS scenario, total system costs are also in the same range. Lower costs for imported molecules help compensate for higher electricity import costs. By 2050, total costs in the IMPORTS scenario are around 3 billion euro lower. However, this difference is smaller than the potential impact of price shocks.

If molecule prices in the IMPORTS scenario turn out to be similar to those in the ROTORS or REACTORS scenarios, total annual costs could increase by 8.6 billion euro by 2050. In that case, IMPORTS becomes the most expensive scenario. Although it requires lower domestic investments, higher imports of molecules and electricity make Belgium more susceptible to price volatility.

4. Our recommendations

Under all three scenarios, electrification leads to a one-third reduction in Belgium's total energy consumption by 2050 – down to 250 TWh. At the same time, electricity demand at least doubles to 155 TWh, mainly due to the electrification of buildings, road transport and industry. Meeting this growing electricity demand will thus require significant investments in wind energy and electricity infrastructure, regardless of which pathway is chosen.

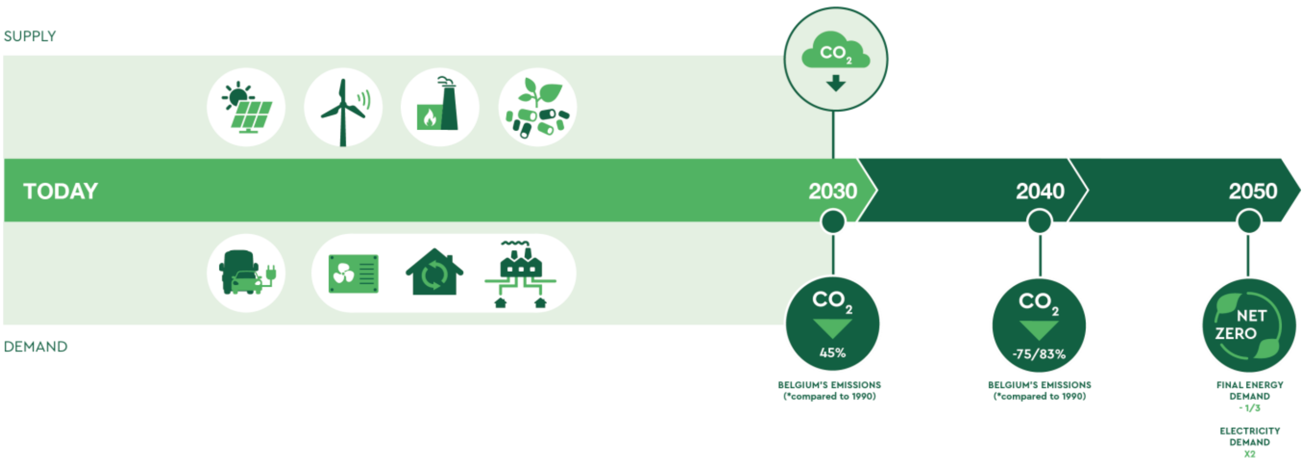
Across all three scenarios, we therefore propose the following short-, mid- and long-term recommendations.

4.1. In a nutshell

4.1.1. Short-term recommendations: what do we need to do between now and 2030?

Cut Belgium's emissions by 45% compared to 1990 levels by:

- Accelerating the electrification of road transport and buildings by speeding up the rollout of electric vehicles and heat pumps.
- Scaling up wind and solar power generation, and doing so rapidly.
- Banning new fossil heating systems in buildings and expand district heating networks.
- Investing in new gas-fired power plants to support electricity production.
- Defining a clear policy framework for CO_2 storage projects such as Kairos@C, Go4Zero and H2BE to enable upscaling by 2040.



4.1.2. Mid-term recommendations: what do we need to do between 2030 and 2040?

Cut Belgium's emissions by 75%-83% compared to 1990 levels by:

- Ensuring that at least 50% of non-residential and 80% of residential buildings use heat pumps or district heating.
- Electrifying nearly all road transport.
- Securing access to additional offshore wind capacity beyond the Belgian North Sea.
- Deploying large-scale battery systems and enable vehicle-to-grid use for daily storage and self-consumption.
- Building CO_2 pipeline infrastructures to allow for transport and storage.

4.1.3. Long-term recommendations: what do we need to do between 2040 and 2050?

Reach net-zero climate neutrality by:

- Switching entirely to climate neutral energy sources in both buildings and transport.
- Developing flexible nuclear capacity that complements variable renewable energy, f.e. by producing hydrogen when there is a surplus.
- Collaborating internationally to import hydrogen carriers and synthetic fuels such as ammonia, e-methane, methanol and e-kerosene for hard-to-abate sectors.
- Capture and store carbon emissions from energy-intensive industry.

4.2. Our recommendations in full detail

4.2.1. Short-term recommendations: what do we need to do between now and 2030?

Belgium can **reduce its emissions by 45% by 2030 compared to 1990 levels**, according to the TIMES-Be model used in this study. The model shows that both high (185€/ton) and —interestingly— even lower (80€/ton) CO_2 prices in 2030 lead to comparable emission reductions, because the system anticipates the need to reach net-zero by 2050 and reacts to increasing CO_2 prices over time.

However, in a sensitivity scenario where CO_2 prices remain lower (80€/ton by 2030) and no long-term climate neutrality target is assumed, the outcome is very different: industrial emissions barely decline, and the total emissions reduction by 2030 drops to just 37%. This underlines the importance of maintaining a clear long-term decarbonisation trajectory.

By 2022, sectors under the EU Emissions Trading System (ETS) had already reduced emissions by 38%, while non-ETS sectors had only achieved a 7% reduction. This leaves a significant remaining gap of 36 percentage points to close in the non-ETS sectors by 2030.

Changing how we use energy

Transport: Electrification is key

Rapid electrification of road transport plays a crucial role in reducing emissions. By 2030, **nearly 2 million fully electric vehicles** are expected on the road. To achieve this, annual EV sales must double within the next three years, targeting a 60% market share. This electrification trend is consistent with the requirements of the RED III regulation for transport.

Buildings: Renovation, heat pumps and district heating

In both residential and commercial buildings, a strong increase in insulation is needed before 2040. This requires immediate action. In the residential sector, the model assumes a 4% annual renovation rate, leading to a 50% reduction in heat demand in 20% of the current building stock by 2030, especially in homes with energy label D or lower.

The model finds that **no new fossil-based heating systems** are cost-optimal, neither in residential nor in commercial buildings. As a result, demand is progressively electrified. Replacing fossil heating systems requires the same 4% annual rate, which would result in around 30% of homes using heat pumps or district heating by 2030. This transformation represents a greater effort than insulation, as it is only just beginning. Ideally—according to the model, which does not account for system inertia—this share would reach 43% by 2030 (36% via electric heat pumps and 7% via district heating), compared to less than 10% today.

Industry: Electrification of low-temperature processes

In the industrial sector, electrification is applied to low-temperature heat demand, notably in the **food, pulp, paper, and wood sectors**, which switch to heat pumps.

Changing how we produce energy

Wind and solar: The need for speed

To meet growing electricity demand, **renewable energy generation** must expand significantly.

Offshore wind capacity should increase rapidly, **both in the Belgian North Sea and through direct connections to far offshore zones**. The model finds it cost-effective to have access to more than 7 and up to 9.3 GW of offshore wind capacity by or shortly after 2030. This highlights the urgency of establishing a cross-border framework to accelerate the realisation of existing offshore ambitions.

For **solar PV**, the model indicates a need to **maintain an installation rate of more than 1 GW per year** from now onward, to reach 17–19 GW of capacity by 2030. The model does not provide insights into grid balancing, capacity needs, or storage due to its annual time resolution. Therefore, additional studies are needed on the integration of large volumes of PV and storage solutions.

Thermal generation: Securing backup capacity

New thermal capacity—including natural gas-based CHP and combined-cycle gas turbines (CCGTs)—will be **needed to ensure electricity supply during periods of low renewable generation**. Total capacity may reach 9–10 GW. These plants will operate most intensively between 2025 and 2030, compensating for reduced nuclear capacity. Newer, high-efficiency units may run for more than 4,500 hours annually in this period.

Nuclear energy: Deciding on lifetime extension and planning ahead

To extend the operation of 2 GW of existing nuclear capacity (Doel 4 and Tihange 3) by 20 years, a decision is needed by 2030. If Belgium intends to deploy new nuclear capacity by 2040–2045, a **long-term framework must be designed**. This includes clear commitments related to capital, human capital, public and private sector responsibilities, locations, and permits.

Carbon Capture and Storage: Laying the foundation

To enable the first CCS projects in Belgium by 2030—and to allow for significant expansion by 2040—**a clear CCS policy framework** must be put in place. By 2030, CO_2 capture volumes of **1.5 to 4 million tonnes** could be achieved through projects such as Kairos@C, Go4Zero, H2BE, and others.

4.2.2. Mid-term recommendations: what do we need between 2030 and 2040?

CO_2 emissions should decrease by 75-83% compared to Belgium's 1990 emissions, to be on track for achieving 2050 net-zero.

Evolving energy demand

Transport: Widespread electrification and new fuels

By 2040, road transport is **almost fully electrified** across all modelled scenarios, confirming it's the cost-effectiveness of electrification as a no-regret measure. Unlocking **the flexibility potential of vehicle-to-grid applications** will require early coordination among policymakers, grid operators, vehicle manufacturers, charging infrastructure providers, and end users—starting in the early 2030s.

In international transport:

- **Aviation** will need to use at least **34% sustainable aviation fuels** (SAFs), amounting to 3 TWh of fuel demand for Belgium.
- The **maritime sector** must reduce carbon intensity by 31%. Compliance with the legislation can be achieved through **the use of dual-fuel LNG engines**, which are 30% more efficient and have a 24% lower emission factor than traditional heavy fuel oil.
- In the IMPORTS scenario, **access to cheaper green ammonia** leads to an uptake of 2 TWh as maritime fuel by 2040.

Buildings: Deep renovation and fossil phase-out

Efforts in the buildings sector—both residential and commercial— must remain just as high after 2030 as before. In the residential sector, maintaining a 4% annual renovation rate would result in a 50% reduction in heat demand across 60% of the current building stock. At the same time, phasing out fossil heating at a similar 4% would lead to **around 70% of homes using heat pumps or district heating by 2040**.

In densely populated areas, **district heating networks will expand**, delivering up to 11.5 TWh of heat from sources such as waste incineration, deep geothermal energy, and biomass-fueled CHP. By 2040, oil heating will be nearly phased out, with less than 4 TWh of demand remaining.

Expanding and balancing energy supply

Electricity system: Renewables, flexibility and imports

Total renewable electricity capacity grows to at least 44 GW, with major investments in:

- Offshore wind: 11–16 GW
- Onshore wind: 8–10 GW
- Solar PV: In scenarios with less offshore wind and/or nuclear capacity (REACTORS and IMPORTS), PV capacity increases to 20–29 GW

To maintain system stability, batteries and vehicle-to-grid solutions play a key role in day-night storage and flexibility:

- Battery storage reaches 1.3–2.5 GW by 2040, in line with the temporal detail the TIMES-Be model captures. This reflects the minimum needs, and actual needs may be higher when accounting for different weather years and using more detailed temporal modeling, including grid balancing and ancillary services.
- Vehicle-to-grid is providing 0.5–0.7 GW of storage/flexibility.

In the IMPORTS scenario, 1 GW of additional interconnection capacity is needed by 2040, enabling up to 25 TWh of net electricity import.

Nuclear energy: Waiting for small/advanced modular REACTORS

The TIMES-Be model does not invest in large scale, non-flexible nuclear capacity (EPR Gen III+) based on least-cost optimisation, but, knowing they become available, decides to wait for small/advanced modular REACTORS to appear by 2045.

To test the impact of new nuclear, a sensitivity analysis includes a forced investment in one 1.6 GW large non-flexible reactor from 2040 onwards. This leads to similar flexibility needs–gas turbines and 2.5 GW of battery storage–as the IMPORTS scenario without new nuclear. The analysis shows that if SMRs are available and cost-competitive by 2045, there may be no added value in investing in a large EPR Gen III+ reactor–either from an energy system perspective or in terms of cost-effectiveness. However, in a sensitivity analysis where SMRs are not available, the EPR Gen III+ is selected.

Carbon Capture and Storage: Scaling up fast

Between 2030 and 2040, CCS expands significantly. Total CO_2 captured, transported and stored reaches 20 million tonnes per year by 2040. CCS infrastructure becomes essential to connect industrial sites with hard-to-abate process emissions in sectors such as cement, lime, glass, high value chemicals and iron & steel.

In the ROTORS scenario, where Belgium has a limited access to CO_2 storage, captured volumes are lower–6.5 million tonnes per year–primarily from cement, lime and glass. This scenario results in the highest remaining CO_2 emissions in Belgium across all scenarios: 30 million tonnes per year by 2040.

4.2.3. Long-term recommendations: what do we need between 2040 and 2050?

All modelled scenarios reach net-zero emissions by 2050, with 2 million tonnes of CO_2 emissions remaining. This outcome results from an exogenous constraint on emissions imposed on the model.

Transforming energy demand

Buildings and road transport: Full electrification achieved

By 2050, buildings and road transport–including both the passenger fleet and trucks– are **fully electrified, except for 13 TWh of district heating**. If more biomethane were available, heating buildings in large cities could be achieved without the need to roll out district heating networks.

Industry: Second wave of electrification

From 2045 onwards, a second wave of industrial electrification occurs. In the ROTORS scenario, stable and affordable electricity enables the **electrification of processes such as the naphta cracker furnaces, and specific iron & steel productions steps**, including Electric Arc Furnaces for DRI and the electrification of casting and rolling.

Future energy supply: Balancing renewables, molecules and flexibility

Wind and solar energy: Steady growth to meet rising electricity demand

By 2050, total electricity demand as final energy increases from 155 to 170 TWh, depending on the scenario–IMPORTS being the lowest, ROTORS the highest. To meet this growing demand, the model shows a **continuous expansion of wind and solar PV capacity**, reaching 65 to 80 GW of renewable electricity capacity by 2050.

To ensure balance and flexibility in the system:

- Battery storage capacity increases to 6–7.3 GW
- Vehicle-to-grid services contribute more than 2.5 GW of flexibility

In the IMPORTS scenario, **interconnection capacity expands to over 8 GW** by 2050 (peak import capacity, excluding transit flows), enabling up to 32 TWh of net electricity import.

Thermal generation: Bio-based and clean molecule integration

By 2050, **thermal capacity** (non-nuclear) remains relatively stable at 7.5 to 9.3 GW across scenarios. Within that total:

- **1.8 to 2.6 GW is biobased**, operating more than 3,000 hours annually

The remaining gas-based capacity **switches from natural gas to clean molecules between 2045 and 2050**–driven by the target to reach net-zero–operating a maximum of 1,000 hours per year

Nuclear energy: New capacity in selected scenarios

In the ROTORS and REACTORS scenarios, **new nuclear capacity of 4 to 8 GW** respectively **is** included as part of the energy system after 2040. The REACTORS can **operate up to 7,000 full-load hours annually**, while also providing flexibility when needed.

In these scenarios, nuclear generation is **combined with a Solid Oxide Electrolysers, which can produce up to 16 TWh of hydrogen in ROTORS**. This hydrogen may be combined with captured CO_2 in methanol synthesis, serving as feedstock for plastics production through methanol-to-olefins.

Clean molecules: Demand driven by international transport

The defossilisation targets of international transport–especially maritime shipping and aviation– drives a large demand for clean molecules. The model assumes a **full shift to net-zero in international shipping** and a **70% reduction in emissions from international aviation**, in line with EU regulations. As a result:

- Maritime transport requires 44 to 59 TWh of imported **e-methane and ammonia** by 2050
- Aviation uses up to 15 TWh of **e-kerosene**

The power sector shifts from using natural gas in the thermal plant to **hydrogen, hydrogen-based derivatives, and e-methane** by 2050, from a mere 4 TWh to almost 20 TWh in the IMPORTS scenario.

To unlock large-scale import of green hydrogen derivatives into the EU, **coordinated action is needed** across policy frameworks, strategic port and pipeline infrastructure, and resilient supply chain market dimensions with clear certification, risk-sharing, and digital tracking systems.

Carbon Capture and Storage: Key for hard-to-abate sectors

CCS remains critical to **reduce around 20 million tonnes of CO_2 from hard-to-abate industrial processes and residual fossil energy use**. While fossil fuel use in industry declines by 36 to 54%, it still ranges between 36 to 50 TWh depending on the scenario.

In the ROTORS scenario, the model captures 13.7 million tonnes of CO_2, even though only 10 million tonnes can be stored annually. The remaining 3.7 million tonnes is used for methanol production, as described above.