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Additional investments in existing net-zero emissions scenarios for Belgium: a comparative analysis

March 2025

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Executive summary

As a member of the European union, Belgium's contribution to transition towards a net-zero GHG emissions EU by 2050 hinges on significant changes in investment patterns. Not only the level but also the nature of investments is expected to change. Assessing the necessary investment requirements for decarbonizing the economy is crucial for understanding the macroeconomic impact of the climate transition in Belgium and to inform the societal and policy debate.

A scenario-based approach

This report compares the currently available net-zero transition scenarios published in the last years by both public and private authors in Belgium. These scenarios were developed within their technological and regulatory contexts. As this context is constantly evolving, for instance following the 2025 federal government agreement, other scenarios may be proposed in the future by different authors and could usefully be added to an update of this study.

The different scenarios showcase possible transition pathways or orientations. These pathways reflect important strategic choices that are yet to be made by policymakers. The study identifies the major orientation choices and evaluates their relative investment needs as well as their recurrent costs/savings implications.

A common feature among the scenarios across all sectors is the use of numerous energy efficiency levers (such as building insulation and heat pump installation) and the adoption of non-fossil energy, primarily through electrification (vehicles, heat pumps, renewable energy sources, and the strengthening of electricity grids). However, these scenarios differ significantly in their reliance on moderating the growth of or even reducing certain activity volumes, such as new constructions or the number of kilometers traveled in personal vehicles (e.g., increased use of carpooling or public transportation), or shifting certain activities (e.g., modal shift).

Four broad conclusions emerge from the analysis and comparison of the scenarios

Firstly, it is observed that potentially very significant investment levels will need to be mobilized by 2050. The analyzed decarbonization scenarios lead to an average total investment (CAPEX) over the period that is equal to or, in most cases, higher than the level observed in 2024[1]. Investment levels could rise by up to approximately 25 billion euros per year on average compared to 2024.

Secondly, there is a significant difference in investment levels between the scenarios. This variation is mainly explained by the extent to which sufficiency levers are used. The reduction in the volume of certain activities (such as the decrease in the number of private vehicles and the reduction in square meters of new construction) significantly limits the total investment requirements in these scenarios.

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[1] The level of investment for the year 2024 is estimated using the same calculation methodologies as described in the appendices, and is therefore not based on actual investment figures in 2024 since these are not available at the necessary level of granularity.

The additional investment expenditures between 2025 and 2050 compared to the current situation in 2024 are as follows. At the upper end of the range, additional investments amount to 25 billion euros (4.3% of GDP) on an annual average; when investments not related to decarbonization technologies in the building sector are included, this amount is reduced to 17 billion euros (2.9% of GDP). At the lower end of the range, scenarios that make the most use of sufficiency levers show an increase of 11 billion euros (1.9% of GDP) on an annual average, a level which is brought down to almost zero due to the reduction in investments unrelated to decarbonization technologies in the building sector.

Thirdly, the composition of investments changes at the sector level.

- In the energy production sector, all the studied decarbonization scenarios anticipate a drastic increase in investment needs. This increase is driven by the rising demand for electricity, the shift in the energy mix toward decarbonized sources, and the necessary development of grids and intermittency management. This results in an investment increase ranging from 3 to 8 billion euros on an annual average compared to the 2024 situation (a three- to sevenfold increase).

- In the transport sector, several effects are at play. On the one hand, the purchase of decarbonized vehicles tends to increase investment costs related to vehicle replacement. On the other hand, depending on the scenarios, part of this mobility is shifted towards public transport (mainly rail or buses). These alternatives require significant additional investment expenditures, but the total investment is still lower than the reduction they generate in terms of individual vehicle investments. Finally, in some scenarios, the demand for individual mobility is reduced or shifted towards active transport modes, which directly decreases investment expenditures. Overall, scenarios that make little or no use of modal shift and mobility reduction lead to investment expenditures up to 71% higher than in 2024. Conversely, scenarios that heavily rely on modal shift and mobility demand reduction lead to a 6% decrease in investment expenditures compared to 2024.

- At the building sector level, there is a shift, or even a transition, in investment expenditures from new buildings excluding decarbonization technologies toward investment expenditures for the decarbonization of new buildings and, more importantly, existing buildings, including demolition and reconstruction. These expenditures for the renovation of existing buildings and the decarbonization of new buildings increase significantly in all scenarios. They rise to levels ranging from 7 to 10 billion euros[2].

As a reminder, the industrial sector could not be modelled in detail, and we refer to specific studies on this subject (see the industry section), which estimate a range of **10 to 40 billion euros** for additional capital investment for industrial decarbonization in Belgium by 2050 (between 0.4 and 1.6 billion euros yearly). This range should be added to the results shown above in order to get a full picture of the total additional investment.

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[2] Excluding scenarios assuming a particularly high level of demolition and reconstruction, an assumption that is currently being revised by the authors of these scenarios.

It is noted that the additional investment levels from these studies appear relatively low compared to the additional investment expenditures in the other sectors. However, this does not imply that these amounts may not be significant at the level of a specific industry or company.

Fourthly, all decarbonization scenarios increase investment expenditures but reduce operational costs compared to a reference scenario characterized by no policy changes. Compared to the historical level, only two scenarios contain rather than reduce operational costs.

This can be explained by a combination of two factors.

- First, many decarbonization levers involve making investments that reduce energy demand. Examples include building insulation, modal shift, and energy efficiency improvements enabled by vehicle electrification.

- Moreover, on the supply side, increased electrification relies heavily on renewable energy sources, which are more capital-intensive than their carbon-based alternatives. As a result, decarbonization scenarios lead to a significant reduction in operational costs (OPEX) associated with the use of carbon-based energy. Even though the price of electricity and, in particular, synthetic fuels may be higher than that of carbon-based fuels, their overall cost is generally lower due to reduced consumption volumes.

Public policy implications and future work

The analyzed scenarios each rely on a set of levers enabling decarbonization. The choice of one scenario over another is a societal/political decision that must consider numerous factors not examined in this report.

The scenarios studied do not specify the public policies that are needed to enable the levers they identified. Nevertheless, one would expect that public intervention is essential for enabling the levers and mobilizing the investments identified in this study.

This report represents the first phase of work aimed at identifying investment needs. A second phase could involve analyzing these different types of public intervention from the perspective of public investment.

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1. Introduction

As a member of the European union, Belgium's objective to transition towards a net-zero GHG emissions society by 2050 hinges on significant changes in investment patterns. Not only the level but also the nature of investments is expected to change. Assessing the necessary investment requirements for decarbonizing the economy is crucial for understanding the macroeconomic impact of the climate transition in Belgium and to inform the societal and policy debate.

The role of public investment in the climate transition is essential and is part of the Study Committee on Public Investment (SCPI) research mandate: "identify the needs and opportunities for public investment, particularly in the context of the dual transition (ecological and digital)."[3] In order to leverage on the best available expertise at the federal level, the SCPI has carried out this research jointly with the DG Environment of FPS Public Health.

The paper answers the following research question: "What are the additional investment needs to reach net-zero by 2050 in Belgium?". This leaves the complementary question of "the role of public finances herein" for further research.

By investigating this question, we intend not only to detail the level of investment requirements but also to showcase the relative weight of the sectors in which investment is required. We explain the dynamics at play that drive the investment needs in each of the sectors.

This paper follows a meta-study approach as it bases itself on a selection of publicly available net-zero transition scenarios published in the last years by both public and private actors in Belgium. Further, the analysis harmonizes cost and certain technology assumptions for all scenarios in order to be able to compare their implications in a neutral manner. As a result, the levels of investment derived from this analysis may differ somewhat from those reported directly by the authors of some of the works analysed.

The different scenarios showcase possible transition pathways or orientations. These pathways reflect important strategic choices that are yet to be made by policymakers. For instance, one pathway might go for high electrification in transportation while another one might also opt for a modal shift. This study identifies the major orientation choices and evaluates their additional investment as well as their recurring costs/savings implications compared to the reference scenarios for those sectors, which are responsible for 90% of GHG emissions in Belgium.

The second section of this study is a literature review of the major international and Belgian studies conducted on the investment needs for climate mitigation and transitioning to a net zero economy. Section three expands on the research question and sets up the main building blocks of our methodology. The fourth section summarizes the sample of scenario's assessed and the most important transition levers they activate (sufficiency, efficiency and technology). The fifth part presents and discusses the salient results, in terms of sectoral investments and operational expenditures estimates. Section six draws the aggregation of total additional investments and its implications. The paper ends with avenues for further investigation.

3 Royal Decree of February 16th, 2023.

2. Literature Review

In today's drive towards achieving net-zero emissions by 2050, scrutinizing and better understanding the financial and investment dimensions of the climate transition is necessary to guide policy choices, also taking into account the constraints on public and private finances. While 2050 may sound far in the future, now is the time to outline these policy choices given the decades-long life cycle of assets and the time needed to adapt behaviours.

As of today, a number of studies have been conducted at the international and national level on the additional investment requirements for climate mitigation for the economy. Generally, these indicate a need of roughly 2 to 3% of global GDP on average through 2050 above current or business-as-usual levels (see below).

Much of the literature points in the same direction, mentioning a substantial investment gap between climate-transition funding as of today and what is required to achieve a net-zero economy by 2050. Various institutions have undertaken research on analogous questions, resting upon a range of different methodologies across various geographical regions and sectors. In this study, several of these studies are referred to, which provide valuable insights for our work. The literature generally does not provide an estimate for the annual additional investment through 2050.

The IEA (2021) and IRENA (2021) have estimated the total investment needs at about 4.8 to 5 trillion US dollars per year to reach net zero on a global scale through 2030. In a similar way, BNEF (2022) has calculated a total investment gap of 4.5 trillion US dollars per year. It is important to note however, that these estimates only provide a view through 2030. Nevertheless, it is safe to say that the figures projected up to 2030 are about three times as high as the total investment observed in 2023, which hovered between 1.8 and 2 trillion US dollars, according to the IEA and IRENA.

Studies have also been carried out at the European level. The Institut Rousseau (2024) and I4CE, the Institute for Climate Economics (2024), have suggested that an additional 360 and 406 billion euros respectively will be needed per year to reach net zero by 2050 in the EU. This infers a need of about 2-3% of the current EU-27 GDP. Furthermore, the Institut Rousseau highlights that the lion's share of the 1,520 billion euros total investment needs cumulated up to 2050 is set to be concentrated in the transport and buildings sectors (45% and 29% respectively). Nevertheless, just 360 billion euros of this amount are considered additional investments as compared to a business-as-usual scenario. Most of the additional investment needs lie within the buildings and energy sectors (39% and 22% respectively).

Earlier in 2025, the ECB[4] published a thorough analysis of additional investment needs by 2030 to decarbonize the EU. They conduct a review of the literature at EU level and advance figures of 2.9% to 4.0% of the EU GDP additional investment needs per year with respect to current levels. They also underscore the high degree of uncertainty of estimates. They stress that both the private and public sector have a role to play in channeling this funding.

[4] Referred to in the bibliography by its authors Nerlich et al. (2025)

Further, Mario Draghi's flagship report on the future of European Competitiveness (2024) estimates that the EU will have to increase its investment by 5 percentage points of its current GDP to enhance competitiveness. This comprises not only the investments aimed at becoming net zero by 2050. It also posits an additional investment need of 340 billion euros between 2025 and 2040 to decarbonize the four largest carbon-intensive industrial sectors[5] in the EU.

At the national level, data remains rather heterogenous, with only a limited number of sources having calculated the additional investment requirements for individual countries. As such, the most notable studies have been carried out in the UK (CCC, 2020) and France (Pisani-Ferry & Mahfouz, 2023). These studies have indicated additional investment requirements of 56 billion and 85 billion euros above current levels, respectively, or between 2 and 3% of national GDPs.

When it comes to Belgium, we can mention seven authors addressing these questions:

- A section of the NECP[6] is focused on required investment to implement the countries' ambitions and estimated them, with few details, at 60 billion euros cumulated until 2030. However, the Belgian NECP is not expected to reach anywhere near net zero emissions by 2050.[7]
- McKinsey (2023) calculated an average annual incremental investment requirement equivalent to 2 to 3% of Belgium's 2022 GDP.
- The National Bank of Belgium (2024) assesses with rough back-of-the-envelope computations that the abatement costs for climate neutrality in Belgium lies around 17 billion euros per year, around 3.5% of today's GDP and in the range of 2 to 3% of the 2050 GDP.
- EnergyVille (2022) evaluated investment and O&M costs related to the energy and climate transition, yet without sharing the baseline that would make it possible to assess the *additional* investment.
- EPOC (2023), BFP (2022), Elia (2022), have assessed energy system costs in a climate neutrality context in a narrower scope, which is the electricity system costs only.

The existing studies have thus different time horizons, sectoral scopes, or reference points, making them difficult to compare.

This study aims to compare the investments of different transition scenarios and therefore follows a holistic and common approach in terms of included sectors, reaching climate objectives (i.e. net-zero by 2050) as well as the level of detail regarding each sector's variables to ultimately examine the financial impact (investments/capital expenditures and recurrent/operational expenses).

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5 Chemicals, metals, non-metallic minerals and pulp and paper products
6 National Energy and Climate Plan (Plan national énergie-climat or Nationaal Energie- en Klimaatplan)
7 Federal Planning Bureau (2024), Energy outlook in Belgium with announced policies

3. Research question and methodology

The mandate of the SCPI refers to the ecological transition, which we understand as an all-encompassing term for various environmental and socio-economic issues. The Stockholm Resilience Centre for instance defines no less than 9 planetary boundaries to look at for an ecological transition, amongst which climate change due to anthropogenic GHG-emissions, biodiversity loss and land use change, ocean acidification, freshwater use and access, etc.

When dealing with climate change, three categories of actions are usually identified: mitigation[8], adaptation[9] and loss and damage[10] recovery. This work focuses on mitigation, i.e., all the actions helping to reach the net-zero GHG emissions target by 2050 for the Belgian economy. One shall note however that approaches for mitigation may have spillover effects on adaptation efforts and/or other planetary boundaries (and vice versa).

The main objective of this report is to provide, for the selected scenarios to reach net-zero, 'order of magnitude' investment and recurrent expenditures estimates, in order to inform decision-makers in the public and private sector in Belgium.

These expenditures are estimated per key emission sector for reaching a net-zero GHG emissions Belgium by 2050 for different transition scenarios published by public and private actors over the last years (see below). The analysis harmonizes the unit cost and prices assumptions (and partly the technological assumptions, when information is lacking) of these different scenarios in order to be able to compare their investment implications.

In this section, we further define our research question and variable of interest (additional investment needs), we detail the economic sectors covered by the analysis and further explain our scenario and modelling approach.

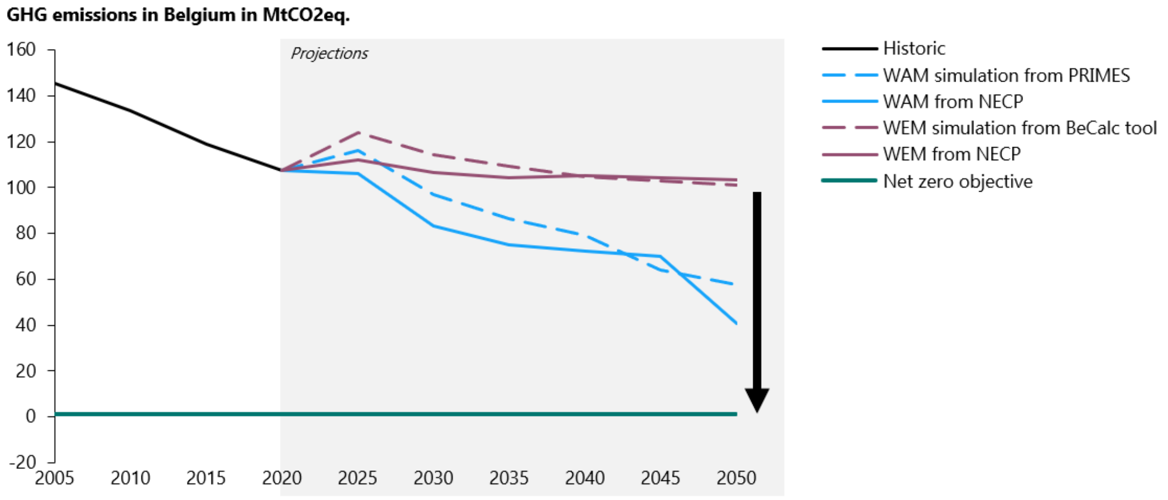
Research question

The Belgian National Energy and Climate Plan (NECP), the official climate change plan of Belgium, provides a projection of emissions through 2030 in a "With Existing Measures" (WEM) situation and in a "With Additional Measures" (WAM) situation. Graph 1 presents an update of these official estimated emissions trajectories for these WEM and WAM pathways up to 2050. These emissions trajectories show that Belgium is currently not on track yet to reach climate neutrality by 2050.

Consequently, this paper seeks to answer the research question "What are the additional investment needs to reach net-zero by 2050 in Belgium?" Asking for *additional* investment needs require to set a reference benchmark against which to compare (see below).

8 actions that deal with the reduction of GHG-emissions
9 actions that deal with the adjusting to the effects of climate change
10 actions that have to do with repairing damage caused by climate change induced hazard

Graph 1 GHG emission projections for Belgium



Note:

1. The WAM simulation was conducted by the Federal Planning Bureau with the PRIMES model and published in a May 2024 paper.
2. The WEM simulation was conducted by SCPI and FPS Health with the BeCalc online simulation tool.
3. WEM and WAM emissions curves are taken from the official reports of the CNC-NKC (exl. LULUCF).

Source: Federal Planning Bureau (2024) and BeCalc tool, all based on updated *draft* NECP (2023) and CNC-NKC (2023).

Variables of interest

This analysis focuses on the capital expenditures (CAPEX) for physical investments and their related operational expenditures (OPEX). The former sometimes extends beyond the accounting category of gross fixed capital formation to include durable consumption goods such as private vehicles. OPEX expenditures are either fixed or variable and relate to operation & maintenance or the use of energy vectors. All prices are expressed in euros of 2024 and all taxes included (excise duties, VAT, ETS 1[11]). CAPEX expenditures do not include cost of capital assumptions.[12]

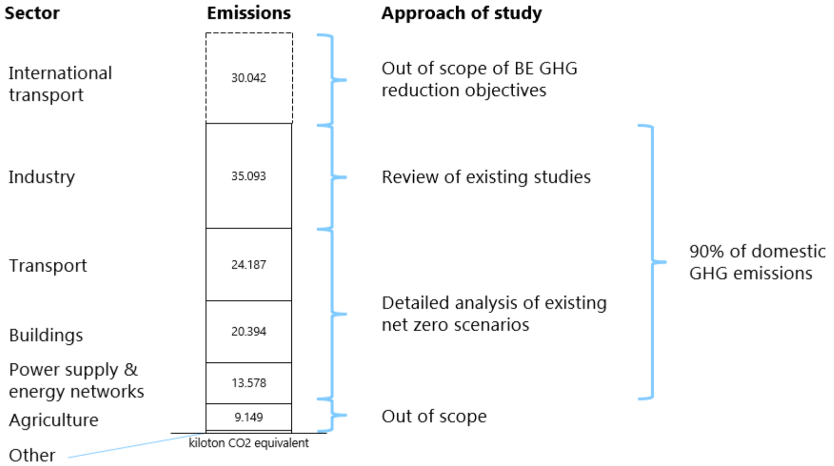
Non-physical investments (such as R&D, investments in human resources, development of training programs, etc.) are not included. Investments for adaptation or loss and damage are not included by themselves either, but some of the mitigation investments, such as home thermal insulation, may have positive externalities on adaptation efforts.

Sectoral scope

The analysis covers 4 major GHG emission sectors: electricity supply and energy networks, buildings, transport, and industry.[13] As can be seen in figure 2, these sectors cover 90% of Belgian domestic GHG emissions in 2022.[14] International maritime and aviation transport, agriculture, waste processing and LULUCF[15] sectors are not covered.

11 Emissions Trading System 1, European GHG emissions pricing mechanism for the energy and high emitting industrial sectors
12 WACC is kept at 0
13 We consider petrochemicals industry to be part of the industry sector, as the transition scenarios posit a future without fossil fuels as an energy carrier.
14 Figures are from the European Environment Agency
15 Land Use, Land Use Change and Forestry

Figure 2 2022 GHG Emissions of Belgium



Comments: petrochemicals industry are placed within the industry sector
Source: European Environmental Agency

For the electricity supply and energy networks, buildings and transport sectors, we built a detailed bottom-up techno-economic model, that computes the investment needs per sector for the different scenarios. For the industrial sector, we provide a range between a minimum and maximum investment need based on literature estimates.

In the modelling, we have identified 14 subsectors within the energy, buildings and transport sectors that were deemed the key subsectors for achieving the transition (e.g. passenger cars, railways, building renovation, electricity grids, hydrogen networks, etc., see full list in figure 5).[16]

Choice of reference scenario

As mentioned in previous sections, the goal of this study is to assess additional investment needs for a set of net-zero scenarios at the Belgian level. It is therefore necessary to define a reference to which the scenarios will be compared in order to determine the part of investments that is additional. This reference must necessarily have the same scope (sectors, duration, level of granularity) as the net-zero scenarios.

It is important to note that the definition of a reference has a significant impact on the final results and on how to interpret those. Indeed, the choice of the reference defines what is included in the baseline and what is considered as "additional investment", which is always debatable. Different choices of references are therefore possible, and we have decided to select two of them.

We have reconstructed a "with existing measures" (WEM) scenario based on the Belgian National Energy and Climate Plan (NECP) with the help of the 2050 Pathways BeCalc Explorer tool published online

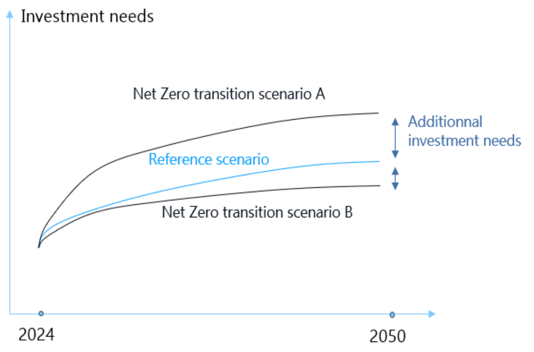
[16] Within the transport sector, notable left outs are the metro and tramways for which no clear development is discussed in the scenarios, neither are motorbikes or active mobility assets such as bicycles. Within the energy sector, conversion assets for the production of biomass, e-fuels and storage of these gas and liquids was not estimated. For buildings, things such as structural reinforcement of buildings when deep renovations are needed, or the use of more efficient electric appliances are not included. See full list of what is included and excluded in the model in Appendix 5, 6 and 7.

by the FPS Health.[17] This scenario does not reach net-zero by 2050, but it already includes some GHG-mitigation investments, mainly for renewable electricity production capacity. It is also important to note that the construction of new build hypothesis of this scenario is relatively high, which impact the final results.

Another reference scenario is based on 2024 investment levels. This scenario assumes that investment levels remain constant at the 2024 level throughout the entire 2025-2050 period. The level of investment for the year 2024 is estimated using the same calculation methodologies as described in the Appendices, and is therefore not based on actual investment figures in 2024 since these are not available at the needed level of granularity.

Belgium's *additional* investment needs are defined and computed as the difference between investment needs in the transition scenarios and those in the reference scenario[18] (see graph 3), from 2025 until and including 2050. The average yearly additional investment needs are the cumulative additional needs divided by 25 years. In each graph, the reference(s) used is (are) explicitly mentioned.

Graph 3 The model computes "additional" investment between a reference and transition scenarios



Source: SCPI

Modelling approach and calculation logic

We use a bottom-up approach, starting from existing net-zero scenarios for Belgium.[19] The selected net-zero scenarios are described in the next section. Available activity data[20] are collected from all scenarios and completed with own assumptions when necessary (for more details on the methodology, see Appendix 5, 6 and 7). Harmonized unit cost assumptions are then applied to each activity data in order to derive the total capital expenditure/investments (CAPEX) and recurrent expenditures (OPEX).

17 The simulation with the tool was done to replicate the policy measures from the NECP as much as possible so as to be able to model the investment needs in the WEM scenario based on a set of activities in a similar way as the other scenarios. The simulated WEM is consistent with the official WEM curves from the NECP for the four sectors analyzed in this work.

18 The reference scenario is itself implying additional investments compared to today's situation due to demographics, economic activity or stated policies.

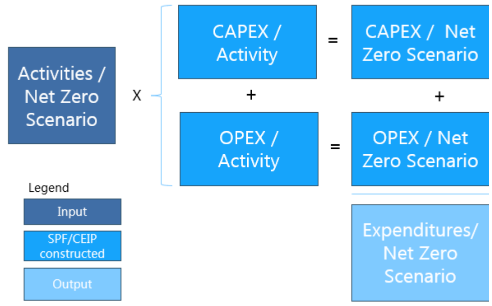
19 We do not resort to the often-used method of "abatement cost curves" that does not enable us to have a detailed modelling per sector, sub-sector and asset type. Abatement curves classify activities or technologies according to their GHG intensity and their cost. This enables to rank activities or technologies according to their cost-effectivity in reducing GHG emissions.

20 By activity data, we mean data that describes the activity level of the scenarios such as: passenger-kilometers per car or train, number of cars, ton-kilometers by trucks, boat or train for freight, total built area, renovation rate of buildings, total installed electricity generation capacity of solar or wind, etc.

In other words, the activity mixes are inputs to our model derived directly from the different scenarios, while the cost factors are our own estimates. The cost harmonization is necessary for a consistent comparison of the implications of the transition scenarios. As a result, investment estimates may differ from estimates sometimes advanced by the scenario authors (see literature review).

When necessary to compute investment needs or OPEX, we also use some common hypotheses for each technology in all the scenarios (e.g. efficiency rates, lifetime of assets, etc.). Their full list is in Appendix 4.

Figure 4 CAPEX and OPEX are modelled with the scenario's activities as input



Source: SCPI

Unitary cost and price assumptions

Cost hypotheses include assumptions on three types of unitary costs: investment costs (CAPEX), operations & maintenance costs and energy costs (OPEX). These CAPEX and OPEX unitary costs have been found in the literature and include assumptions on price evolutions through 2050 (for the full list of cost assumptions, see Appendix 3). The energy consumption OPEX depends primarily on the price evolution of energy vectors, for which we consider two scenarios (prices in a reference scenario and prices in transition scenarios[21]). We run sensitivity analyses on higher energy prices for the buildings and transport sector to test the robustness of our messages, since energy price projections are facing substantial uncertainties.[22]

21 In these reference and transition scenarios, it is assumed that Belgium and the rest of Europe are consistently in either a WEM or a transition scenario, as the course followed by other countries influences the price levels of energy vectors in Belgium.

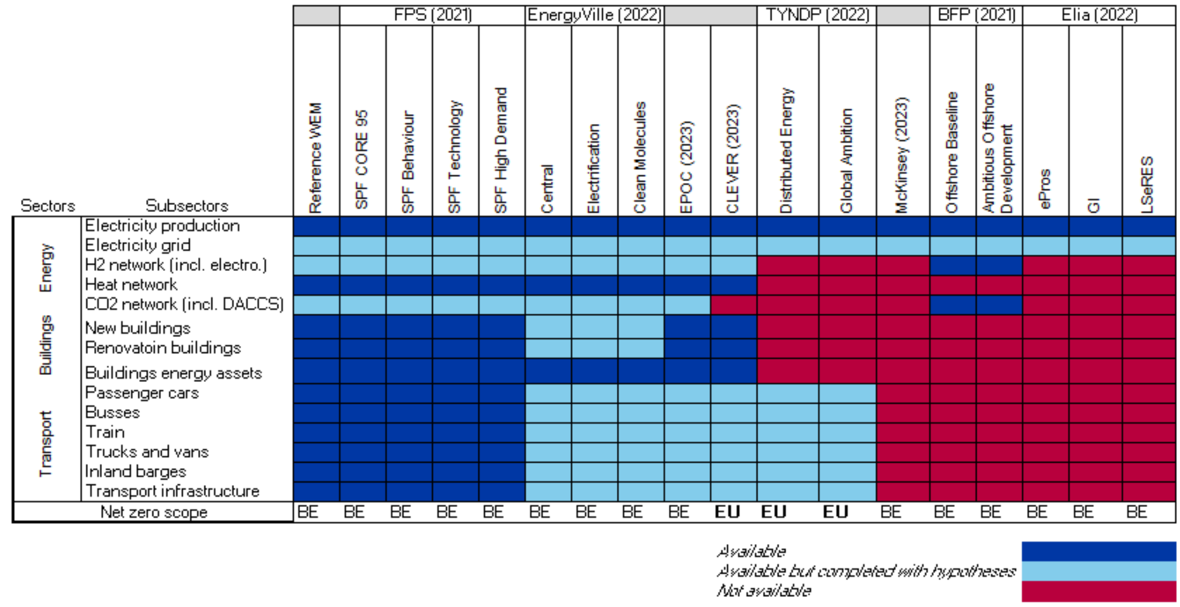
22 As such, energy prices are taken as exogenous to the model. Except for the reference scenario, the fuel prices are not influenced by the specific transition pathway of the various transition scenarios.

4. Net-zero scenarios and the drivers they activate

As described in the methodology section, our analysis is based on a set of existing transition/neutrality scenarios for Belgium. Those scenarios are then compared to a reference scenario which assumes no major changes in investment patterns and does not lead to net-zero GHG emissions in 2050. The transition scenarios, on the other hand, model the changes needed to shift toward net-zero emissions by 2050.

We conduct a meta-study that reviews the different transition pathways by various authors available for Belgium. These scenarios have different scopes and are based on different modelling approaches. Figure 5 shows the sectors and subsectors where each scenario provides activity data required to conduct the meta-study.

Figure 5 Sectoral scope of the transition scenarios



Comments: Agriculture is comprised in the net zero scope of SPF scenarios only.
Source: SCPI based on the author's scenarios

The sample we collected consists of 17 transition scenarios from 8 different authors. All of them reach net zero GHG emissions for Belgium by 2050, except for Clever and TYNDP scenarios that are based on European models and may have residual emissions in some European country compensated by net negative emissions in another European country. Whenever scenarios had insufficient data regarding the activities they propose for certain sectors, they were either completed with hypotheses or the sub-sector was left out of the sample. Further details on the hypotheses used are available in the Appendix 5, 6 and 7. The selected transitions scenarios are the following:

- FPS[23] (2021). The Federal Public Service Public Health (Directorate-General for Environment) has devised 4 net zero scenarios. The "SPF Behaviour" scenario emphasizes transformational changes in mobility, housing and dietary patterns, while the "SPF Technology" scenario relies

[23] Federal Public Service, Service public fédéral or Federale overheidsdienst

more heavily on technological developments. A “SPF CORE 95” scenario is defined based on a balanced approach between these two dimensions. A fourth scenario, the “SPF High Demand” scenario, is set to explore the implications of a pathway characterized by a significantly higher level of energy demand than in the other climate neutral scenarios and by constant industrial production volumes in 2050 when compared to 2015.

- EnergyVille (2022). Three PATHS2050 scenarios are developed using the TIMES-Be model, which calculates the most cost-effective pathway that would allow to meet the energy demand through 2050. The scenarios assume a constant production output in the industrial sector and focus primarily on energy technology and efficiency solutions on both the supply and demand sides, without accounting for significant changes in consumer behaviour or societal shifts. In all three scenarios, fossil fuel phase-out, electrification and use of clean molecules still lead to a remainder of 2 million ton of GHG emissions, compensated by other measures to reach net-neutrality.

- EPOC (2023). Various authors from VITO-EnergyVille and the ICEDD have used combined expertise from various models for power dispatching, adequacy, transport and buildings to construct this scenario. In doing so, they have created a version of the TIMES energy model detailed at the regional level for taking into account local specificities (a tri-regional Belgian TIMES). The complete decarbonization is mainly realized through a significant push in electrification, for which part of the demand is met by imports.

- The CLEVER (Collaborative Low Energy Vision for the European Region) scenario aggregates national visions into one single European one. It was developed in 2023 by a consortium of European national and European scenario builders from the academic world, research, or civil society. To achieve this, the scenario assesses and mobilises the energy demand reduction potential made possible through sufficiency and efficiency, and the energy that can be supplied by renewable energy development, at both national and European levels.

- TYNDP (2022). Two scenarios are developed to project the long-term energy demand and supply for the drafting of ENTSOG’s (European Network of Transmission System Operators for Gas) and ENTSO-E’s (European Network of Transmission System Operators for Electricity) Ten-Year Network Development Plans (TYNDP) within the context of the ongoing energy transition. The “Distributed Energy” scenario ambitions energy autonomy thanks to renewable energy sources. The “Global Ambition” scenario is based on a wide range of low-carbon technologies as well as the use of global decarbonized energy trade.

- McKinsey (2023). In June 2023, McKinsey & Company published a report “Net zero or growth? How Belgium can have both” devising a pathway for Belgium to meet its climate neutrality objectives. In this report, the McKinsey’s Decarbonization Scenario Explorer tool has been used to model the evolution of over 50 economic activity sectors with GHG abatement cost curves associated with various technological solutions.

- BFP[24] (2021). Two scenarios are developed by the Federal Planning Bureau using the Artelys Crystal Super Grid optimal dispatch model. The demand projections are based on a previous publication by the Federal Planning Bureau (Devogelaer, 2020), but they explore variations in the electricity supply strategy. The "Offshore Baseline" scenario incorporates the installation of a single offshore hybrid hub in Danish waters, enabling both wind generation and interconnection. The "Ambitious Offshore Development" scenario includes two hybrid hubs: one in Danish waters and an additional hub in Dutch territorial waters.

- Elia (2022). Elia conducts a "Federal Development Plan" study every four years to assess the needs for power network development. To achieve this, Elia develops various scenarios, which are then translated into a load-flow model. The E-Prosumer (ePros) scenario builds on the TYNDP "Distributed Energy" storyline, where decarbonization is achieved autonomously through electrification, energy efficiency, flexibility, and renewable energy. The Global Import (GI) scenario envisions a future with lower ambitions for electrification and energy efficiency, offset by decarbonized energy trade. This scenario aligns with the TYNDP "Global Ambition" storyline. The Large-Scale e-RES (LSeRES) scenario combines elements from the two previous scenarios. It features higher electrification levels than the GI scenario, alongside a significant penetration of renewable energy sources.

Other transition scenarios were identified but left out of the meta-study for various reasons.

- Elia Blueprint (September 2024). In this study, Elia considers new total power demand scenarios for Belgium based on the scenarios from other actors that we also included in our meta-analysis. These are Global Ambition and Distributed Energy from TYNDP (2024), Shift from EnergyVille and an electrification scenario. It is unclear however what production capacities are linked to these scenarios in the Blueprint study. Therefore, these scenarios are not comprehensively modelled in this paper.

- EnergyVille Shift (2024). The newest of EnergyVille's scenarios aiming for more sufficiency than the initial PATHS2050 publication has been thoroughly studied but eventually left out of the selection for two reasons. First, the scenario is not precise enough for various activity data and requires too large a number of hypotheses to be integrated in our model. Secondly, when modelling the scenario with own hypotheses, the results are not significantly different from the other EnergyVille scenarios, adding little value to the analysis.

- BFP[25] Deep Electrification and Diversified Energy Supply scenarios of 2020. They have been studied closely, and ultimately left out for two main reasons. First, they were designed as 'stress test' scenarios to assess extreme transition situations, taking assumptions such as "all hydrogen used in the economy is produced domestically". Secondly, the policy choices that have been made in the meantime rule them out. For instance, they rely on gas power plants with CCS in 2050, which is no longer part of the political agenda.

[24] Federal Planning Bureau, Federaal Planbureau or Bureau fédéral du Plan

[25] Ibid

Transition drivers

The scenarios used in this study showcase a variety of policy orientations for the transition. In order to reach climate neutrality, the scenarios combine different types of levers: sufficiency, efficiency and technology.

Sufficiency measures essentially change the volume of activities (e.g. km travelled per person, total energy consumption, square meters of buildings per person). Efficiency measures reduce energy consumption per unit of activity (e.g. thermal insulation of buildings reduces energy consumption to maintain the same temperature in the building). Technology measures consist in replacing or improving physical assets by assets with different technologies for the same service in order to reduce emissions (e.g. electric car rather than thermic, heat pump rather than traditional thermic heating).

Roughly, we can relate these levers to the different terms of a Kaya-inspired identity for each sector. This identity links carbon emissions with activity, demographic and energy variables (see figure 6). Even though the boundary between these drivers can sometimes be blurry, it provides with a structure for the comparison of transition approaches.

Figure 6 Drivers activated by the scenarios

Adapted from the Kaya identity

$$CO_2emissions = Population \times \frac{Activity\ mix}{Population} \times \frac{Energy}{Activity\ mix} \times \frac{CO_2emissions}{Energy}$$

	Demand driver / Sufficiency	Energy intensity / Efficiency	CO2 emissions intensity of energy / Technology
Buildings	Living space per person, rational use of non-residential area, heating and cooling behaviours	Thermal insulation; appliance efficiency	Electrification of heating; district heating ...
Transport	Passenger distance ; freight transported; modal share; occupancy rate of vehicles, car sharing	Motorization efficiencies, ...	Electrification of vehicles; e-fuel switch ...
Power supply and energy networks	Demand Side Management, Storage	More performing generation assets ...	Energy production share of fossil, renewable, nuclear ...
Industry	Demand for goods and services; lifetime of goods, ...	Efficiency of production processes; material efficiency; recycling, ...	Green fuels or feedstock (electricity, hydrogen, e-fuels, biomass), CCS, ...

Comments: the term "GDP" was replaced in the Kaya identity with the term "activity mix" to disentangle transition drivers more clearly. Indeed, the relation between GDP and activity is complex, and the notion of GDP does not enable to identify as clearly what is a result of price or quantity changes of activities.

Source: SCPI

In the next section, when discussing the modelling results, we group scenarios that propose similar combinations of these drivers to reach climate neutrality. This allows us to relate the specific transition choices to their consequences in terms of investment and current expenditures.

5. Main results per sector

In this section, we outline the results of our model estimating the additional capital and operational expenditures for the buildings, transport and energy sector of the different transition scenarios compared to the reference WEM scenario and the current level in 2024. For the buildings and transport sectors, we test whether conclusions with regards to operational expenditures remain robust under various energy price evolution projections. We also share estimates for additional investment needs in the industry from other existing studies.

5.1. Buildings Sector

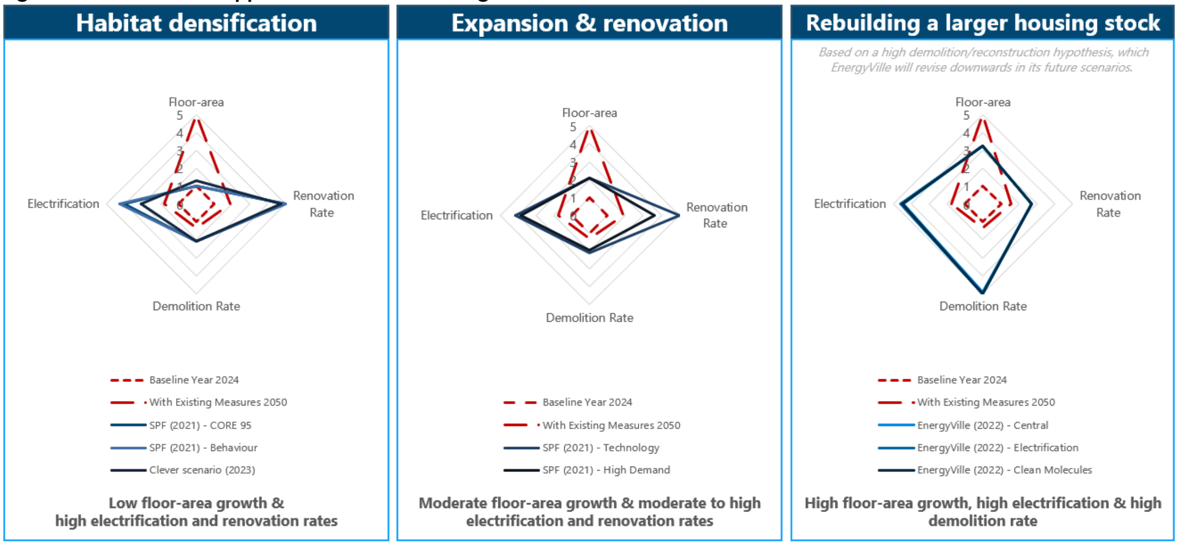
Our estimates cover both residential and non-residential buildings and focus on heating appliances and the renovation of buildings for insulation purposes. The decarbonization scenarios exhibit notably distinct approaches, particularly regarding building surface area and renovation strategies aimed at enhancing thermal insulation of the building stock. These differences result in varying levels of investment.

5.1.1. Net-zero approaches for buildings

We have chosen to classify the building decarbonization scenarios according to four parameters that are representative of the variety of approaches (see figure 7):

- Floor area (m^2): the projected surface area in residential and non-residential buildings.
- Electrification rate (%): the ratio between the electricity demand in buildings and the total energy demand in buildings. This includes the electricity demand for lighting and electric appliances other than heating.
- Renovation rate (%): the ratio between yearly renovated area and the total floor area.
- Demolition rate (%): the ratio between yearly demolished and reconstructed area and the total floor area.

Figure 7 3 net-zero approaches in the buildings sector



Comments:

1) Activity variables of scenarios in 2050 were compared against 2024 values and that ratio was normalized to show a scale from 1 to 5 for each variable
2) The EPOC scenario sits between habitat densification and expansion & renovation

Source: SCPI based on the author's scenarios

From Figure 7, we observe that three distinct groups of scenarios emerge:

- Habitat densification: these scenarios have a limited floor area expansion or even no expansion at all, despite population growth, paired with high renovation and electrification rates.
- Expansion and renovation: these scenarios apply fewer restrictions on floor area expansion and have moderate renovation and electrification rates.
- Rebuilding a larger housing stock: these scenarios put the focus on a high electrification and demolition rate, with little effort to reduce floor area expansion. It should however be noted that the three EnergyVille scenarios, dating from 2022, assume a particularly high rate of demolition-reconstruction of buildings. New scenarios are currently being developed by the same authors and will significantly revise this assumption downward.

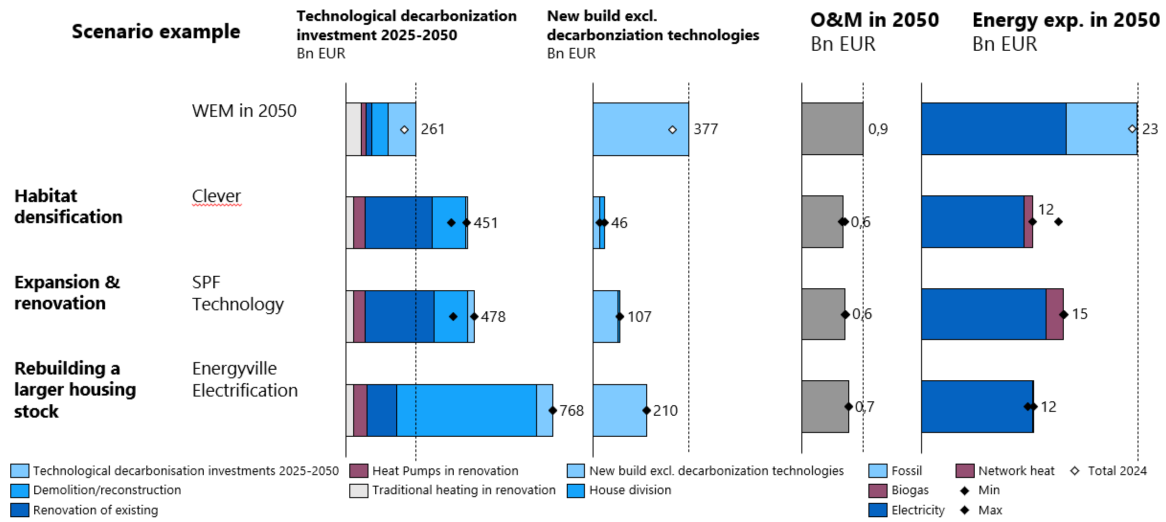
For each group of scenarios described above, we have selected one representative scenario for which results will be presented in the following sections.

5.1.2. Buildings decarbonization CAPEX and OPEX

For each transition approach, the graph below selects a representative scenario and presents its cumulative investments between 2025 and 2050, alongside maintenance costs and energy expenditures projected in 2050. Detailed results for all scenarios can be found in Appendix 2.

We distinguish investment expenditure linked exclusively to decarbonization technologies (renovation expenditure and, for new buildings, additional cost of decarbonization technologies compared to carbon-based alternatives) from capital expenditure linked to the construction of new buildings apart from these additional costs[26] (foundations, structural work, non-decarbonized techniques, finishes) and house division.

Graph 8 Investments, maintenance and energy expenditures for the buildings sector



Comments:
1) The biogas category also comprises the volumes of heating from biomass burning, not modelled separately.
2) Energy expenditures include energy for heating and cooling, as well as electricity for lighting and appliances.
3) Reference situation value is the 2024 value multiplied by 25 to cover the 2025-2050 period, i.e. maintaining investments constant.
Source: SCPI model

Two main observations can be drawn from Graph 8.

First, technological decarbonization investments are in all scenarios significantly higher than the reference WEM scenario, ranging from 190 (+73%) in Clever scenario, to 507 billion euros (+194%) in Energyville scenarios. This is essentially due to substantial additional investments in renovation and/or demolition-reconstruction compared to the baseline.

Second, a substantial shift in investment nature is observed in all scenarios. In particular, there is a shift from investment in new build (excl. decarbonization technologies) toward investment expenditures for the technological decarbonization of new buildings and, more importantly, existing buildings. This lower investment in new build excluding decarbonization technologies (from -167 to -331 billion compared to WEM in, respectively, EnergyVille and Clever scenarios), offsets partially or more than completely the additional investment needs in technological decarbonization of buildings, leading to total additional investment needs of, respectively, -141 and +340 billion in this sector.

Two factors drive the sizeable variation of investment expenditures across the different decarbonization strategy approaches: building surface area expansion and tradeoff between renovation and demolition-reconstruction.

Building surface area expansion. We note that all scenarios envisage total floor area that remains lower than our WEM scenario in 2050. Scenarios within the "habitat densification approach" emphasize a strong reduction in new constructions (both residential and non-residential) through strict spatial

[26] We assumed that the decarbonization share in total investments for the construction of new buildings is 20%, which represent the additional costs of making a building "passive", estimated between 10% and 30% in practitioners' literature.

planning policies and limit soil artificialization.[27] This approach results in a smaller floor area per capita, in spite of expected population growth and shrinking household sizes. More precisely, this means an average of 115 square meters per household[28] in 2050 as compared to 127 in 2024 and 145 in a WEM scenario in 2050. In these scenarios, the investment cost related to "house division" (extra costs due to more compact housing within the current buildings stock) is –by far- much lower than the investment cost related to building new dwellings. Conversely, scenarios without stringent on new buildings constraints (in terms of habitat sizes for the residential sector, this means an average of 131 square meters per household, and non-residential floor areas remain constant around 17.1 square meters per inhabitant) result in much larger investment requirements.

Tradeoff between renovation and demolition-reconstruction. A second key factor is the choice between conventional renovations versus demolition-reconstruction for refurbishing dwellings[29]. The choice to prioritize demolition-reconstruction leads to higher investment needs, which are more than twice as expensive as for more economical approaches.

Heating assets are also included in the investment expenditures, accounting for approximately 12% of total CAPEX needs. Over the period, traditional heating systems (e.g. fuel boilers) are progressively replaced by heat pumps. The direct cost of electrification is relatively low compared to other components of renovation strategies, as the price difference between heat pumps and conventional boilers is minimal in well-insulated buildings.[30]

All transition scenarios lead to lower recurrent operational expenditures than the reference WEM in 2050. This is despite higher maintenance costs of heat pumps, due to higher maintenance costs in poorly insulated buildings that require oversized heating systems. Transition scenarios consistently lead to a 30% reduction in heating system maintenance costs and to an energy bill reduction of 40–50% compared to the baseline.[31]

Transition scenarios involve a complete shift away from fossil fuels to electricity and, to a lesser extent, to biogas. Heat networks are proposed by scenarios in the "habitat densification" and "extend buildings and renovate" category and represent a small share of energy consumption costs. We note that transition strategies favoring newbuild do not exhibit significant energy bill savings over transition strategies favoring renovation, despite their large additional CAPEX requirements.[32]

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[27] Close to "stop concrete" strategies (stop béton, betonstop)

[28] Hypothesis for number of households is 5.16 in 2024 evolving to 5.74 by 2050 in all scenarios following population growth of 11.65 million inhabitants in 2024 to 12.57 million by 2050. The average size of households is posited to decrease of 2.26 persons to 2.19 persons. More info on the assumptions and sources in Appendix 5.

[29] It should be noted that the three EnergyVille scenarios, dating back to 2022, assume a particularly high rate of building demolition-reconstruction. This contributes to the large difference in capital expenditure levels between the scenarios. New scenarios being developed by the same authors will revise this assumption significantly downwards.

[30] Expensive other versions of heating such as floor heating have not been considered in this exercise.

[31] Except for the EPOC scenario which is represented in the maximum value of "habitat densification" group, where non-residential values are particularly high. They may reflect a larger scope in commercial buildings considered (potentially overlapping with the industry sector) or different technical assumptions in terms of energy consumption per area.

[32] The reduced electricity bill in the transition scenarios compared to the WEM scenario in 2050 may seem counterintuitive with an electrified heating system. We point to the scope of energy expenditures in the model which comprises all the buildings energy expenditures (so also lightning and other appliances for instance). Scenarios may model other energy efficiency measures for these non-heating consumptions that were not captured in the model, or have different technical assumptions in terms of electric consumption for non-heating purposes.

To sum up, a number of scenarios achieve net-zero emissions in the buildings sector with lower cumulated investment over the 2025-2050 period than the WEM. In such scenarios, investments in renovation and heating assets are compensated by reducing investment in new constructions, provided that renovation is prioritized over demolition-reconstruction strategies. This conclusion at the aggregate level does not translate at the level of individual households or commercial entities, depending on their circumstances. All transition scenarios lead to lower recurrent operational expenditures.

Comparison with regional renovation strategies

Around 2020, each of Belgium's three regional governments published its own renovation strategy aimed at achieving an energy efficient buildings stock[33]. Their estimates of absolute cumulative investment needs between 2020 and 2050 in Belgium range from 340 to 410 billion euros above current levels. In this total, investment needs of 103–150 billion euros are foreseen for residential and 57 billion euros for non-residential buildings in Flanders. Respectively 117 billion and 34–57 billion euros are estimated for Wallonia's residential and non-residential buildings. And 29 billion euros for residential buildings in Brussels.

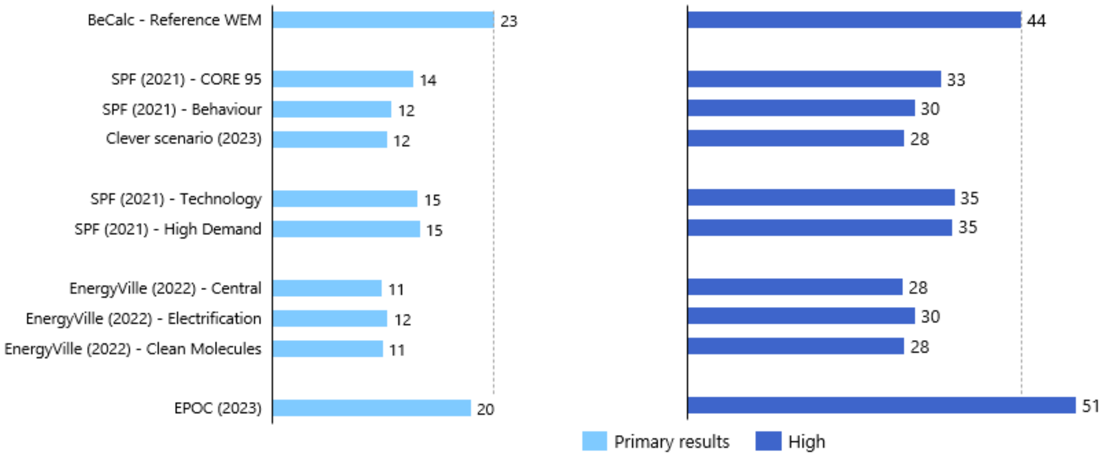
These estimates are consistent with our estimates of expenditures for scenarios which do contain floor area growth. Nevertheless, the methodologies and scopes of the different analyses are different between regional estimations as well as with our study, and comparison should be made carefully.

5.1.3. Energy consumption costs in buildings: sensitivity analysis

Electricity will be the primary energy vector consumed in buildings in neutrality scenarios in 2050. Recently, electricity prices have fluctuated significantly, leading to considerable variation in price projections. To test the robustness of our conclusions, we applied a more substantial increase in electricity prices (+60% in reference WEM, and +135% in transition scenarios, see Appendix 3.2), which is reflected in the "high" results in the graph below.

33 VR (2020), RBC (2019 & 2020) and SPW (2020), see bibliography

Graph 9 Energy consumption costs in 2050 in the building sector, with different electricity price assumptions (in Bn EUR)



Comments:
1) "High" considers very high electricity prices, as projected by POLES.
2) For reminder, electricity consumption includes lighting and appliances, which is significant in reference WEM as well as transition scenarios.

Source: SCPI model

This analysis indicated that energy expenditures are lower in all transition scenarios compared to the reference WEM. Even with the higher electricity price sensitivity, this message remains consistent, with the exception of the EPOC scenario. It is important to note that this sensitivity also applies to electricity consumption for lighting and appliances, which is significant in both the reference WEM scenario and the transition scenarios.

5.2. Transport Sector

The analysis covers the investment needs for vehicles (cars, trucks, vans, busses,[34] trains and inland barges), electric charging stations, and overall infrastructure for Belgium's domestic transportation. The investment needs of the transition scenarios are highly contingent on the share passenger car transportation will have in the future, which is set to account for the lion's share of investments in most scrutinized scenarios.

5.2.1. Net-zero approaches for transport

We have chosen to classify the transport decarbonization scenarios according to four parameters that are representative of the variety of approaches (see figure 10):

- Total motorized transport demand: the sum of car, bus and rail transport demand, expressed in passenger-kilometers for passenger transport, or the sum of truck, van, rail and inland barges transport demand in ton-kilometers for freight transport.

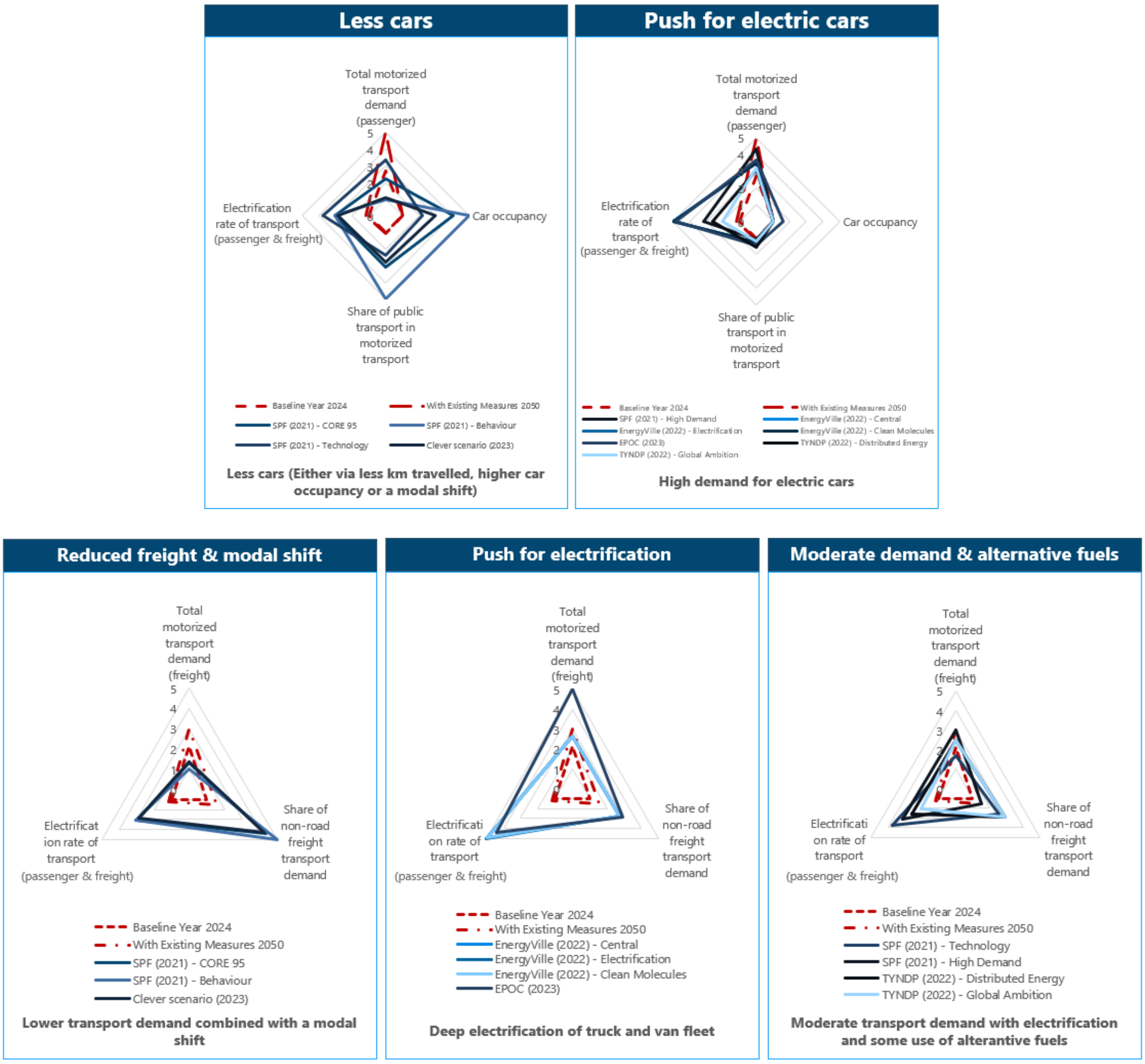
- Car occupancy: the average number of passengers in a car. This indicator is specific to passenger transport.

[34] Comprises both the public transport bus fleets and private coaches

- Electrification rate of transport (in %): the ratio between final electricity demand of the transport sector and the total final energy demand for passenger and freight vehicles.

- Share of public transport and share of non-road transport demand (both in %): the ratio between public transport demand and total motorized passenger transport demand for passenger transport, and the ratio between rail and inland barges freight transport demand and total motorized freight transport demand for freight transport. This indicator measures the modal shift towards low-carbon transportation modes.

Figure 10 2 and 3 net-zero approaches in the passenger and freight transport sectors respectively



Comments:
1) Activity variables were compared against 2024 and normalized to show a scale from 1 to 5 for each variable.
2) Trucks and vans are taken altogether in this category

Source: SCPI based on the author's scenarios

From figure 10, we observe that three distinct groups emerge for passenger and freight transport:

- Less cars: for passenger transport, these scenarios are based on a combination of levers that all contribute to a smaller car fleet. These levers include demand for passenger travel demand, car occupancy and modal shift. For freight transport, these scenarios combine area reduced demand for freight transport with an ambitious modal shift from road to rail as well as inland waterways.

- Push for electrification: these scenarios build on moderate passenger transport demand and high freight transport demand with a high level of electrification of both passenger and freight vehicles.

- Moderate demand & alternative fuels: this only applies to freight transport and consists of scenarios that envisage a reduced level of freight transport demand with electrification and, to some extent, the use of alternative fuels.

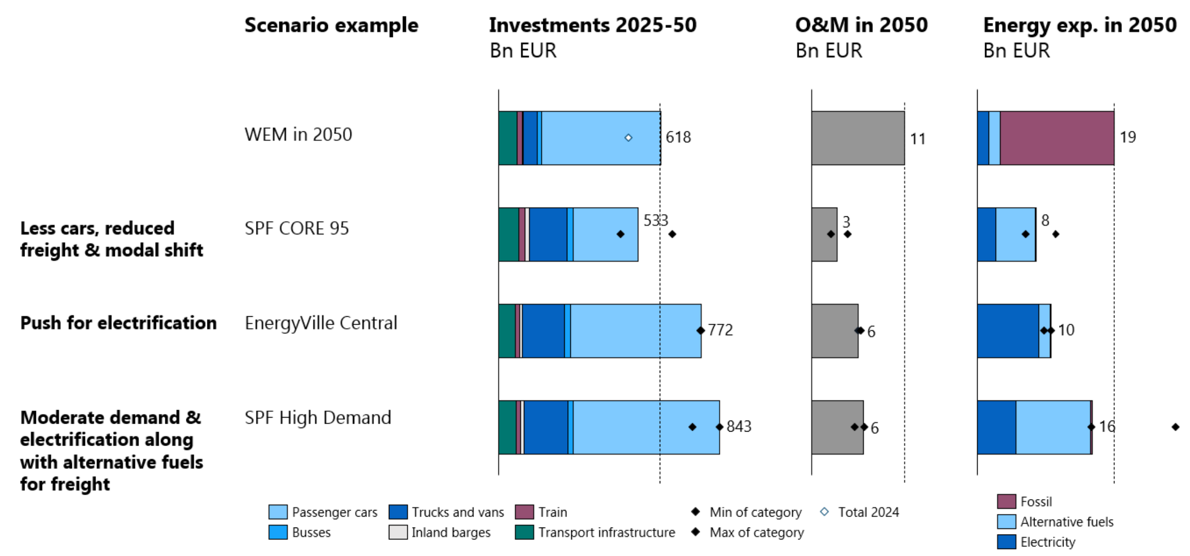
We note that all scenarios but one (SPF High Demand) assume a lower growth in passenger demand than the reference WEM scenario.

For each group of scenarios described above, we have selected one representative scenario for which results will be presented in the following sections.

5.2.2. Transport decarbonization CAPEX and OPEX

For each transition approach, the graph below presents cumulative investments between 2025 and 2050, alongside maintenance costs and energy expenditures projected for 2050. Tables representing the results of other scenarios can be found in Appendix 2.

Graph 11 Investments, maintenance and energy expenditures for the transport sector



Comments:
1) transport fuels labelled as “new fuels” include all sorts of sustainable gaseous and liquid fuels: biofuels, hydrogen, e-fuels and blends of them.
2) Reference situation value is the 2024 value multiplied by 25 to cover the 2025-2050 period, i.e. maintaining investments constant.
Source: SCPI model

Graph 11 shows that investments in transition scenarios for the transport sector range from lower than the baseline in the SPF CORE 95 scenario to much higher in the SPF High Demand scenario.[35]

Scenarios, such as SPF CORE 95, that emphasize reducing passenger and freight transport demand lead to comparable investments levels, amounting to a decrease of 3.4 billion euros (14%) per year on average over the period compared to the WEM scenario, and 1.6 billion euros (8%) per year on average with regards to 2024 levels. On the other side of the spectrum, scenarios such as SPF High Demand, which maintain high transport demand and prioritize electrification and alternative fuels over modal shift, for passenger and freight transport, result in a more substantial increase in investments needs, with an annual rise of 9 billion euros (36%) on average with regards to reference WEM, and 14 billion euros (71%) with regards to 2024 levels.

Most transition scenarios lead to lower recurring operational expenditures. Maintenance costs decrease in all transition scenarios, thanks to the lower maintenance costs of electric vehicles and/or lower number of vehicles overall. Energy expenditures show a downward trend in most scenarios[36] and a strong shift from conventional fuel to electricity and biofuels, e-fuels, hydrogen, and other blends (aggregated under the label "new fuels"). Some of these scenarios (e.g. SPF CORE 95 and SPF High Demand) results in an important new fuels energy bill.

In short, cars, followed by trucks, dominate investment needs across both reference and decarbonization scenarios. A number of scenarios achieve net-zero emissions in the transportation sector with cumulated investment over the 2025-2050 period lower than the WEM. In such scenarios, the additional cost of electric vehicles is compensated by the reduction in vehicle fleet due to increased modal shift and car-pooling and reduced overall transport volume (passenger-kilometers and ton-kilometers).

Zoom on the evolution of the road vehicle fleet

Graph 12 focuses on investments in cars, vans[37] and trucks and provides a breakdown per engine technology. This graph highlights the extent of the shift from internal combustion engine (ICE) vehicles to electric vehicles (EVs) in each scenario. While cars account for the majority of investments across both reference and decarbonization scenarios, the nature of these investments differs substantially between the two approaches. In the baseline scenario, vehicle investments are made predominantly in ICE engines, while in decarbonization scenarios, investments are mostly made – unsurprisingly –in EV engines.

While all decarbonization scenarios assume widespread electrification of the car fleet, they differ significantly in their required fleet sizes. The combined effect of evolution of kilometers travelled (absolute reduction or modal shift) and car occupancies lead to slight downward changes in the needed vehicles

[35] The disaggregation of decarbonization and non-decarbonization investments, applied in the previous section to new buildings, has not been applied to new cars—the other major category of investment expenditures for which this measure would also be relevant. Such an application would require a more detailed analysis, which could be the subject of future work, to account for factors such as the substitution between investments in personal cars and public transport.

[36] TYNDP is an outlier due to its European scope that includes maritime and aviation, and that implies net zero emissions at European level but not necessarily at national level

[37] Vans are included in the freight vehicles category in this exercise

fleet for scenarios SPF Behaviour, SPF CORE 95 and Clever. This results in the lowest level of investment. With numbers, this becomes more tangible:

- For scenarios that go for less cars, the number of passenger cars is around one for two households[38] in 2050 as compared to 1.2 cars per household in 2024 and 1.4 in a WEM scenario in 2050. For the most ambitious scenario in terms of car reduction (SPF Behaviour), the car occupancy driver leads to less than one car for three households. For freight transport, these scenarios do not significantly reduce the number of trucks (0.01 per capita on average, aligned with the reference in 2024 and 2050). The average number of vans remains constant compared to current number of 0.05 per capita.

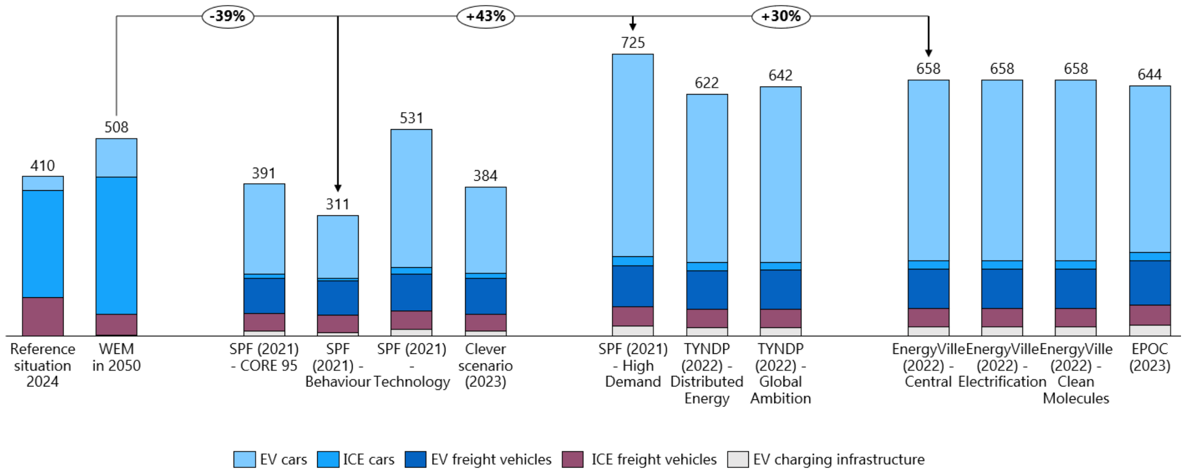
- For scenarios that push electrification, the average number of passenger cars is reduced to 1.1 per household in 2050 as compared to 1.2 cars per household in 2024 and 1.4 in a WEM scenario in 2050. For freight transport, the number of trucks and vans per capita is kept roughly constant.

- For scenarios that bet on alternative fuels, the average number of passenger cars is reduced to around 1 to 1.3 per household in 2050 as compared to 1.2 cars per household in 2024 and 1.4 in a WEM scenario in 2050. For freight transport, the number of trucks and vans per capita is kept constant.

Overall, decarbonization scenarios with the strongest emphasis on electrification (EnergyVille and EPOC) see vehicles road investment levels up to 30% more than in the WEM scenario for the period 2025-2050, which represents up to 6 additional billion euros per year on average. These results are consistent with the estimated 41% higher cost of electric cars compared to ICE cars and 78% higher cost of electric compared to ICE trucks, in a context of lower transport demand compared to the referenceWEM. When a reduction of passenger kilometers travelled is used as a lever on top of the electrification and increased usage of vehicles (car occupancy for instance), investment needs may be reduced by up to 39% compared to the reference WEM.

[38] Hypothesis for number of households is 5.16 in 2024 evolving to 5.74 by 2050 in all scenarios following population growth of 11.65 million inhabitants in 2024 to 12.57 million by 2050. The average size of households is posited to decrease of 2.26 persons to 2.19 persons. More info on the assumptions and sources in Appendix 5.

Graph 12 EV and ICE vehicles breakdown - cumulated CAPEX 2025-2050 (in Bn EUR)



Comments: reference situation value is the 2024 value multiplied by 25 to cover the 2025-2050 period, i.e. maintaining investments constant
Source: SCPI model

Finally, EV charging infrastructure assets only represents a relatively small part of total electric road mobility investment needs. The cumulative investment needs for EV charging infrastructure ranges from 9.7 (SPF Behaviour) to 29.2 (EPOC) billion euros. These numbers represent around 0.4 to 1.2 billion euros on a yearly basis.

Zoom on transport infrastructure

Our infrastructure investment estimates include investments in rail[39], road, inland waterways and bicycle infrastructures.

The road infrastructure investment need is slightly lower (up to 2.4%) in transition scenarios compared to the WEM scenario and roughly comparable across transition scenarios. Scenarios with no or little reductions of road transport (both freight and passenger) require slightly higher levels of road infrastructure investments compared to the other transition scenarios.

Half of the scenarios (SPF Behaviour, SPF CORE 95, SPF Technology, Clever and EPOC) require additional investments needs in rail infrastructure compared to the 2024 situation. Among those, the scenarios relying on the most significant changes in rail transport demand and modal shares (SPF Behaviour, SPF CORE 95) require the highest levels of rail infrastructure, up to 17% higher than reference WEM. Rail infrastructure and rolling stock investments are detailed in Appendix 1.1.

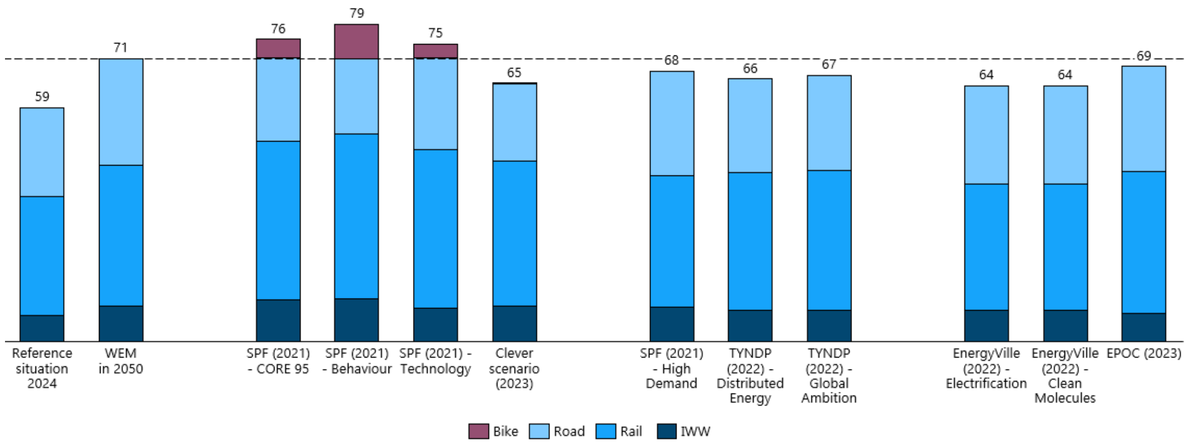
Overall, scenarios with lower passenger transport demand met with road transport (passenger cars) and envisioning a modal shift require the highest levels of rail investment, up to 77% above current 2024 levels. By 2050, rail investment levels will need to be either roughly similar to the ones in the reference WEM scenario (over 2 billion euros a year on average) or up to 30% higher for ambitious rail scenarios (additional 0.64 billion euros per year, i.e. 30% above the baseline).

39 Tram and metro are not included

Bicycle transport demand is often omitted by the authors of decarbonization scenarios. In scenarios which include an increasing bike transport demand, the deployment of biking infrastructure can represent a significant need for additional investments, with up to 0.34 billion euros per year on average.

Investments in inland waterways (IWW) slightly exceed baseline levels in scenarios including freight modal shift away from road.

Graph 13 Infrastructure Investments - cumulated CAPEX 2025-2050 (in Bn EUR)

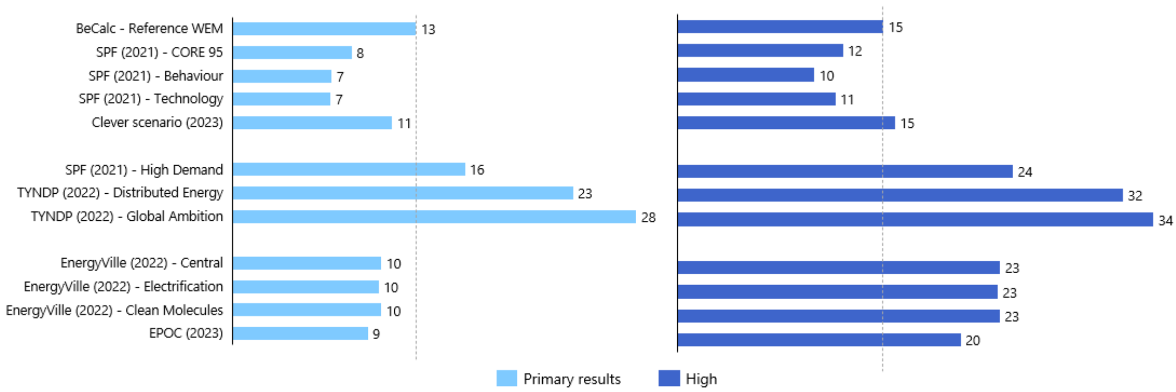


Comments: reference situation value is the 2024 value multiplied by 25 to cover the 2025-2050 period, i.e. maintaining investments constant
Source: SCPI model

5.2.3. Energy consumption costs in transport: sensitivity analysis

This section examines how energy costs are affected by higher electricity prices (+60% in reference WEM, and +135% in transition scenarios, see Appendix 3.2), as shown in the "high" results in the graph below. Similarly to buildings, by 2050, neutrality scenarios foresee electricity as the dominant energy carrier consumed in transport, which makes the energy consumption costs quite sensitive to electricity prices. By contrast, the costs of transport in the reference WEM scenario will be less affected by electricity consumption costs.

Graph 14 Energy consumption costs in 2050 in the transport sector, with different electricity price assumptions (in Bn EUR)



Comments:
1) "High" considers very high electricity prices, as projected by POLES.
2) TYNDP is an outlier due to its European scope that includes maritime and aviation
Source: SCPI model

In the transport sector, the primary conclusion is that fuel costs are lower in most transition scenarios, except for the TYNDP and SPF High Demand scenarios, compared to the reference WEM scenario. However, with higher electricity prices, energy consumption costs surpass those of the reference scenario in most scenarios, particularly in electrification-driven scenarios (only exceptions being SPF Behaviour, CORE 95 and Technology scenarios).

5.3. Energy Sector

All the decarbonization pathways in the transition scenarios show an increasing electrification and a gradual phase-out of fossil fuel energy sources in all sectors, which impacts the energy sector. The energy sector in our model covers the electricity supply system which is further detailed in sections 5.3.1. and 5.3.2. New energy networks are detailed in section 5.3.3.

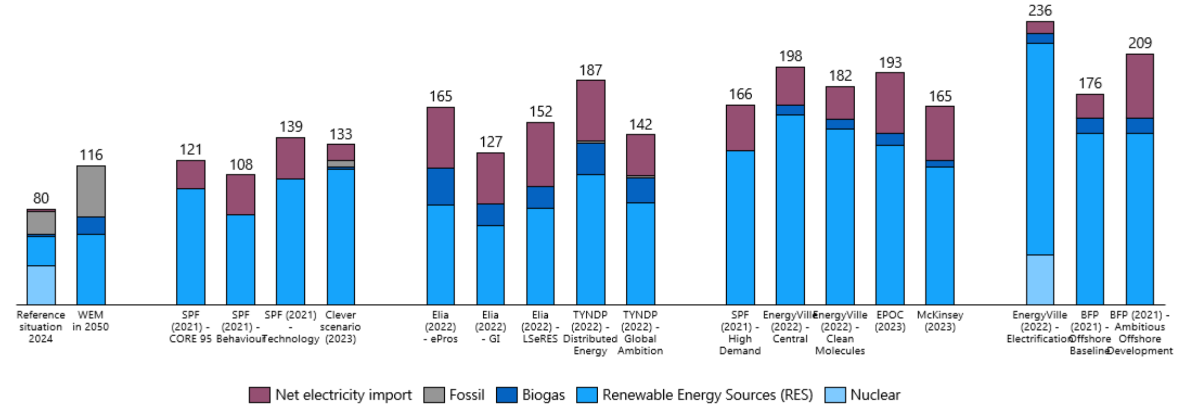
All transition scenarios phase out fossil fuels, so no related additional investments are envisaged. In this exercise, the transformation of the upstream oil business assets in Belgium, such as refineries, is considered part of the industry sector.

5.3.1. Net-zero approaches for the electricity supply system

In our analysis, the electricity supply system includes the electricity production assets (new capacities and renewal of existing), the electricity transmission and distribution networks and flexibility assets.[40]

All scenarios rest on a significant increase of annual electricity demand and supply volumes compared to 2024.[41] Electricity production goes more precisely from 80 TWh in 2024, to 108 to 236 TWh in 2050. Only one transition scenario, SPF Behaviour, results in projected volumes in 2050 lower than 116 TWh, the level projected for the reference WEM scenario. As can be seen from graph 15, transition scenarios differ in the emphasis they put on the use of dispatchable production (mainly biogas) and the extent to which they rely on net imports from neighboring countries.

Graph 15 Power supply by source in 2050 per scenario (in TWh)



Comments: The WEM scenario does not foresee any net electricity import volumes. Potential production gaps are compensated by gas-produced electricity.
Source: SCPI based on the author's scenarios

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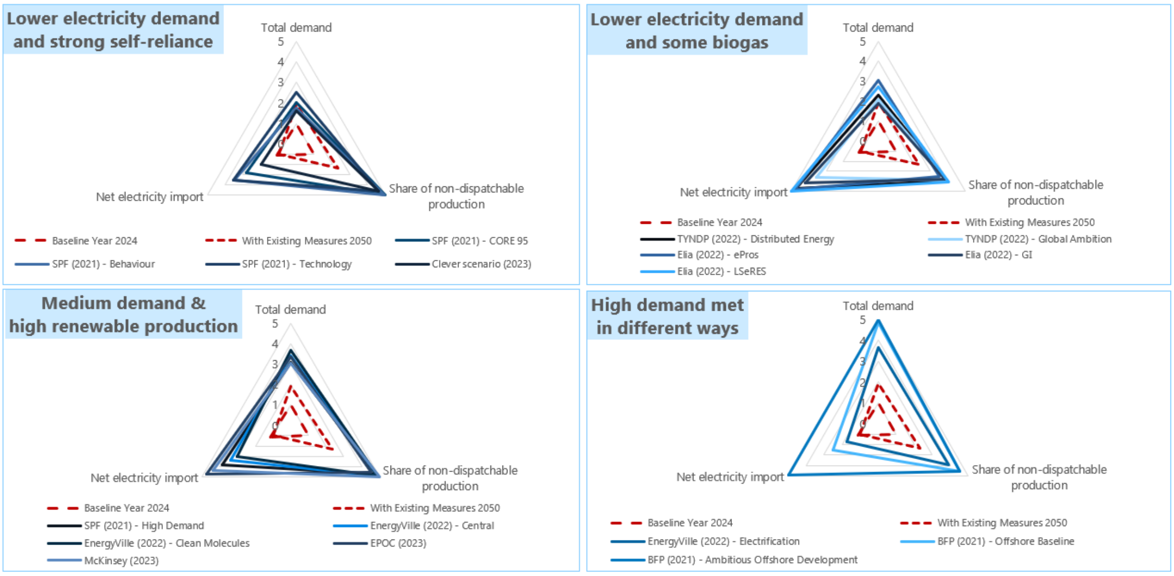
40 Such as batteries, smart meters for Demand Side Management (DSM) in buildings and pumped hydro storage installations

41 The difference between demand and supply volumes is due to technical losses and curtailment.

We have chosen to classify the electricity supply system decarbonization scenarios according to the three parameters discussed above and in Graph 15 that are representative of the variety of approaches:

- Total demand volume: total electricity demand expressed in TWh.
- Reliance on dispatchable production: ratio of electricity production from dispatchable sources and total electricity production, expressed in %.
- Net imports: total imported electricity minus total exported electricity expressed in TWh.

Figure 16 4 net-zero approaches in the energy sector



Comments:
1) Activity variables of scenarios in 2050 were compared against 2024 values and that ratio was normalized to show a scale from 1 to 5 for each variable
2) Offshore production in international energy island hubs with third party countries in BFP scenarios is modelled as imported electricity volumes. Hence, it does appear in the "share of imported power" driver rather than in "share of non-dispatchable power". The CAPEX computations take this capacity in scope, while the OPEX does treat the volumes as net imports.
Source: SCPI based on the author's scenarios

From figure 16, we observe that four distinct groups emerge for the electricity supply system:

- Lower power demand and strong self-reliance: These scenarios envision a transition with increased electrification, but with contained total demand volumes. Electricity production comes almost entirely from renewable energy sources. Reliance on foreign sources for either gaseous energy vectors or electricity imports remains limited.
- Lower power demand and some biogas: These scenarios also foresee contained demand volumes and do rely more heavily on imports. The share of dispatchable production is higher, and a notable use of biogas-based electricity production is made to cover periods with insufficient production.
- Medium demand and high renewable production: The third group has an average yearly electricity supply volume in 2050 that is more than double of the volume of 2024. These scenarios

rely on important renewable energy sources capacities, on some biogas production and on net electricity imports from neighbors.

- High demand met in different ways: The final group is slightly more heterogenous and is mainly characterized by the very high electricity supply and demand volumes (over 200 TWh).

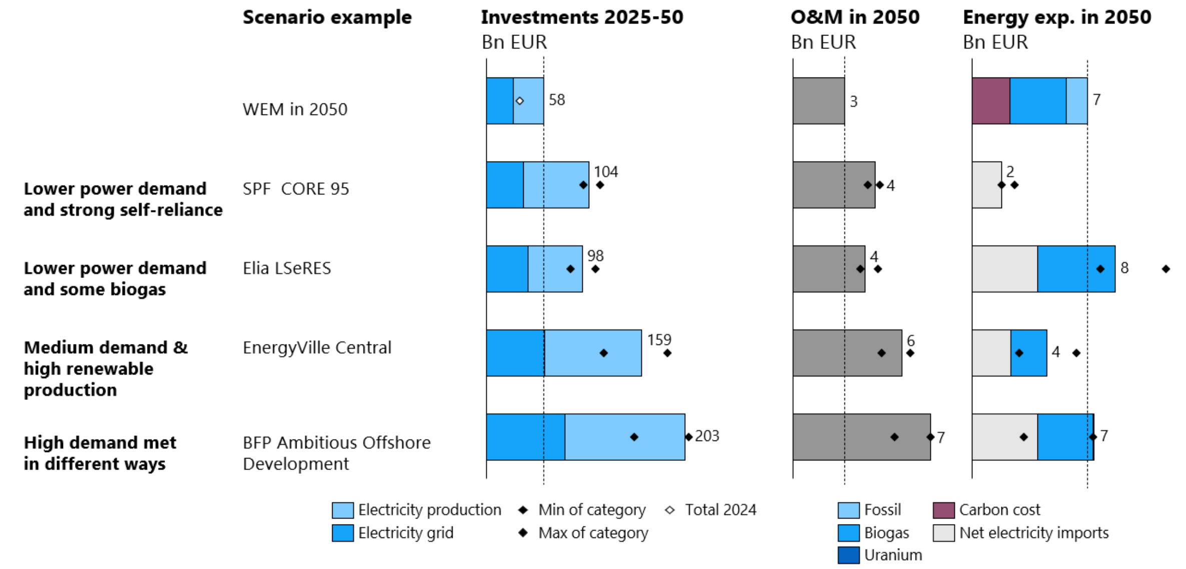
One shall note that the decarbonization approach of the power supply system is not independent from the transition in the other sectors. Indeed, the electricity demand, and its supply, are closely related to the decarbonization approach in the demand sectors. Therefore, total investment needs for power supply are dependent on the degree of electrification and the activity levels in the transport, buildings and industry sectors, as well as in the energy transformation sector (e.g. H2 production).

For each group of scenarios described above, we have selected one representative scenario for which results will be presented in the following sections.

5.3.2. Electricity supply system decarbonization CAPEX and OPEX

The graph below presents cumulative investments between 2025 and 2050, alongside maintenance costs and energy expenditures projected for 2050. Tables representing the results of other scenarios can be found in Appendix 2.

Graph 17 Investments, maintenance and energy expenditures for the power supply sector



Comments:
1) “Production” comprises the production assets and “grid” comprises transmission, distribution and flexibility assets.
2) Reference situation value is the 2024 value multiplied by 25 to cover the 2025-2050 period, i.e. maintaining investments constant.
Source: SCPI model

In all scenarios, the investment in the electricity sector needs to increase massively, especially for production capacities but also for grid expansion and reinforcement (see graph 17). Generally, the increase in generation capacity is larger than the increase in grid investments. For both categories the increase is largely correlated with the increase in electricity demand volumes.

In lower electricity demand scenarios, investments need to double compared to the reference WEM scenario in 2050. In the medium and high demand scenarios, the increase is three- to fourfold. Across the full series of scenarios, the CAPEX needs range from 85 to 206 billion euros cumulatively over the period, a respective 47% to 255% increase compared to the reference WEM scenario. Compared to the 2024 levels based on historic figures, this would represent 2.5 to 6 times more investments on average and per year for the whole electricity sector.

Although the total additional investments in the electricity supply sector are not the largest component of the total additional investment (see next section), their increase compared to current levels is massive.

When looking at energy expenditures, three main cost drivers are at play: the cost of carbon for the reference WEM scenario, the volumes of net electricity imports and the volumes of biogas-based electricity production in the fully transitioned system. Price curve projections for wholesale power prices (used for net electricity imports) and for wholesale biogas prices are detailed in Appendix 3.2.

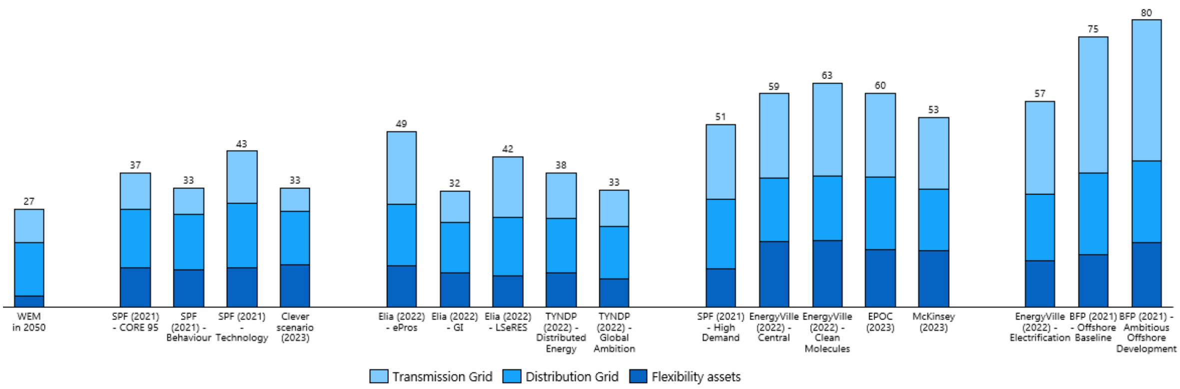
In the reference WEM scenario, some of the dispatchable power production is still fossil based. A carbon cost that covers either emission allowances or CCS installations is therefore computed, based on projections of carbon prices for the European Trading Scheme 1 (full details in Appendix 3.2.).

Energy expenditures in lower demand scenarios with strong self-reliance are less than a third of expenditures in the reference WEM scenario. In such scenarios, the energy expenditures are solely due to imported electricity as all the domestic production is renewables based. Lower demand scenarios with biogas on the contrary have higher energy expenditures in 2050 than in the reference WEM scenario. This is related to the higher wholesale price for biogas in these transition scenarios than natural gas prices plus carbon costs in the reference WEM scenario. Medium and high demand scenarios have energy expenses that range from half the ones in the reference WEM scenario to similar levels as for the reference WEM scenario.

Zoom on investment needs in grid and flexibility assets

In all the transition approaches, additional investments in the electricity network (grid and flexibility) are strongly needed (from +19% to +195%) compared to the reference WEM scenario. Investment needs for the electricity transmission and distribution network are largely driven by the renewable energy production volumes of the scenarios.

Graph 18 Grid and flexibility investment needs (yearly average 2025 to 2050, in Bn EUR)



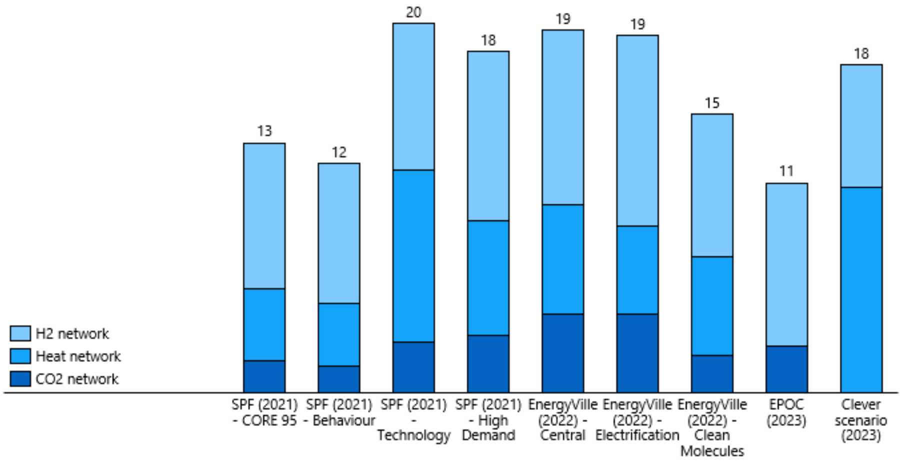
Source: SCPI model

When adding up an average yearly CAPEX and the projected OPEX in 2050 in the different transition scenarios, and relate them to total electricity supply, one can have a rough idea of the system cost of electricity. This system cost of electricity appears to be consistent across all scenarios and hovers around 0.095 euros per kWh. For more details about this rough approximation, we refer to Appendix 1.2.

5.3.3. New energy networks

For a selection of scenarios, we have been able to estimate investment needs in new energy networks (CO_2, hydrogen and heat). These are based on the expected volumes produced and/or imported in Belgium. When net zero scenarios rely on these networks, their cumulative capital expenditures over the 2025-50 period range from 11 to 20 billion euros, or 0.44 to 0.8 billion a year on average. Roughly half of these investments are needed for hydrogen networks (electrolyzers, pipes – from which a part is retrofitting natural gas pipelines – and an import/export terminal). Second comes heat districts, for which the expenditures relate to pipes and exchangers in the building sector. Industrial heat networks are deemed investments within the industrial scope. Finally, carbon networks include expenses related to the pipes themselves, the export value chain and the installation of Direct Air Capture assets (DACS). Other Carbon Capture and Storage assets (CCS) are not included and are part of the industry sector scope.

Graph 19 New energy networks CAPEX (cumulated 2025 to 2050, in Bn EUR)



Comments: none of such networks is assumed in a WEM scenario
Source: SCPI model

5.4. Industry Sector

Industrial activity, more specifically manufacturing industries and construction materials, is a major source of GHG emissions in Belgium, accounting for around 35 million tons of CO_2 equivalent in 2022[42], or 26% of the country's total.[43] Most of the emissions are due to combustion of fossil fuels as an energy carrier or to carbon emitting processes.

Competitivity challenges are critical in the industry sector, and industrial actors themselves face though choices when it comes to ramping up their investments demanded by the transition.

Only a few neutrality scenarios have a detailed roadmap for decarbonizing Belgium's industry. Indeed, modelling transition pathways and related investment needs for the industry is hazardous, as they are subject to significant uncertainties. The industry sector comprises a large diversity of activities. Besides the important emitters (chemicals, refinery, cement, metallurgy, glass, limestone, paper, food), thousands of singular industrial processes exist. A lot of different options exist for industries to reduce their GHG-emissions, ranging from electrification and fuel switch, to developing new processes, devising alternative products or materials or even shutting down certain activities. Furthermore, industrial data and decarbonization choices made in industry are often confidential. Choices made by industrial companies are discretionary and obey transnational dynamics, such as global competition, international regulations, geopolitics, price evolution of energy and materials, etc.

We rely on existing analyses to provide an estimate for the additional investment needs of the industrial sector. A series of studies follow a top-down approach and give an overall number for the sector:

42 This includes emissions from energy use in industrial processes, from process emissions themselves and emissions from refining and manufacture of solid fuels.

43 European Environment Agency, 2024.

- In it’s net-zero study for Belgium from 2023,[44] McKinsey estimates the additional investment needs in the industry between **25 and 40 billion euros** cumulated until 2050[45] to achieve an emission reduction in industry of 96%. The study expects the main efforts to be realized in high emitting sectors such as steel, ethylene and cement production. These drivers include amongst others the doubling of energy-efficiency measures, 90% electrification of low and medium temperature heat, the use of CCS, hydrogen and green molecules to phase out fossil fuel uses.

- A 2020 study by Deloitte and Climact[46] computes an additional investment of **12 to 18 billion euros** needed by 2050 to reduce GHG emissions of the industry in Flanders by 86% compared to the 2005 levels. This reduction makes use of new production processes and products using biofuels, hydrogen and electricity instead of emitting feedstock and energy carriers. In this analysis, the investments in carbon capture technologies represent 2 to 8 billion euros.

- In 2021, Bond Beter Leefmilieu and Climact published a study on a 95% GHG emission reduction for industry in Flanders.[47] The study estimates the necessary investments between **12.5 and 13.7 billion euros**. The study covers Flanders alone, and focuses mostly on Chemicals, Steel, Ceramics & Glass, Paper & Food and Refineries. The major drivers used are a reduction in produced volumes in most of the sectors, especially in refining, and a shift to alternative production technologies, in particular for Chemicals and Paper & Food processing. The study also assumes shifts in the energy vectors used in certain processes (electrification and hydrogen) and the use of carbon capture technologies.

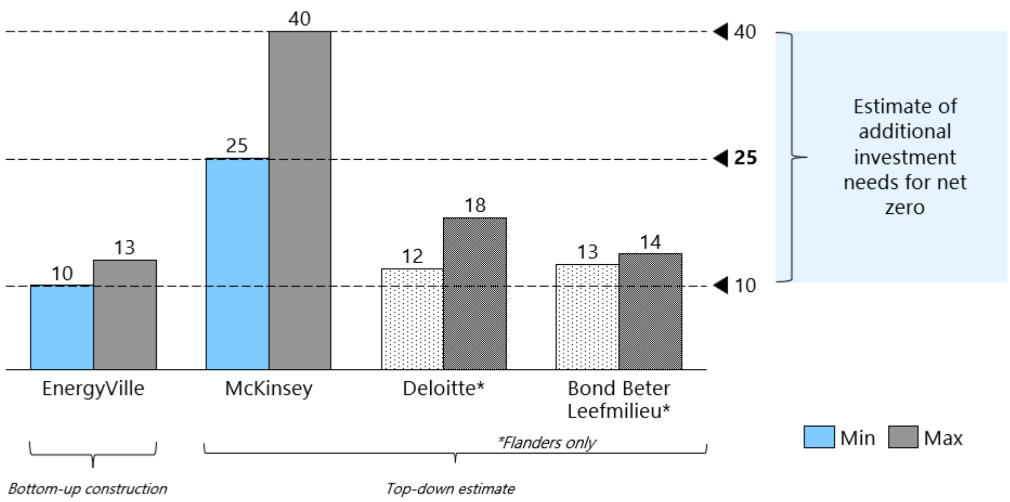
EnergyVille (2022) computed bottom-up Capital Expenditures for their transition scenarios, respectively Clean Molecules, Electrification and Central. According to this author, the cumulated additional investment needs for transitioning the Belgian industry are range from **10 to 13 billion euros**.

Taking these estimates together, we obtain a range of **10 to 40 billion euros** for additional capital investment needs for industrial decarbonization in Belgium by 2050, which corresponds to between 0.4 and 1.6 billion euros yearly.

Although these estimates are small in the total investment gap of all sectors together (see next chapter), they should not be overlooked. Indeed, investments in buildings and transport are spread over a full population, while investments in industry rest upon the shoulders of a smaller number of companies (likewise in the energy sector).

44 McKinsey & Company (2023)
45 The study mentions a figure of 30 to 45 billion euros which includes 5 billion euros for hydrogen and carbon network infrastructure. In this study, this has been modelled within the energy sector. Therefore, we exclude this amount.
46 Deloitte and Climact (2020)
47 Bond Beter Leefmilieu and Climact (2021)

Graph 20 Additional cumulated Capital Expenditures for the industry sector up to 2050 (in Bn EUR)



Source: SCPI analysis based on EnergyVille, McKinsey & Company, Deloitte and Bond Beter Leefmilieu publications

All these estimates assume stable production volumes across industries (except for Bond Beter Leefmilieu). This means that they do not foresee production increase or decrease across industries due to changing consumption patterns induced by the transition (either due to regulation, subsidy or carbon pricing) or new opportunities (e.g. bio-based industries, critical raw material processing, circular economy, or decarbonization technologies industries).

Moreover, these studies do not cover GHG emissions from digital services. In Europe, around 3% of electricity consumption is from data centers alone and this figure is increasing rapidly.[48]

[48] Connaissance des énergies (2024)

6. Aggregation of results

6.1. Introduction

This section addresses the aggregation of investment and operational expenditures from scenarios developed by various authors, covering at least the building, transport, and energy production sectors.

To properly interpret this section, the following points should be noted:

- The scenarios currently available and usable (sufficiently detailed and covering the main sectors) are relatively few. Moreover, **these scenarios were developed within their technological and regulatory contexts between 2021 and 2024**. As this context is constantly evolving, other scenarios may and will likely be proposed in the future by different authors.

- This report compares the currently available and usable scenarios **without making any judgments about them**, including their relevance. The choice of one scenario over another is a societal/political decision that must consider numerous factors not examined in this report.

- Net-zero scenarios are compared either to a historical reference situation corresponding to the year 2024 or to a "With Existing Measures" (WEM) reference scenario, which aims to account for a series of policy-unchanged developments up to 2050. It is important to keep in mind that the choices underlying the development of the latter necessarily influence any comparison with decarbonization scenarios.

- This section presents **two aggregations of investment expenditures**. The first aggregation includes the **total construction costs of new passive (or high-energy-performance) buildings**. The second aggregation, which is still exploratory at this stage, includes **only their additional cost compared to a building with average energy performance** (see the section dedicated to buildings). The use of these two aggregations aligns with various practices in the literature[49] and allows for a rich and nuanced description of the results. Thus, the first aggregation is more relevant for assessing the macroeconomic consequences of different scenarios and better reflects the investment needs for the environmental transition and other societal issues (such as energy security, air pollution, biodiversity, road congestion, etc.). The second aggregation is more focused on investments related to decarbonization technologies. It has only been applied to new buildings and not to new cars, the other major category of investment expenditures for which this measure would also be relevant. Such an application would require a more detailed analysis, which could be the subject of future work, to account for factors such as the substitution between investments in personal cars and public transport.

[49] The recent report of the European Central Bank, Occasional Paper Series n°367, "Investing in Europe's green future ; Green investment needs, outlook and obstacles to funding the gap" notes on page 13 that "the estimates differ according to whether the full costs of a green investment are taken into account, or only the difference compared with an investment when the old technology is used. For example, for electric vehicles, the estimates of the European Commission and I4CE include the full costs of electric vehicles, while the IEA only considers their battery costs."

- Care should also be taken **not to interpret investment and operational expenditures as "the costs" of the climate transition**. Indeed, the scenarios and the investments that characterize them have a range of consequences that are not analyzed here. These include, for example, their macroeconomic impacts, such as their effects on growth, employment, inflation, or public finances.

This section is organized as follows. It starts by comparing the investment levels corresponding to the different scenarios, then addresses the issue of operational expenditures resulting from these various investments.

6.2. Scenarios and Investment Expenditures: Comparison of Their Levels and Compositions

6.2.1. Net-zero approaches across sectors

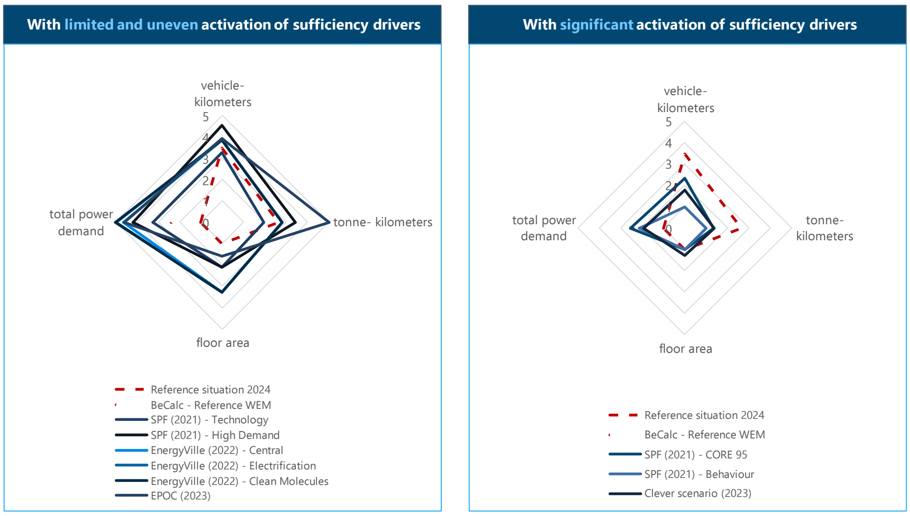
Sectoral analyses (see previous sections) have grouped the scenarios based on the decarbonization levers that differentiate them the most for each sector. A common feature among the scenarios across all sectors is the use of numerous energy efficiency levers (such as building insulation and heat pump installation) and the adoption of non-fossil energy, primarily through electrification (vehicles, heat pumps, renewable energy sources, and the strengthening of electricity grids).

However, **these scenarios differ significantly in their reliance on moderating the growth of or even reducing certain activity volumes, such as new constructions or the number of kilometers traveled in personal vehicles** (e.g., increased use of carpooling or public transportation), or shifting certain activities (e.g., modal shift). The implementation of these levers has a major impact on the required capacity of the energy system, particularly electricity. The literature refers to these levers using the term "sufficiency".

Figure 21 groups the different scenarios studied based on their use of sufficiency levers. On one side, there are scenarios that implement few levers to limit activity volumes (such as the total number of vehicle kilometers or total building area) or apply these levers unevenly. These scenarios generally assume that these activities will continue to grow compared to 2024 (red dashed line), but at a slower rate than the "With Existing Measures" (WEM) scenario (red dotted line).

On the other side, scenarios such as "Clever" or "SPF Behaviour" apply these levers much more extensively and assume that some activity levels will decrease compared to 2024 (vehicle kilometers or freight kilometers) or remain almost unchanged (total building area), despite population growth.

Figure 21 Illustration of Scenario Groupings Based on the Prevalence of Sufficiency Levers



Source: SCPI based on the author's scenarios

Some scenarios, particularly those that make extensive use of sufficiency levers, have been designed by their authors to integrate, alongside the challenge of reducing greenhouse gas emissions, other distinct but directly related societal issues (a systemic approach). These authors consider, for example, that indicators related to the number of cars have an impact on air pollution, even when vehicles are decarbonized. Similarly, the reduction in the number of new constructions (decreasing land artificialization) can lower natural resource consumption and support biodiversity conservation.[50]

6.2.2. Investment expenditures (CAPEX)

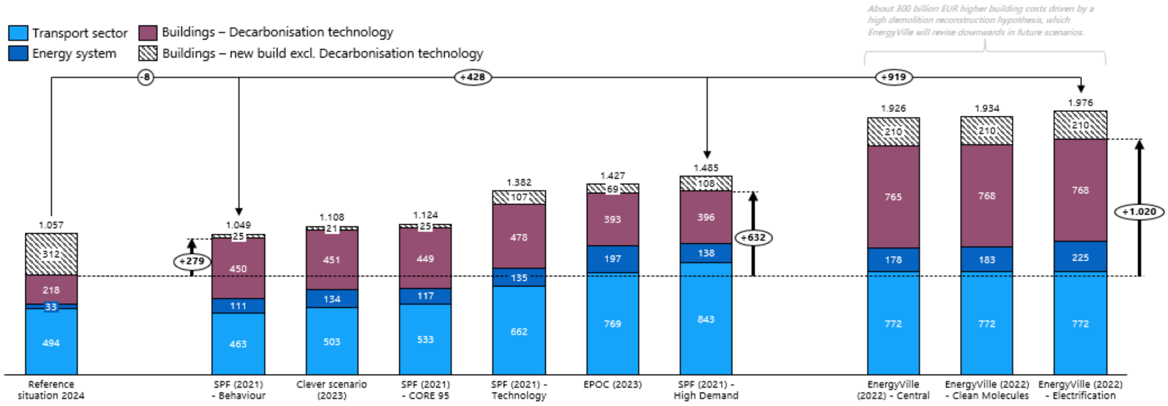
As stated in the introduction (as well as in the section dedicated to buildings), the use of two investment expenditure measures for buildings aims to distinguish expenditures exclusively related to decarbonization technologies (renovation expenditures and, for new buildings, the additional cost of decarbonization technologies compared to carbon-intensive alternatives) from expenditures related to the

[50] See, for example, the "Clever" scenario: *"Finally, the kind of deep changes considered cannot be assessed only through energy demand, supply and GHG emission criteria. The transformations are likely to have much more systemic implications on other environmental issues (biodiversity, land use, depletion of materials, etc.) as well as on social, economic and societal issues. Although these aspects are not directly covered through modelled quantification in the CLEVER scenario, the scenario was built with a constant concern for such a strong sustainability."* (source: CLEVER (2023) "Climate neutrality, Energy security and Sustainability: A pathway to bridge the gap through Sufficiency, Efficiency and Renewables", June 2023, p.9.); pour les différents scenarios SPF (2021) scenarios, voir par exemple pp 9-10 de SPF (2021), "Scenarios for a climate neutral Belgium by 2050", as well as the description of the impacts on soils, material demand, air pollution, etc., in the same publication; see also Climact (2021), *"Study on the Electrification Needs of Mobility in Belgium and the Related Impacts,"* December 2021, for the challenges related to the decarbonization of mobility within the framework of these same scenarios.

construction of new buildings, excluding these additional costs (foundations, structural work, non-decarbonized techniques, and finishing).

Graphs 22 and 23 present the total investment expenditures (CAPEX) detailed in the previous sections for the three modeled sectors over the entire period (excluding industry).

Graph 22 Investment expenditures per scenario for the considered period (2025-20250) compared to 2024 in billion EUR



Additional investment expenses as a % of 2024 GDP

	SPF (2021) - Behaviour	Clever scenario (2023)	SPF (2021) - CORE 95	SPF (2021) - Technology	EPOC (2023)	SPF (2021) - High Demand	EnergyVille (2022) - Central	EnergyVille (2022) - Clean Molecules	EnergyVille (2022) - Electrification
Total investment excluding hatched area	1,9%	2,3%	2,4%	3,6%	4,1%	4,3%	6,6%	6,6%	6,9%
Total investment	-0,1%	0,3%	0,5%	2,2%	2,5%	2,9%	5,9%	5,9%	6,2%

Comments:
1) 2024 value, for comparison with a situation where the investment envelope would be kept constants, is obtained by multiplying the 2024 investment 25 times.
2) GDP estimate for 2024 is 591 billion euros, retrieved from 2023 GDP of 585 Bn euros from FPS Economy (2024) and 1.1% growth projection from FPB (2024).
3) GDP estimate for 2025-2050 is 737 billion euros, retrieved from the report on aging from the Federal Planning Bureau (2024)

Source: SCPI model

Firstly, it is observed that potentially very significant investment levels will need to be mobilized by 2050. The analyzed decarbonization scenarios lead to an average **total investment (CAPEX) over the period that is equal to or, in most cases, higher than the level observed in 2024**, regardless of the investment aggregation method used. Investment levels could rise by up to approximately 40 billion euros per year on average compared to 2024.

Secondly, there is a significant difference in investment levels between the scenarios. This variation is mainly explained by the extent to which sufficiency levers are used. The reduction in the volume of certain activities (such as the decrease in the number of private vehicles and the reduction in square meters of new construction) significantly limits the total investment requirements in these scenarios.

It should be noted that the three EnergyVille scenarios, dating from 2022, assume a particularly high rate of demolition-reconstruction of buildings, which significantly increases their investment expenditure levels (see below). This largely contributes to the substantial differences observed in investment expenditures between the scenarios. New scenarios currently being developed by the same authors will significantly revise this assumption downward, leading to a considerable reduction in the associated investment expenditures.[51]

Excluding these three scenarios for the reasons mentioned above, the additional investment expenditures compared to the 2024 reference scenario are as follows.

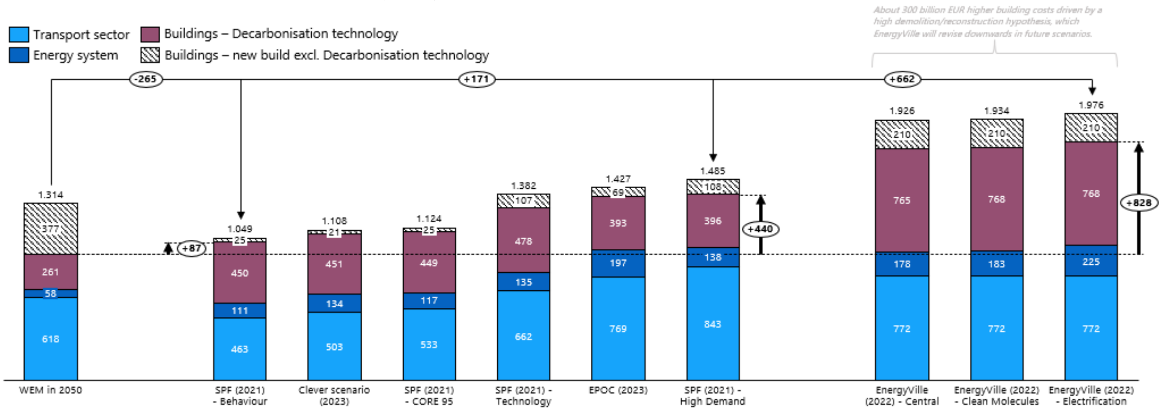
- **At the upper end of the range, additional investments amount to 25 billion euros (4.3% of GDP) on an annual average; this figure is reduced to 17 billion euros (2.9% of GDP) due to a decrease in investments unrelated to decarbonization technologies in the building sector** (see the "SPF High Demand" scenario).
- **At the lower end of the range, scenarios that make the most use of sufficiency levers show an increase of 11 billion euros (1.9% of GDP) on an annual average; this figure is brought down to almost zero due to the reduction in investments unrelated to decarbonization technologies in the building sector** (see the "SPF Behaviour" scenario).

However, the With Existing Measures (WEM) scenario already assumes an increase in investment expenditures. Comparing investment expenditures with this WEM scenario helps assess the need for additional policies. For this comparison, both forms of investment expenditure aggregation should be considered (see above).

If the second aggregation approach is used (which includes only the additional cost of decarbonization technologies for new buildings), it is also observed that all the studied scenarios lead to a higher total average investment (CAPEX) over the period than the WEM scenario (solid horizontal line).

[51] The assumed demolition-reconstruction rate is 1.15% per year. This rate should be revised to values around 0.2%. This change will significantly impact the assessment of investment expenditures for buildings, given that the cost of renovation is significantly lower than that of demolition and reconstruction.

Graph 23 Investment expenditures per scenario throughout the whole period (2025-20250) compared to the With Existing Measures scenario (WEM) in billion EUR



Additional investment expenses as a % of 2025-2050 GDP

	SPF (2021) - Behaviour	Clever scenario (2023)	SPF (2021) - CORE 95	SPF (2021) - Technology	EPOC (2023)	SPF (2021) - High Demand	EnergyVille (2022) - Central	EnergyVille (2022) - Clean Molecules	EnergyVille (2022) - Electrification
Total investment excluding hatched area	0,5%	0,8%	0,9%	1,8%	2,3%	2,4%	4,2%	4,3%	4,5%
Total investment	-1,4%	-1,1%	-1,0%	0,4%	0,6%	0,9%	3,3%	3,4%	3,6%

Comments:
1) 2024 value, for comparison with a situation where the investment envelope would be kept constants, is obtained by multiplying the 2024 investment 25 times.
2) GDP estimate for 2024 is 591 billion euros, retrieved from 2023 GDP of 585 Bn euros from FPS Economy (2024) and 1.1% growth projection from FPB (2024).
3) GDP estimate for 2025-2050 is 737 billion euros, retrieved from the report on aging from the Federal Planning Bureau (2024)
Source: SCPI model

If the first investment aggregation approach is used[52], it is also necessary to take into account the expenditures related to the construction of new buildings, excluding their additional decarbonization cost (hatched section in Graphs 23 and 24). Since all scenarios assume a smaller increase in new square meters compared to the WEM, these expenditures are lower than those in the WEM for all scenarios. Thus, investment expenditures in new constructions, excluding decarbonization technologies, amounted to 12 billion euros in 2024 and 15 billion euros on an annual average in the reference scenario. In the decarbonization scenarios, this amount is reduced to a level ranging from 8 billion euros (Energyville) to 1 billion euros (SPF Behaviour). **For the sufficiency scenarios that most significantly reduce new square meters compared to the WEM, this effect is even stronger, to the point that their total investment levels are lower than those of the WEM**.

Thirdly, the composition of investments changes at the sector level.

- **In the energy production sector**, all the studied decarbonization scenarios anticipate a **drastic increase in investment needs**. This increase is driven by the rising demand for electricity, the shift in the energy mix toward decarbonized sources, and the necessary development of grids and intermittency management. This results in an investment increase ranging from 3 to 8 billion euros on an annual average compared to the 2024 situation (a three- to sevenfold increase) and between 2 to 7 billion euros compared to the reference scenario (a two- to fourfold increase).

- **In the transport sector,** several effects are at play. On the one hand, **the purchase of decarbonized vehicles tends to increase investment costs** related to vehicle replacement. On the other hand, depending on the scenarios, part of this mobility is shifted towards public transport

[52] As a reminder, the first aggregation approach refers to the total investment needs in the buildings sector. These estimates include the total expenditures of the construction of new buildings, including decarbonization technologies as well as foundations, structural work, finishes, etc.

(mainly rail or buses). These alternatives require significant additional investment expenditures, but the total investment is still lower than the reduction they generate in terms of individual vehicle investments. Finally, in some scenarios, the demand for individual mobility is reduced or shifted towards active transport modes, which directly decreases investment expenditures. Overall, **scenarios that make little or no use of modal shift and mobility reduction lead to investment expenditures up to 71% higher than in 2024** and 36% higher than the reference WEM scenario. Conversely, **scenarios that heavily rely on modal shift and mobility demand reduction lead to a 6% decrease in investment expenditures compared to 2024** and a 25% decrease compared to the reference WEM scenario.

- **In the building sector**, there is a **shift**, or even a transition, in investment expenditures **from new buildings excluding decarbonization technologies** (see the hatched sections in Figures 1 and 2) **toward investment expenditures for the decarbonization of new buildings and, more importantly, existing buildings**, including demolition and reconstruction. These expenditures for the renovation of existing buildings and the decarbonization of new buildings increase significantly in all scenarios. They rise to levels ranging from 7 billion euros in the "High Demand" scenario, 10 billion euros in the "SPF Technology" scenario, and even up to 22 billion euros in the "EnergyVille" scenarios, on an annual average compared to the situation in 2024. However, it should be noted that the "EnergyVille" scenarios, which define the upper end of the range described above, are characterized by particularly high investment expenditures due to the assumption of a particularly high level of demolition and reconstruction.

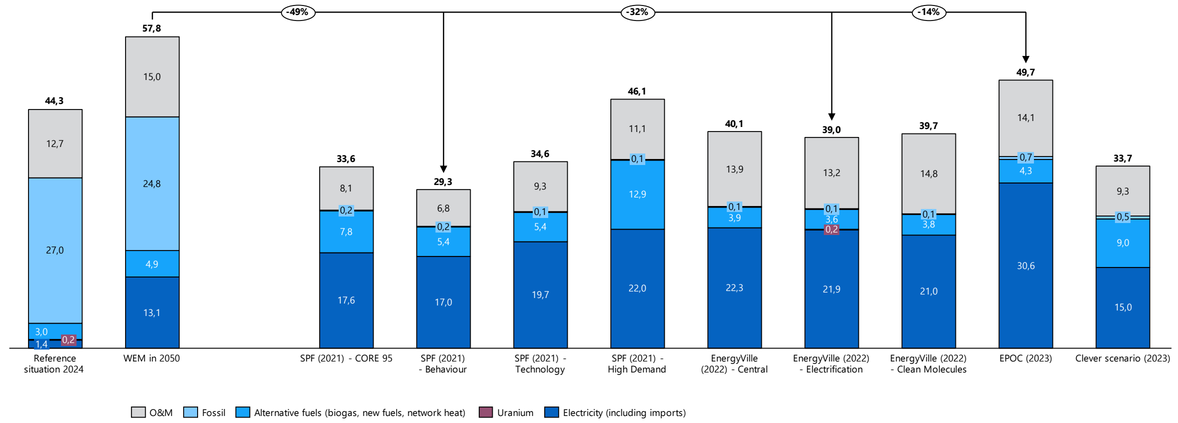
As a reminder, the industrial sector could not be modelled in detail, and we refer to specific studies on this subject (see the industry section), which estimate a range of **10 to 40 billion euros** for additional capital investment for industrial decarbonization in Belgium by 2050 (between 0.4 and 1.6 billion euros yearly). This range should be added to the results shown above in order to get a full picture of the total additional investment.

It is noted that the additional investment levels from these studies appear relatively low compared to the additional investment expenditures in the other sectors. However, this does not imply that these amounts may not be significant at the level of a specific industry or company

6.2.3. Operational expenditures (OPEX)

Graph 24 presents operational costs, including fuel or primary energy sources, in 2050, which is the point at which climate neutrality is achieved.

Graph 24 Operational expenditures by scenario in 2050 in billion EUR



Comments:
1) Alternative fuels encompasses biogas, hydrogen, e-fuels and network heat. Fossil fuels comprise liquid fossil fuels and natural gas. The fuel consumption costs across all sectors have been consolidated and aggregated to obtain a comprehensive total.
2) Industry O&M and energy consumption not included.
3) Since electricity production costs are estimated within the energy sector, the wholesale component of electricity prices is excluded from the demand sectors to prevent double counting. This implies that only the network charges and fiscal elements of electricity costs are accounted for in the demand sectors.
Source: SCPI model

It is observed that **all decarbonization scenarios increase investment expenditures but reduce operational costs compared to the WEM reference scenario**. Compared to the historical situation, only two scenarios (SPF High Demand and EPOC) contain rather than reduce operational costs.

This can be explained by a combination of two factors.

First, **many decarbonization levers involve making investments that reduce energy demand**. Examples include building insulation, modal shift, and energy efficiency improvements enabled by vehicle electrification.

Moreover, on the supply side, increased electrification relies heavily on **renewable energy sources, which are more capital-intensive than their carbon-based alternatives.** As a result, decarbonization scenarios lead to a significant reduction in operational costs (OPEX) associated with the use of carbon-based energy. Even though the price of electricity and, in particular, synthetic fuels may be higher than that of carbon-based fuels, their overall cost is generally lower due to reduced consumption volumes.

7. Public investment and public policies: considerations for possible future study

The analyzed scenarios each rely on a set of levers enabling decarbonization. However, they do not model or assume the implementation of specific public policies. Nevertheless, public intervention is essential for mobilizing the investments analyzed in this study.

As a reminder, this report represents the first phase of work aimed at identifying investment needs. A second phase could involve analyzing these different types of public intervention from the perspective of public investment. At this stage, we outline five levels at which such intervention could take place.

Firstly, a series of transition investments must be planned and directly financed by the government. This is particularly relevant for sectors where public authorities—whether at the federal, regional, community, or local level—own the relevant assets. The primary examples include public buildings, such as government offices, schools, or social housing. Significant investments must be made, and their public funding must be secured.

Secondly, as established by the Study Committee,[53] public intervention in investments can take various forms, including (i) investment subsidies, (ii) equity participation and loans, (iii) public-private partnerships, and (iv) public regulation of infrastructure financed by private capital. These four forms of intervention should be leveraged in the context of the climate transition. Some of them involve strategic planning and decision-making, such as public transport infrastructure or energy networks, including emerging networks for hydrogen or carbon transport. Other, more decentralized investments may require support or guidance, particularly when they are not profitable at an individual level (for households or businesses). The selection of appropriate instruments should be based on the existing policy framework at various levels, as well as underlying distributional and competitiveness concerns. The implications for public finances could vary significantly depending on the chosen approach.

Thirdly, if the implementation of sufficiency levers is adopted, a series of public policies must be put in place. In some cases, this involves already established public investments, such as those related to public transportation aimed at promoting modal shifts and reducing the share of car travel. In other cases, it involves specific investments or policies, for example, in land use planning or circular economy initiatives.

Fourthly, regardless of the chosen scenario, investments in human capital must also be mobilized. The shift of various activities between sectors, and especially within different sectors, requires reallocation in terms of employment and, more importantly, skills. The acquisition and upgrading of skills partially rely on public authorities.

Finally, even though this aspect could not be considered within the scope of this exercise, investments in climate change adaptation will need to be made. In some cases, this involves new types of investments, such as water management infrastructure, most of which is collectivized and therefore requires

53 See SCPI (2024), Public Investments: Definition and Role, section 2.2, box 2

public intervention. In other cases, certain adaptation investments are linked to transition investments, such as those related to building overheating or infrastructure for passenger, freight, or energy transport.

Additionally, an update of this study could usefully incorporate additional scenarios or revisions of the currently examined ones, for instance, in light of the 2025 federal government agreement.

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