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Stranded assets and energy transition: Implications for the Belgian residential gas sector

A scenario-based cost-benefit analysis on the Resa case

Author: Satine Van Beirs
Supervisor: Pr Bert Willems
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Signed the 27.05.2025 in Grez-Doiceau

Abstract

Decarbonising the Belgian residential sector is a major challenge, both in terms of climate and economics. This master thesis examines the economic and environmental implications of phasing out natural gas, based on the case of the Walloon network operator Resa. Three transition trajectories are compared: maintaining the current state of play, a controlled gradual phase-out, and a planned withdrawal scenario that progressively prohibits the replacement of gas-fired boilers. The analysis is based on a partial cost-benefit analysis approach, focusing on consumer surplus, stranded assets and climate externalities related to avoided CO_2 emissions. The results suggest that the scenario based on a gradual ban on the replacement of gas boilers performs significantly better than the others, due to the environmental benefits it captures. This study sheds light on the trade-offs between the pace of transition, economic sustainability and climate efficiency, and offers a basis for consideration in assessing local decarbonisation trajectories for gas networks.

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Abbreviation	Full term
ACER	European Union Agency for the Cooperation of Energy Regulators
CAPEX	Capital Expenditures
CBA	Cost-Benefit Analysis
CO2	Carbon Dioxide
CREG	Commission de Régulation de l’Electricité et du Gaz
CWaPE	Commission Wallonne pour l'Énergie
DSO	Distribution System Operator
ETS	Emissions Trading System
HP	Heat Pump
kWh	Kilowatt-hour
NECP	National Energy-Climate Plan
NPV	Net Present Value
OPEX	Operational Expenditures
RAB	Regulatory Asset Base
TSO	Transmission System Operator
VAT	Value Added Tax
VREG	Vlaamse Regulator van de Elektriciteits- en Gasmarkt

Introduction

While the European Union is aiming for carbon neutrality by 2050, the gradual reduction in residential use of natural gas seems unavoidable. In Belgium, where natural gas is still the dominant energy source for domestic heating, the anticipated long-term structural decline in demand poses significant challenges for network operators.

With twenty-five years remaining until the target horizon, the need to develop a coherent and anticipatory transition strategy has become both urgent and unavoidable. Gas distribution network operators are in a particularly delicate position: they must continue to maintain infrastructures that are still fully functional, originally designed for widespread and long-term use, even though demand is expected to decline. Gas distribution is based on largely fixed costs structure. As some users progressively disconnect from the network, overall maintenance costs remain largely unchanged, which automatically increases the bill for the remaining households and undermines the economic equilibrium of the system. One of the major risks associated with this dynamic is ‘stranded assets’, infrastructure that becomes unprofitable or obsolete before the end of its economic life. As some users progressively disconnect from the network, overall maintenance costs remain largely unchanged, which automatically increases the bill for the remaining households and undermines the economic equilibrium of the system. Managing this transition requires a rigorous assessment of network development options, economic incentives, and cost allocation mechanisms to address the inertia of a system that was historically optimised for a lifetime usage now being called into question.

In this context, this research proposes a cost-benefit analysis of different gas phase-out scenarios for the Resa distribution network in Wallonia. The aim is not to discuss the desirability of such a phase-out, but to assess its economic and climate implications according to three contrasting trajectories: maintaining the status quo, gradual phase-out, and rapid phase-out accompanied by large public support.

1 Background: The Belgian gas market

The Belgian gas sector is shaped by a complex network of actors, from suppliers to regulators. This section outlines their respective roles and examines recent trends, future prospects, and low-carbon alternatives for residential heating.

1.1 Actors and governance of the Belgian gas network

In Belgium, natural gas supply is handled by licensed providers who purchase gas from international producers and sell it to end-users, as the country relies entirely on imports to meet its consumption needs (SPF Economie, 2025). This activity requires prior authorisation from the federal regulator (CREG, n.d.).

The Belgian Transmission System Operator (TSO), Fluxys, is responsible for transporting natural gas from import terminals to large consumers and local networks (CREG, n.d.). It operates a 4,000 km high-pressure pipeline system, the LNG terminal in Zeebrugge, and the Loenhout storage site (Fluxys, n.d.).

Distribution System Operators (DSOs) ensure gas delivery to households and small businesses. They manage new grid connections, maintenance, and meter readings. The main DSOs are Fluvius (Flanders), Sibelga (Brussels), ORES and Resa (Wallonia), covering nearly the entire country (VREG, 2018).

Regulatory responsibilities are shared between the federal and regional levels. The CREG regulates the national energy market, while regional regulators VREG (Flanders), Brugel (Brussels), and CWAPE (Wallonia) oversee distribution activities (CREG, n.d.). At the European level, ACER coordinates cooperation among national regulators (ACER, n.d.).

1.2 Trends in Belgian gas sector

Energy demand and price trends are shaped by two key concepts: primary and final energy consumption. Primary consumption reflects total national demand, including end-user consumption, energy sector needs, and losses from transformation and distribution. For natural gas, this includes gas used for electricity generation. Final consumption refers only to the energy delivered to and used by end-users, excluding the energy sector’s own use but possibly including non-energy uses (SPF Economie, 2025).

In 2023, final energy consumption in Belgium amounted to 36.4 million tonnes of oil equivalent (Mtoe)[1], the lowest value recorded between 2014 and 2023. The fluctuations observed are largely influenced by climatic conditions. Hard winters like in 2021 have led to a sharp rise in heating demand, particularly for natural gas. In 2023, natural gas was the second most important energy carrier in the final consumption mix, with a share of 24.6% (or 9.0 Mtoe), behind petroleum products (47.9%) and ahead of electricity (17.5%). This breakdown has remained broadly stable over the past decade. In 2022, 71.3% of the energy consumed by households was devoted to space heating. Natural gas (43.4%) and petroleum products (37.9%) accounted for the largest share of this consumption. The share of space heating in total household energy consumption has varied, depending on weather conditions, between 70% and 77% since 2010 (SPF Economie, 2024, 2025).

In economic perspective, the average price of natural gas paid by Belgian households in 2023 was 10.7 eurocents per kilowatt-hour, down 7.2% on 2022. The bill was split as follows: 72.9% for energy costs, 15.3% for network tariffs and 11.9% for taxes, including VAT and other charges (notably excise duties). Faced with soaring prices in 2022, several measures have been adopted: temporary extension of a social tariff (until June 2023) and the temporary reduction in the VAT rate from 21% to 6% in 2023, offset by a reform of excise duties (SPF Economie, 2025).

1.3 The future of natural gas in Belgian residential heating

In all major prospective scenarios, exploring pathways to carbon neutrality in Belgium by 2050, natural gas is progressively phased out from the residential sector. The PATHS2050 report published by Energyville shows that, regardless of the scenario considered, whether it favors renewables, nuclear power or imports, gas consumption in housing is essentially replaced by electricity (via heat pumps) and marginally by biomethane. At the same time, final energy consumption in the residential sector falls by over 40%, thanks in particular to electrification, improved energy efficiency and the rise of district heating (Correa Laguna et al., 2023; PATHS2050 Coalition, 2025). Elia's Blueprint 2024 corroborates these trends, stating that a highly electrified scenario would reduce energy demand by 25-45% and make electricity the main form of energy consumed, covering up to 80% of final demand (Elia, 2024). The central

[1] 1 Mtoe = 11,63 TWh according to the IEA unit converter

"CORE-95" scenario of the federal report Climate-neutral Belgium by 2050 forecasts complete decarbonization of the residential sector via a combination of massive building renovation, demand reduction of up to -57%, and almost complete electrification of heating (FPS Public Health, 2021).

1.4 Low-carbon alternatives to fossil heating

Several options are available to replace fossil fuel-based heating. Heat pumps stand out for their energy efficiency, with a coefficient of performance (COP) of up to 3 to 4 (depending on the type of dwelling and insulation), which means they produce three to four times more thermal energy than they consume in electricity (CREG, 2025, p. 26). Despite strong growth in sales in recent years, this dynamic seems to be slowing down at the start of 2024. Heat pumps currently account for just 11% of new heating system sales, despite an installed share of just 4.6% in the existing mix. At the same time, sales of air-conditioning systems are growing strongly, which could ultimately increase energy consumption in the residential sector (SPF Santé publique, 2024, pp. 47–48).

District heating networks currently account for a marginal share of heat consumption in Belgium, covering only around 1% of the heating and cooling needs of residential buildings (CREG, 2025, p. 63).

Finally, biomethane and solid biomass appear to be renewable vectors likely to contribute moderately to covering heat needs, particularly at high temperatures. Their combined potential is estimated at 5,700 GWh/year and 7,979 GWh/year respectively in Wallonia by 2050, i.e. 22% and 31% of projected substitutable heat demand. (CREG, 2025, p. 67) .

2 *Stranded assets: literature review*

This literature review provides a non-systematic overview of the evolving academic understanding of stranded assets, complemented by insights from key grey literature sources.

2.1 Definitions

Several definitions of *stranded assets* have been proposed in the literature reflecting the evolving understanding of the financial risks associated with environmental and policy transitions (Daumas, 2024).

A widely cited definition originates from the International Energy Agency (IEA) in its *"*World Energy Outlook Special Report" published in 2013, stranded assets are described as "investments which have already been made but which, at some time prior to the end of their economic life (as assumed at the investment decision point), are no longer able to earn an economic return" (IEA, 2013, p. 98).

The Generation Foundation suggests a similar formulation, stating that a stranded asset is "an asset that loses significant economic value well ahead of its anticipated useful life, as a result of changes in legislation, regulation, market forces, disruptive innovation, societal norms, or environmental shocks" (Generation Foundation, 2013, pp. 6, 26). This definition expands the scope of potential drivers of asset stranding to include political, technological, market, and social dynamics. The political driver is also adopted by the Carbon Tracker Initiative, which attributes the stranding of assets to "changes in the market and regulatory environment associated with the transition to a low-carbon economy" (Carbon Tracker Initiative, n.d.).

In academic literature, one of the most widely cited definitions of stranded assets is provided by Dr. Ben Caldecott, a leading figure in the field of sustainable finance and Director of the Oxford Sustainable Finance Group at the University of Oxford. He defines stranded assets as "assets that have suffered from unanticipated or premature write-downs, devaluations, or conversion to liabilities" (Caldecott, 2018, p. 5). This definition underscores the potential for stranded assets not only to lose value unexpectedly, but also to become financial liabilities, thereby directly impacting the balance sheets of firms and financial institutions.

Lastly, van der Ploeg and Rezai expand the conceptual framework by proposing a broader definition that encompasses not only fossil fuel reserves and capital infrastructure, but also countries and workers affected by the low-carbon transition. They write: “a broader definition of stranded assets also includes countries reliant on fossil fuel exports and workers with technology-specific skills ”. In addition to widening the scope of the concept, they emphasize the role of irreversibility in asset stranding. They argue that for an asset to become stranded, it must exhibit a degree of rigidity or sector-specificity that prevents its redeployment to alternative uses without incurring substantial costs. So, stranding arises not merely from policy or market shifts, but from the inability of certain capital assets to adapt in a timely and economically viable way to changing conditions. This reinforces the idea that stranded assets are not just economically unviable, but structurally locked in, rendering their loss in value both premature and difficult to recover (van der Ploeg & Rezai, 2020, pp. 281, 289).

Overall, the various definitions of stranded assets reveal significant differences in terms of the asset types they include, with a central and widely adopted distinction opposing physical assets to financial assets. Another boundary marker can be made between stranded assets which are characterized as previously valorised investments that have lost value or turned into liabilities and stranded resources, which refer to natural resources that have never been economically exploited and are likely to remain unextracted due to technological, spatial, regulatory, market, or socio-environmental constraints (Bos & Gupta, 2019, p. 3). Building on this distinction, a three-level structure has been proposed, articulating resources, physical capital (stranded capital), and financial assets (stranded paper), while highlighting potential contagion effects between these layers of exposure (Daumas, 2024, pp. 604–605). Another, more systemic, classification identifies five categories of assets at risk of stranding: physical, financial, natural, human, and social illustrating the broad spectrum of dimensions potentially affected by stranding dynamics, particularly in environmentally sensitive contexts (Caldecott et al., 2013, pp. 12–13)

2.2 Systemic risks and regulatory responses to stranded assets

Beyond the conceptual variation, the literature largely converges in emphasizing the systemic financial risks associated with asset stranding. Van der Ploeg & Rezai point out that the loss of profitability, or even the transformation into a liability, of certain fossil fuel assets can generate irreversible substantial financial losses and affect macroeconomic stability, particularly if the markets suddenly revalue these assets in a context of heightened political or technological uncertainty. They add that the risk of stranded assets may emerge when policymakers abruptly decide to implement emission limits, without sufficient prior warning to the private sector (van der Ploeg & Rezai, 2020, p. 282).

These risks manifest themselves through a variety of channels, identified by Daumas in his critical review of transition risks: asset depreciation (market risk), repayment defaults (credit risk), liquidity contractions (liquidity risk), insurance, reputational or legal risk. The chain of these mechanisms could lead to a 'Climate Minsky Moment', i.e. a financial crisis triggered by a sudden adjustment in expectations about carbon assets. Vulnerability is increased by the high exposure of institutional portfolios (pension funds, banks, governments) to carbon-intensive sectors (Daumas, 2024, pp. 602, 607).

In the specific context of the decommissioning of gas infrastructures in Europe, the report published by DNV and Trinomics provides an operational framework combining academic lessons with regulatory recommendations. The report begins by identifying the need to anticipate the progressive decommissioning or repurposing of gas assets and formulates the following key recommendations. The costs of conversion or decommissioning should be included in the regulated asset base (RAB) so that they can be amortised via authorised revenues. Infrastructure conversion should be assessed on a case-by-case basis through cost-benefit analyses carried out jointly by gas and hydrogen operators, with validation by the regulator. When this makes it possible to avoid anticipated replacement costs, the temporary maintenance of fully depreciated assets can be encouraged by explicit incentives. Finally, assets with no prospect of future use should be removed from RAB, and residual costs allocated to consumers, public authorities or operators in a transparent manner (Grote et al., 2022).

3 Regulatory and Strategic Landscape of the Gas Transition

This section analyses how the European and Belgian regulatory frameworks address the transition to carbon-neutral residential heating and anticipate the risk of stranded assets in gas networks. It is structured around the four key regulatory levers identified later in the scenario creation of the cost-benefit analysis: heat planning, connection rules to the gas network, stranded asset management strategies, and public financial support.

3.1 European regulatory framework

The European Union has gradually strengthened its regulatory framework to support fossil fuels phase-out and accelerate the decarbonisation of residential heating. The European Climate Act sets a legally binding target of climate neutrality by 2050, as well as a net reduction in greenhouse gas emissions of 55% by 2030 compared with 1990 (Regulation EU 2021/1119, 2021). This climate ambition structurally implies the gradual phase-out of fossil fuels for end uses such as heating buildings and transport. To make this ambition a reality, the 'Fit-for-55' legislative package introduces a series of texts framing the transformation of the energy system. The revision of the Directive on Renewable Energies requires an accelerated increase in the share of renewable gases in particular biomethane and green hydrogen (Directive (EU) 2023/2413, 2023), while the Directive on Energy Efficiency reinforces the objectives of reducing final consumption, by directly targeting fossil fuels (Directive EU 2023/1791, 2023).

The dynamic was strengthened by the adoption in March 2024 of the legislative package on the decarbonised gas and hydrogen markets. It constitutes the regulatory pivot towards a new governance paradigm for gas networks and is define of the two following legal papers.

Directive (EU) 2024/1788 (2024) requires transmission system operators to publish every two years a ten-year network development plans, identifying assets likely to be decommissioned and assessing their potential for reuse, particularly for renewable or hydrogen transport. Regulation (EU) 2024/1789 (2024) complements this by allowing regulators to adapt tariff rules, including asset depreciation periods and remuneration schemes for repurposed infrastructures.

At the same time, the European carbon pricing architecture is changing radically. Until now, the valuation was primarily carried out through indirect instruments such as green certificates or national carbon taxes. However, with the adoption of the "Fit-for-55" legislative package, a new emissions pricing framework is being deployed through the establishment of a second emissions trading system (ETS II).

The ETS II system is introduced by Directive (EU) 2023/959 (2023). It aims to extend the carbon market logic to historically uncovered sectors, particularly road transport and building heating. Its entry into force is scheduled for January 1, 2027, with monitoring and reporting obligations starting in 2025 and 2026. In contrast to the historical ETS, ETS II is applied upstream: it is the fuel suppliers who will have to surrender allowances for the volumes released for final consumption. The system is based on a separate market, with quotas auctioned, and an automatic stabilisation mechanism if the price exceeds 45 €/tCO_2 for more than six months market .

3.2 Belgian regulatory framework

3.2.1 Belgium's climate planning framework

Belgium, as a member state of the European Union, is mandated to adhere to the stipulations established in Regulation (EU) 2018/ 1999 in 2018 regarding the governance of the Energy Union. This regulation requires that each member state submit a National Energy-Climate Plan (NECP), updated every decade and revised every five years, that defines its contribution to the European climate and energy objectives, including achieving carbon neutrality by 2050.

Belgium's NECP is structured around the contributions of the three Regions, each responsible for energy and environmental policy within their territory (Gouvernement Belge, 2023). While strategies and targets vary, all three regional plans feed into the NECP and reflect a common ambition to reduce emissions, promote heating electrification, and progressively phase out natural gas in the residential sector (Vlaamse Regering, 2023; Gouvernement Wallon, 2023; Bruxelles Environnement, 2023).

3.2.2 Regional support schemes for energy renovation

As part of their climate commitments, the three Belgian regions have set up financial aid schemes for the energy renovation of residential buildings. Although these schemes are regionally distinct, they share a common objective of improving the energy efficiency of the residential buildings, reducing overall consumption, and phasing out fossil fuels. They cover a wide range of renovation works such as insulation, ventilation, heating systems or hot water production The installation of air-to-water heat pumps, identified as a key technology in the transition, receives differentiated support according to household income level. For a middle-income household, the subsidy amounts to €4,750 in the Brussels Region (Région de Bruxelles-Capitale, n.d.), €3,000 in Flanders (VEKA, 2025), and €1,800 in Wallonia (Service public de Wallonie, 2025). In Wallonia, this represents a significant decrease compared to the previous scheme, which offered around €4,500 for a similar household profile (Service public de Wallonie, 2024) .

3.2.3 Gas connection restrictions

In addition to financial incentives for energy renovation, the three Belgian Regions have implemented or announced regulatory reforms that seek to restrict or even ban new residential connections to the gas distribution network.

In Flanders, the introduction of a prohibition on connecting new buildings to the gas network has been in force since 2021 for major construction projects and is applied to all new buildings since 2025. A ban on oil-fired boilers has been in place since 2022 for new builds and major energy renovations, with their replacement in existing buildings only permitted if no connection to the natural gas network is available (Vlaamse Overheid, n.d.-a, n.d.-b).

In Brussels-Capital Region, the installation of gas-fired boilers has been prohibited since 1 January 2025 in new buildings or buildings treated as new, buildings for which an application for permission is submitted after this date. The Government Decree of 6 June 2024 specifies that heating systems in these buildings must either run exclusively on electricity or renewable energy, or be connected to an efficient thermal energy network (homegrade.brussels, 2024; Arrêté du 6 Juin relatif aux exigences PEB, 2024).

Finally, in Wallonia, PACE 2030 called for a ban on the installation of oil-fired boilers in new buildings from March 2025, and in existing buildings from January 2026. However, this commitment remains programmatic, and to date (March 2025) has not been transposed into law. The installation of gas or oil boilers therefore remains legally possible, pending a formal decision by the new Walloon Government (Wallonie Energie SPW, 2024).

3.2.4 Regulatory approaches to stranded gas assets

In Belgium, consideration of the risk of stranded assets associated with the transition away from gas remains incomplete and fragmented. To date, there is no unified national framework for the gradual phase-out of gas infrastructures, particularly at distribution level. While the tariff methodology for the transmission network now includes full depreciation of assets by 2050, no similar measure is formally planned for local networks. The issue of stranded assets is nevertheless recognised by regulators and incorporated into technical planning work, particularly through the principle of 'maintaining without extending' networks . Several options for accounting treatment or alternative financing have been identified, but their implementation will depend on future policy directions. In the absence of a stable, anticipated framework, the treatment of risk therefore remains largely reactive and dependent on local initiatives (Grote et al., 2022).

3.2.5 Stakeholders positions

In 2023, different players in the gas market were consulted by the authorities as part of a technical consultation on the exit strategy for fossil gas. Although the contributions received were not systematically made public, some players, such as CWaPE, chose to publish their position. In its contribution of june 2023, the Walloon regulator emphasizes that phasing out fossil fuels should not be confused with abandoning gas infrastructures. These networks are seen as strategic assets that could eventually be repurposed for transporting renewable gases. It calls for a gradual transition, taking into account the technical constraints associated with hydrogen, complementarity with electricity and the specific needs of certain segments (CWaPE, 2023b). This position echoes the ambitions expressed in the strategic plans of the network operators, who are adopting differentiated but generally cautious approaches. ORES emphasises the integration of biomethane into its network, while remaining open to other uses (ORES, 2023). Resa is favouring a defensive strategy based on supply security (Resa, 2022). Fluvius, in Flanders, is limiting its investments to what is strictly necessary to mitigate stranded asset risks (Fluvius, 2023). In Brussels, Sibelga is taking an exploratory approach to hydrogen, albeit hampered by the lack of a regulatory framework (Sibelga, 2023). These positions demonstrate a desire to anticipate changes in the energy system, while preserving the flexibility needed to defend the long-term viability of their infrastructures in a transition context that is still uncertain.

3.3 Comparative overview of gas distribution regulation in selected European countries

Across Europe, regulatory approaches to gas distribution networks are evolving in diverse ways, with countries adopting contrasting strategies regarding connection rules, asset depreciation, decommissioning, and cost allocation.

3.3.1 Traditional approaches

In Austria, Germany, Italy and the UK, distribution system operators are required to connect any customer who so requests, subject to technical or economic feasibility. In terms of depreciation used in regulation, the duration is generally long and linear: 30-40 years in Austria, 45-55 years in Germany, 50 years in Italy, and 45 years in the United Kingdom. In Germany, BNetzA[2] launched a reform in 2024 introducing a degressive depreciation of assets. In the UK, Ofgem[3] requires new assets to be depreciated by 2050. These countries have no specific regulatory mechanisms for organising the decommissioning of existing gas infrastructures. Networks are considered permanent, and there is no provision for anticipating future decommissioning costs in tariffs (RAP & Oeko-Institut, 2024)

3.3.2 The Netherlands

In the Netherlands, recent legislative reforms have significantly facilitated consumer disconnection from the natural gas grid, positioning the country as a frontrunner in regulatory approaches to gas phase-out (RAP & Oeko-Institut, 2024). Under the National Climate Agreement, each municipality must draw up a local plan for decarbonising residential heating (Transitievisie Warmte), setting out gas-free alternatives for each neighbourhood in consultation with local stakeholders (Bei der Wieden et al., 2024; Energy Cities, 2024a).

Since 2018, the Gaswet prohibits network operators from connecting new buildings to gas, with some exceptions. In 2020, 87% of new homes were built without a connection (CE Delft, 2022, p. 15). In 2023, new legal provisions were adopted to authorise, under strict conditions, the disconnection of existing users in neighbourhoods covered by a gas phase-out plan, subject to

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[2] BNetzA (Bundesnetzagentur) is the German Federal Network Agency responsible for regulating electricity, gas, telecommunications, postal services, and railways.

[3] Ofgem (Office of Gas and Electricity Markets) is the independent regulator of the electricity and gas markets in Great Britain.

eight years' notice and provided that an affordable alternative is available (Bei der Wieden, Bürger, Loschke, Anderson, et al., 2024).

In economic terms, the depreciation method has been reviewed for the period 2022-2026: a variable degressive depreciation with an acceleration factor of 1.2 enables operators to recover their investments more quickly, in line with the expected decline in the number of consumers (ACM, 2021, p. 43).

Finally, until 2021, the costs of disconnection were borne by the owners, which hampered the achievement of the climate objectives. Since February 2024, these costs have been socialised (Bei der Wieden et al., 2024; ACM, 2023, p. 6).

3.3.3 Denmark

In Denmark, natural gas accounts for only 12% of final energy consumption, in a context characterised by a nationalised gas infrastructure and a collective heating sector covering 74% of homes. The country is aiming to phase out the use of gas in buildings by 2030 (Bei der Wieden, Bürger, Loschke, Rosenow, et al., 2024, p. 3).

Since the Heat Supply Act was passed in 1979, local authorities have had to draw up local heat supply plans, enabling them to restrict gas connections in areas covered by collective alternatives such as district heating The Heat Supply Act, 2000, p. 5). The installation of fossil fuel boilers has been banned in new builds since 2013, a ban reinforced by BR18 in 2018, which requires the use of renewable sources in areas planned for district heating (Bei der Wieden, Bürger, Loschke, Rosenow, et al., 2024).

In economic terms, investment in gas infrastructure is depreciated over 30 years on a straight-line basis. With regard to decommissioning, in 2023 the operator Evida launched a national mapping of infrastructures to plan their gradual withdrawal. It identified 145 to 184 sub-networks as economically unviable and recommended introducing an obligation to disconnect the users concerned, with two years' notice (Evida, 2023, pp. 5–7).

4 *Case analysis: Resa network*

Given the uncertainty surrounding the practical arrangements for phasing out gas in Belgium, this section aims to compare the consequences of alternative public policy choices. Based on the Resa network, three contrasting trajectories are modelled using a cost-benefit methodology, in the objective to shed light on the trade-offs between economic costs and environmental benefits.

4.1 Model overview

A cost-benefit analysis (CBA) constitutes an economic evaluation method aimed at comparing, on a common monetary basis, the benefits and costs of a project or public policy. It is based on the principles of welfare economics and seeks to measure the net impact of an intervention on aggregate social welfare. The approach adopted in this thesis is based in particular on the methodological recommendations of the CPB Netherlands Bureau for Economic Policy Analysis and the ENTSOG guide for energy infrastructures. (Romijn & Renes, 2013) (ENTSOG, 2023)

The following analysis is based on a structuring hypothesis: the complete phase-out of gas for residential heating by 2050. As explained in sections 3, this constraint is consistent with the carbon neutrality trajectories defined at the Belgian and European levels. The model therefore does not aim to evaluate the opportunity or feasibility of the exit, but to compare three conceivable transition pathways, differentiated by their deployment pace and level of public intervention. The objective is to compare the economic and environmental effects of these scenarios from the perspective of collective well-being.

The analysis follows the standard methodological steps of CBA: definition of the baseline scenario, construction of alternative scenarios, identification of differentiated effects, monetisation of costs and benefits, aggregation of discounted net flows and sensitivity analysis (Romijn & Renes, 2013, pp. 70–73).

In this framework, net welfare is estimated as the discounted sum of the main socio-economic benefits and costs generated by each scenario, around four central dimensions:

Consumer Surplus – Benefit : Consumer surplus reflects the variation in the economic well-being of households related to their total heating expenses. It captures the net effect of changes in technology, energy prices, received subsidies, and required investments to adapt.

Government Surplus – Benefit/Cost: Since subsidies and taxes are merely transfers between the State and consumers, they do not affect overall welfare. To prevent them from being mistakenly counted in the consumer surplus, their total value is accounted for in the government's budget balance, ensuring a consistent evaluation of net welfare.

Stranded assets – Cost : Stranded assets refer to past investments that can no longer generate sufficient economic returns and create financial weight at the end of the period for the DSO.

Climate externalities (CO_2) – Benefit: The environmental benefits related to the reduction of greenhouse gas emissions are integrated as positive externalities.

The approach adopted is partial (microeconomic) and is based on an assessment of the direct effects for residential households connected to the Resa gas distribution network. The analysis is based on a representative average household living in a typical dwelling.

Finally, it is important to note that this analysis does not aim to provide an absolute measure of net welfare, but rather to offer a structured comparison of the differentiated impacts of various gas phase-out trajectories. Due to limited data availability, several assumptions were based on technical reports or plausible estimates. Moreover, the model simplistically assumes that all affected households will switch to a carbon-neutral heating system, namely the heat pump. While this ensures consistency across scenarios, it does not fully capture the diversity of real-world decarbonisation pathways.

4.2 Scenario definition

In order to assess the economic and environmental consequences of a gradual or accelerated phase-out of natural gas in the Walloon residential sector, three transition scenarios have been built around the trajectory of the distribution network managed by Resa. Each scenario reflects a distinct approach in terms of regulation, taxation, investment policy and public support. They are not intended to cover the full range of possibilities, but to illustrate contrasting trajectories, based on practices observed in Belgium and other European countries.

4.2.1 Scenario 1: Baseline

The first scenario is the reference point for the analysis. It describes a trajectory based on the regulatory status quo, in the absence of any new specific measures to prohibit, restrict or guide gas use. In this context, the possibility of connecting new homes to the gas network remains open, and no additional constraints are introduced for existing households.

The adoption rate of heat pumps is estimated using the Bass diffusion model, which describes the uptake of new technologies following an S-shaped curve. This implies a slow initial adoption, followed by a progressive acceleration as the technology becomes more widely accepted.

In terms of investments, Resa is maintaining its development plans as approved by the CWaPE. The network continues to be renewed and extended. The accounting treatment of assets follows current rules, with no acceleration of depreciation or provision for obsolescence.

In this scenario, there is no specific mechanism for managing stranded assets. In the absence of a disconnection policy, the burden of under-utilized infrastructure falls on the remaining consumers, via a gradual increase in unit tariffs.

Finally, no changes are made to the fiscal framework: surcharges follows their historical trend and are not intended to penalise gas in favour of HP or to support public subsidies.

4.2.2 Scenario 2 : Gradual Phase-out

The second scenario is based on a gradual transition, framed by clear but moderate political signals. It is inspired by examples such as Flanders and the Netherlands, where there is a public willingness to plan the phase-out of gas without imposing an abrupt break.

From 2025, new buildings and major renovations may no longer be connected to the gas network. This regulatory change marks a turning point in the dynamics of network access. At the same time, the grant scheme is strengthened: amounts are increase and administrative requirements eased.

Investment in the gas network is reduced compared with the baseline scenario, but is not interrupted. The aim is to maintain a sufficient level of service in areas where demand persists, while avoiding unjustified extensions. In accounting terms, a partially accelerated depreciation rate is introduced to better reflect the anticipated decline in use.

This scenario also introduces a moderate additional tax on gas, part of which is used to finance transition aid. This tax, like the subsidies, does not alter overall welfare, but rather its distribution across actors.

4.2.3 Scenario 3 : Planned break-up

The third scenario explores a much more proactive approach, based on an explicit and rapid ban on the continued use of gas heating in the residential sector. From 2025, households will no longer be able to replace their gas boiler with an identical piece of equipment. At the end of each technical life cycle, they will be forced to opt for a more environmentally-friendly solution, a heat pump.

To ensure the acceptability of this measure, universal, unconditional subsidies are being introduced over a transitional period. They are designed to offset the higher investment costs induced by the regulatory constraint.

Investment in the network has been stopped, with the exception of a minimum level of expenditure to guarantee safety and continuity of service in residual areas. From an accounting point of view, an accelerated depreciation policy has been put in place, to rapidly recover the value of assets before they become completely obsolete.

This scenario aims to eliminate residential gas use by the end of the 2030s. It makes it possible to assess the environmental benefits of rapid decarbonization, while highlighting the economic tensions involved, particularly for households still connected to the network in the terminal phase.

To summarize the structural differences between the three scenarios, a summary table is presented below. For each scenario, it lists the main quantitative assumptions used in the analysis model: disconnection rate, subsidy terms, investment policy, accounting approach and tax framework.

Table 1 : Key assumptions of gas phase-out scenarios: baseline, gradual transition and planned break-up

Dimension	Scenario 1 Baseline	Scenario 2 Gradual phase-out	Scenario 3 Planned break-up
Disconnection rate	New gas connections allowed, HP adoption S-curve (Bass model) (See appendix 1)	No new gas connections - 0.55% /year: average renovation rate (See appendix 2)	- 5%/year from 2025: ban on gas boiler replacement
Subsidies for heat pump	1800€ until 2026 (SPW, 2025)	3000€ until 2040	5000€ until 2030
Asset depreciation rate	Regulated depreciation rate: 2.5% (CWaPE, 2024b)	Accelerate depreciation of 3.5%	High depreciation rate of 5%
Network investments	Linear continuation of past and planned investments through 2029 (CWaPE, 2024b)	75% of Scenario 1's annual investment level	Only essential safety investments (10M€$_{2024}$/y)
Gas fiscal policy	No additional carbon tax or transition-specific levy introduced	Additional tax: 10% of the surcharges estimated in scenario	Additional tax: 50% of the surcharges estimated in scenario 1

4.3 Methodology

This analysis evaluates the socio-economic welfare of households connected to Resa gas network, based on the three gas exit scenarios outlined in the previous section. Total welfare is divided into four main components: consumer surplus, government surplus, stranded assets costs supported by Resa, and avoided CO_2 emissions. Each component is calculated individually for each scenario, then aggregated to obtain total welfare.

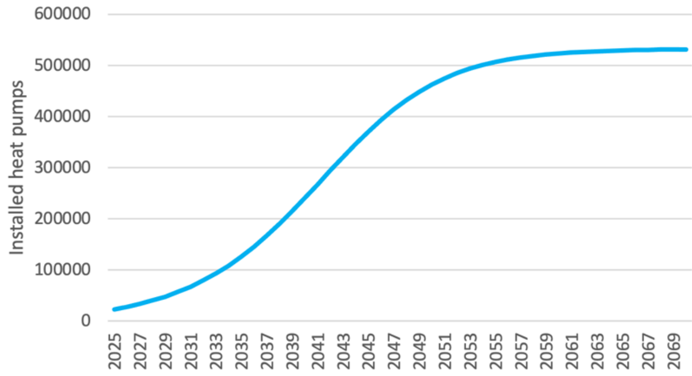
4.3.1 Evolution of the residential heating technology mix

In order to represent the evolution of the residential heating technology mix up to 2050, the three main technologies currently used in Belgium are considered: natural gas boilers, oil boilers and heat pumps. Each connection point is assumed to be served exclusively by one of the three technologies considered.

In all the scenarios examined, the share of oil-fired heating is assumed to decline along the same trajectory, at a rate of 4% per year. This assumption is based on a ban on all new installations of oil-fired boilers, combined with an estimated 25-year average lifespan (CREG, 2024). This technology is therefore considered to be in structural decline, regardless of the scenarios proposed in this analysis.

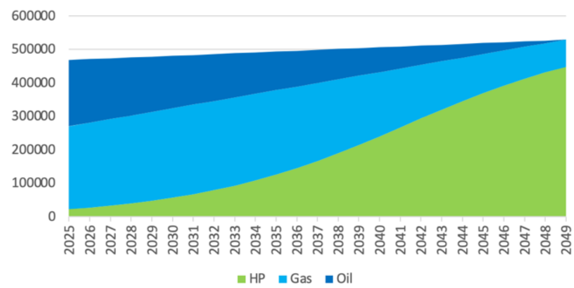
On the other hand, the adoption of heat pumps is the main factor in the technology mix, and changes in different ways depending on the scenario. In the baseline scenario, the adoption is modelled using the Bass diffusion model, which is used to simulate the gradual adoption of technologies over time. This model is based on logistic dynamics, combining an innovation effect represented by the coefficient p and describing the spontaneous adoption of the technology, and an imitation effect represented by the coefficient q and reflecting social influence (neighbourhood, visibility, norms, word-of-mouth) (Bass, 1969). It allows us to reproduce an S-curve adoption dynamic, characterised by a slow start, an acceleration phase and then gradual saturation as the target population is reached (see appendix 1 for methodology details).

Figure 1 : Stock of heat pumps in the Resa sector (2024-2070), according to the Bass diffusion model



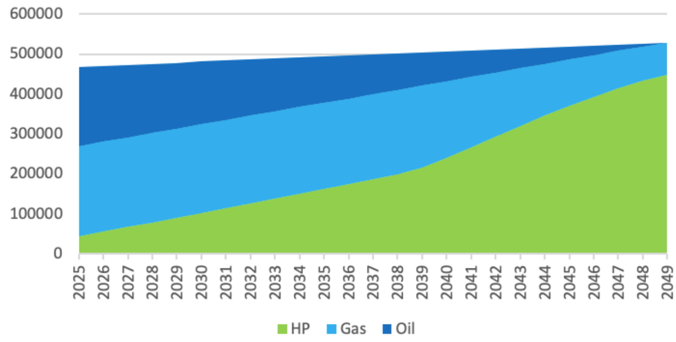
On the basis of Bass' adoption curve for heat pumps and the linear decline of oil-fired boilers, the number of gas connection points is determined residually, as the difference between the total number of households to be equipped and those already covered by these two alternative technologies. The figure below show the evolution of the breakdown between the technologies across time for the scenario 1.

Figure 2: Scenario 1 - Breakdown of households by heating technology (2025-2050)



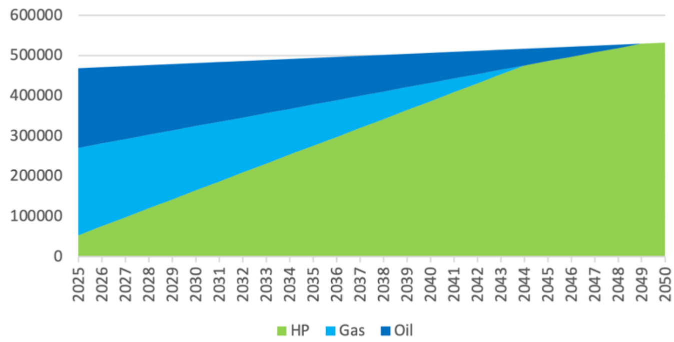
In scenario 2, the central assumption is a ban on new gas grid connections from 2025. Unlike scenario 1, the stock of households connected to gas is capped at the level observed in 2024, and declines at a rate of 0.55% per year, in line with the average rate of in-depth renovation of the residential stock (see appendix 2). In this context, the spread of heat pumps is adjusted on the basis of the Bass model, by imposing a moderate acceleration in adoption in order to respond meet demand will gas connection are banned.

Figure 3: Scenario 2 - Breakdown of households by heating technology (2025-2050)



Scenario 3 is based on a more restrictive assumption: a ban on the replacement of gas boilers. This measure will lead to an accelerated phase-out of natural gas, modelled by a linear decline of 5% per year in the number of connected customers. This rate of decline corresponds to an average boiler life of around twenty years.

Figure 4: Scenario 3 - Breakdown of households by heating technology (2025-2050)



The core of this economic analysis is to assess the effects of switching from gas heating to heat pumps, from a public welfare perspective. It therefore focuses exclusively on households currently connected, or technically connectable, to the gas distribution network. In order to remain consistent with this scope, heat pumps installed to replace oil heating are not taken into account: only cases of direct substitution of gas by a low-carbon technology are included in the calculations (see appendix 3).

4.3.2 Consumer surplus

The consumer surplus constitutes a central socio-economic indicator in the cost-benefit analysis. The objective is to evaluate, for each gas phase-out scenario, the overall impact on the well-being of households initially connected to the gas distribution network.

This study adopts an empirical approach as opposed to the conventional theoretical approach based on the so-called "half-triangle" rule. This rule consists of approximating the consumer surplus as half the product of the price change and the quantity consumed, assuming a linear demand curve (Romijn & Renes, 2013, p. 49). Conversely, this analysis relies on a more intuitive method. The surplus is estimated as the difference between the willingness to pay, which serves as a proxy for what households are prepared to spend for a reliable, efficient, and accessible heating service, and their actual heating costs.

The case of gas distribution is particularly specific, unlike most markets where prices are exogenously given, the regulated gas distribution tariff depends directly on the number of users connected to the network. Since the total allowed revenue is fixed by the regulator, a decline in the number of connected households mechanically increases the unit price, leading to a feedback loop between network size and distribution cost. To avoid introducing unnecessary complexity at this stage, the model initially adopts a static framework, where the unit price of distribution is considered fixed and independent of the number of connections. A more dynamic modelling of this feedback mechanism is discussed in a next section.

Two groups of households are distinguished: those who remain connected to the gas network and those who opt for a heat pump. For each group, the total annual heating cost is compared to the willingness to pay set at 2000 euros per year (arbitrary value with no impact on final results). The difference between this value and the actual cost incurred constitutes the net surplus of well-being for a given year.

For households still using gas, the annual heating cost is calculated as the sum of the energy consumption cost, based on an average consumption of 11 523 kWh[4] per year and the annual investment costs related to the gas boiler. The consumption costs includes three components: the price of the natural gas, the tax surcharges, and the distribution tariffs. The price of the gas itself and the surcharges (excise duties, VAT, specific taxes) are estimated for each year using a linear regression applied to the data from the past ten years based on CWaPE publication's, but excluding the year 2022 due to the exceptional energy crisis. The surcharges evolve differently depending on the scenarios studied. The details of the calculations are presented in appendix 4. The distribution tariff is calculated specifically based on the actual costs incurred

[4] Based on a heat demand of 11,062 kWh and an energy efficiency of 96% (CREG, 2024)

by Resa. As some households leave the network, the fixed costs are distributed among an increasingly smaller number of clients, and the distribution tariffs increase. The annual investment cost of the boiler is set at 344.5€. It is obtained by assuming a purchase price of 6,890€ amortised linearly over twenty years (CREG, 2024, p. 18).

For households that have invested in a heat pump, the total annual cost includes the initial investment, estimated at 14,630 euros without subsidy and amortised over 20 years (CREG, 2024, p. 17), as well as the annual operating costs. These are calculated based on an average electricity consumption of 3,100 kWh [5] per year and an all-inclusive unit price for electricity (energy, distribution, surcharges, etc). As with gas, this price is estimated the last ten years of available data (see appendix 4). The actual cost borne by each household also depends on whether or not there is a subsidy for the purchase of the heat pump, although subsidies are simple transfers and do not affect total welfare.

In scenarios 1 and 2, some households are still equipped with gas boilers in 2049. As the complete electrification of heating is scheduled for 2050, these consumers will have to give up equipment that is still operational. In order to estimate the associated financial loss, we need to assess the residual value of boilers that are taken out of service early. Rather than assuming a uniform distribution of years of purchase over the period, the analysis adopts a more realistic depreciation profile. Given the gradual decline in the attractiveness of gas and households' anticipation of the end of the network, it is reasonable to assume that the majority of new gas boilers are installed before 2035, and very few thereafter. As a result, the average residual value of boilers still in operation in 2049 is estimated at around 35% of their initial value.

At each period, the model calculates the average individual surplus for each group of households, then aggregates these values on an annual basis.

$$CS_t = \sum_{i \in G_t} \left(WTP - C_{gas,t} \right) + \sum_{j \in HP_t} \left(WTP - C_{elec,t} + sub_j \right)$$

With:

- CS_t : Total consumer surplus in year t

[5] Based on a SCOP of 3.57 and 11,062 kWh heat demand (CREG, 2024, p. 22)

- G_t/ HP_t : Number of households using gas / heat pump in year t
- $C_{gas,t}$: Total annual heating cost with gas
- $C_{elec,}$t: Total annual heating cost with heat pump
- sub_j : Annual individual subsidy (if applicable)
- WTP: Willingness to pay for heating = 2000€/year

The details of the calculations for each scenario are provided in the appendix 5.

4.3.3 Government surplus

While consumer surplus captures the direct impact of the transition on household heating expenditures, it also encompasses elements that do not reflect actual improvements in collective welfare. In particular, the subsidies received and taxes paid by households are in reality transfers between consumers and public authorities. Their inclusion in the calculation of the surplus therefore distorts the overall assessment of welfare, since they represent neither the creation nor the destruction of value at the aggregate level. In order to correct this distortion and guarantee the coherence of the analysis, it is necessary to evaluate separately the State budget balance, by aggregating all public expenditure (subsidies) and revenue (taxes) linked to the energy transition (see appendix 11).

4.3.4 Resa's regulated costs, tarrifs and stranded assets

In Belgium, gas distribution tariffs are regulated in such a way to ensure that the income received by network operators corresponds exactly to the costs recognised by the regional regulator. At the start of each five-year tariff period, Resa submits a forecast of its costs, which is then validated by the CWaPE. Those estimations includes depreciation, return on capital, operating expenses (OPEX) and other regulated costs. Distribution tariffs are then set to cover all these costs. Any divergence between revenues actually received and authorised costs is corrected ex post in the following tariff cycle (CWaPE, 2024b).
In this regulatory model, the principle of economic neutrality implies that, by construction, Resa does not generate any economic surplus. However, as part of the undergoing cost-benefit analysis, it is still necessary to estimate all the costs that the operator will have to cover between 2025 and 2050. These projections are used to calculate distribution unit tariffs, which have a direct impact on consumer surplus.

The equation below represents the typology of the costs used in this model to approximate Resa's financial needs for each year. While this formulation captures the core building blocks of the Belgian tariff methodology, it remains a simplification of the actual regulatory framework, which includes adjustment mechanisms.

$$\text{Resa Costs}_t = \text{Depreciation}_t + \text{Capital remuneration}_t + \text{OPEX}_t + \text{Other regulated charges}_t$$

Once Resa total distribution costs are determined (see appendix 8), the unit tariff is obtained by dividing these costs by the annual distributed gas volume (in kWh). The resulting distributions price thus directly reflects variations in cost structure for customers and their surplus (see appendix 9).

The approach described above assumes that as long as the network remains in service, all costs are fully covered by tariffs. However, in all the scenarios considered, residential gas distribution is set to disappear completely in 2050 (or as early as 2044 in scenario 3). At that point, a significant proportion of the network's assets will still be unamortised. These assets then become what the literature refers to as stranded assets, i.e. fixed investments that no longer generate income and whose economic value can no longer be recovered.

In this analysis, the economic value of this assets are approximated by the net book value of the network at the gas exit date. Although this value does not represent an immediate cash loss, it does reflect an investment made on the basis of expectations of future revenues that will not materialise. In other words, when the tariff flows initially forecast disappear due to the cessation of service, the investment can no longer be amortised. The residual value is therefore a relevant proxy for estimating the economic cost of the transition.

Ultimately, the issue is to determine whether these infrastructures should be fully accounted for as stranded assets, or whether their future reuse could mitigate this economic cost.

The potential for reusing gas infrastructures for other purposes, in particular for transporting hydrogen or CO_2, is regularly mentioned in European energy transition strategies (DNV & Carbon Limits, 2021). This type of conversion is particularly studied at transmission network level, where the technical and economic conditions appear to be generally favourable. It is presented as a potential lever for limiting the economic losses associated with the accelerated obsolescence of fossil fuel infrastructures.

However, this perspective remains largely theoretical as far as residential distribution networks are concerned. On the one hand, hydrogen or CO_2 demand scenarios on a local scale are still highly uncertain and poorly documented. On the other hand, current investment plans, particularly under RePowerEU, are mainly focused on inter-regional transport infrastructure for heavy industry (DNV & Carbon Limits, 2021; Trinomics et al., 2025).

In addition, a number of technical obstacles strongly limit the feasibility of reuse on the scale of distribution networks. In the case of hydrogen, increased compression requirements, the risk of steel embrittlement, and the inadequacy of current pumping stations pose major challenges (ACER, 2021; DNV & Carbon Limits, 2021). For CO_2, dense-phase transport requires high pressures, and the presence of impurities can accentuate corrosion phenomena (Luna-Ortiz, 2022) (Georgette Boele, 2024). These obstacles, although partially surmountable, lead to significant costs.

In this context, the model considers that the entire net book value of the infrastructure still active at the end of the gas distribution period constitutes an economic cost effectively borne by the operator.

4.3.5 Externalities

This section details the methodology chosen for the monetary valuation of CO_2 emissions within the framework of cost-benefit analysis.

The adopted approach consists of valuing the avoided CO_2 emissions. This logic is applied within the framework of certain renewable energy support mechanisms in Europe, such as green certificates. These instruments recognise and value the emissions avoided by renewable electricity producers compared to a fossil reference technology. In the absence of market prices fully reflecting climate costs, this principle allows for the monetary valuation of the environmental benefits associated with emission reductions.

The valuation is based on the concept of the "shadow cost of carbon." It is a reference economic price representing the societal marginal cost of one tonne of CO_2 emitted. Unlike a market price or a carbon tax, it is an analytical value constructed to reflect the climate damages avoided. The CBA methodology guide published by ENTSOG in 2023 supports this choice. It explicitly recommends the use of the shadow cost of carbon as a reference for the monetisation of emission reductions. (ENTSOG, 2023, p. 43,44)

The European Investment Bank publishes a trajectory of CO_2 shadow prices in its Climate Bank Roadmap 2021- 2025 (EIB Group, 2020, p. 121). The shadow prices are originally expressed in 2016 euros per tonne of CO_2, with values of €250 in 2030, €525 in 2040, and €800 in 2050. These values were retained after being updated to 2024 euros for consistency with the other flows in the model (see appendix 9).

Avoided emissions of each year are calculated as the difference between the CO_2 emissions from natural gas combustion by using a constant factor of 0.202 kgCO_2/kWh. The resulting net avoided emissions (in tonnes) are then valued using the shadow cost of carbon (see appendix10).

The shadow prices retained here are higher than the levels of carbon prices observed in scenarios produced from techno-economic models such as TIMES be in PATHS2050 (around 350 €/tCO_2 by 20250) (Correa Laguna et al., 2023, p. 31). In these models, the carbon price can be endogenous: it results from the level of taxation or quota necessary to meet a minimum cost emissions constraint. It then reflects a marginal abatement cost internal to the simulated energy system. This price directly depends on the technological, economic, and political assumptions imposed on the model. In contrast, the shadow cost of carbon is an exogenous parameter. It is based on a normative estimate of the societal cost of CO_2 emissions, determined independently of any given energy system, and aligned with global trajectories compatible with a climate goal.

4.3.6 Total Welfare

The calculation of welfare is based on a simple logic: assess the balance between the net economic benefits and costs generated by each scenario. In this model, four main components are integrated into the analysis:

$$\begin{aligned}\text{Net welfare (€/year)} \\ &= \text{Consumer surplus} + \text{Value of avoided } CO_2 \text{ emissions} \\ &- \text{Cost of stranded assets} + \text{Government revenue}\end{aligned}$$

The entire analysis is conducted in constant 2024 euros. A discount rate of 4% is applied to the calculation of the aggregate consumer surplus, following the methodology recommended by the European Commission for cross-border renewable energy projects (European Commission, 2021). See appendix 12 net welfare calculations details.

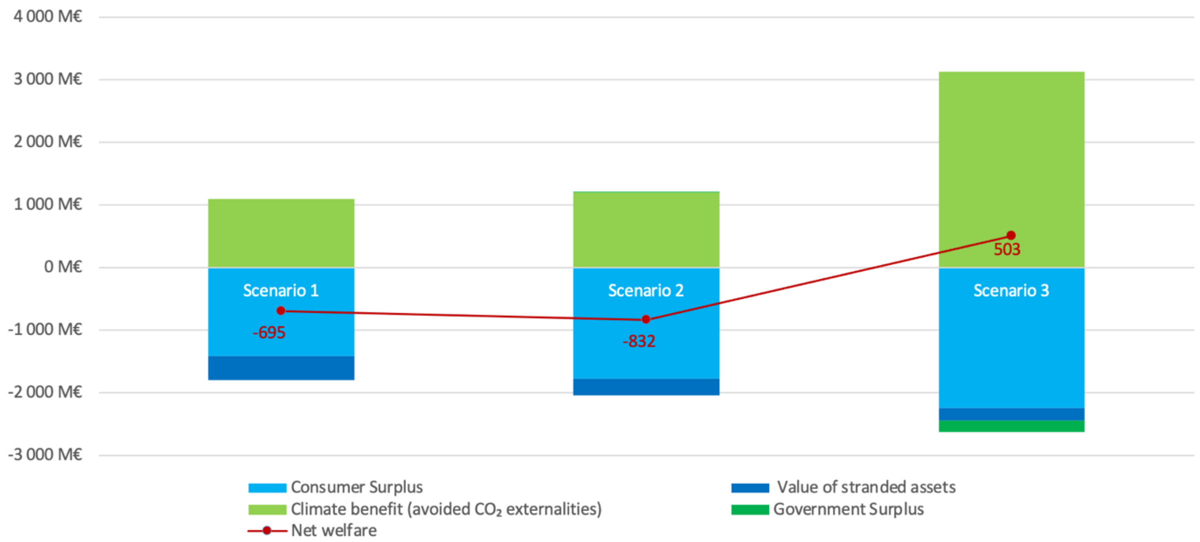
4.4 Results

This section presents the comparative results of the three scenarios analysed. The aim is to highlight the structural differences between the trajectories studied.

4.4.1 Aggregate net well-welfare

The figure below shows the breakdown and the aggregate net welfare for each of the three scenarios.

Figure 5: Net welfare by scenario [M€]



Only scenario 3 results in positive overall net welfare by 2050 (+€503m). This result is essentially explained by the scale of the climate benefits generated by the rapid electrification of residential heating. Conversely, scenarios 1 and 2 show strongly negative balances (-695 M€ and -832 M€ respectively), despite lower overall costs. It should be stressed, however, that negative results depends in part on the willingness-to-pay (WTP) assumption used to calculate the consumer surplus. A higher value would change the absolute level of surplus, without changing the hierarchy of scenarios.

Counter-intuitively, scenario 2 obtains a more unfavourable result than scenario 1, even though it introduces a progressive restriction on gas connections. This paradox can be explained by several dynamics: in scenario 1, the number of connections continues to increase during the first half of the period, which temporarily dilutes the network's fixed costs and keeps distribution tariffs at a relatively low level. At the same time, the uptake of heat pumps accelerates towards the end of the period, making it possible to capture a significant proportion of the environmental benefits at a time when the valuation of avoided emissions is highest (up to €1,000/tCO_2 in constant 2024 euros).

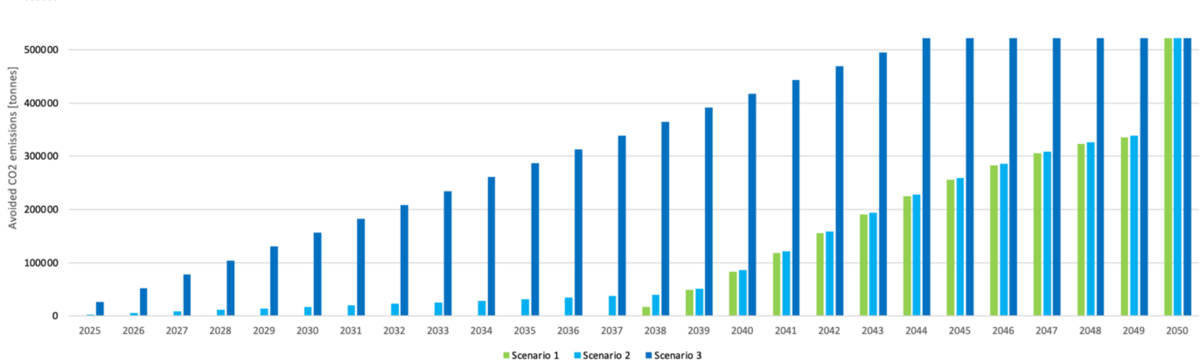
Conversely, the first part of scenario 2 is based on a constant customer base, with a very slow decline (-0.55% per year), calibrated to the rate of deep renovation. This insufficient rate will neither significantly generate substantial climate benefits in the short term, especially as the value of CO_2 avoided is initially low.

The cumulative consumer surplus over the period 2025-2050 is negative in all the scenarios, with an increasing loss as the transition accelerates: 1,41bn€ in scenario 1, 1,77bn€ in scenario 2 and 2.24bn€ in scenario 3.

The present value of stranded assets borne by Resa decreases with the speed of gas withdrawal, falling from 380M€ in scenario 1 to 267M€ in scenario 2, then to 201M€ in scenario 3.

Figure 2 shows the annual change in CO_2 emissions avoided by households switching from gas to heat pumps. It can be seen that the emissions avoided in scenario 3 are both earlier and more massive: from the very first years, the volumes reach significant levels, peaking at more than 500,000 tonnes annually from 2044 onwards, by which time all households have migrated to electricity.

Figure 6: Avoided CO_2 emissions from gas-to-heat pump switching (2025–2050) [tCO2]

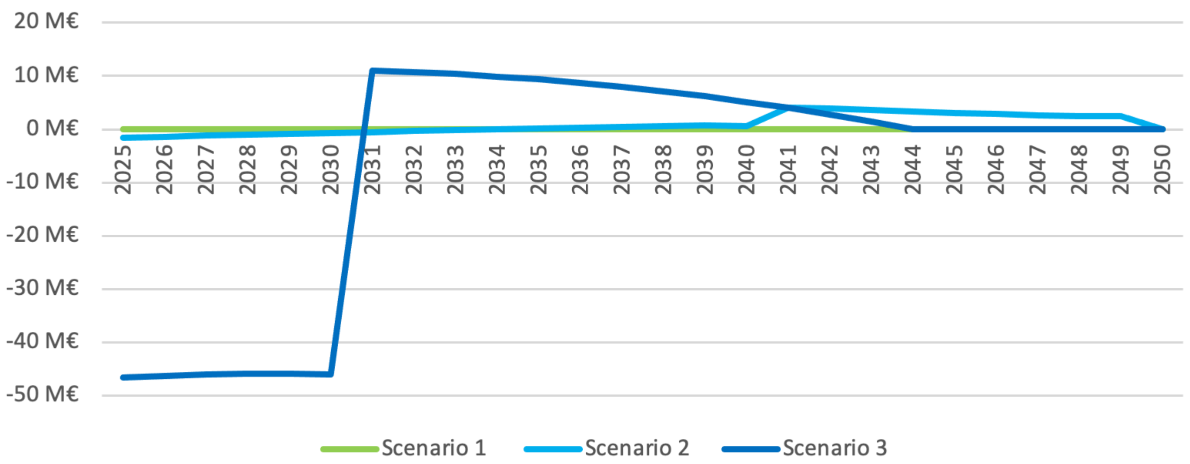


Over the whole period, total emissions avoided amount to :

- 2.86 $MtCO_2$ for scenario 1, valued at €2.54bn,
- 3.18 $MtCO_2$ for scenario 2, valued at €2.70bn,
- 8.60 $MtCO_2$ for scenario 3, valued at €6.20bn.

These amounts are discounted at 4% and calculated on the basis of the shadow price published by the European Investment Bank. Scenario 3 thus appears to be the only scenario that achieves a sufficient volume of avoided emissions to offset, in present value terms, the other associated economic costs (negative surplus and stranded assets).

Figure 7: Government financial balance (2025-2050) [M€]



The graph above illustrates the evolution of the net balance for public finances, by aggregating expenditure on subsidies and revenue from gas surcharges. The accumulated state budget balance over the 25 years is +8 M€ in scenario 2, and -188 M€ in scenario 3.

In scenario 3, the State grants substantial subsidies to households during the first few years (2025-2030), without these being immediately offset by additional tax revenues. Once the subsidy period is over, the expenditure ceases, while the surcharges continue to be collected, although their revenue decreases as households become disconnected.

In scenario 2, the flows are more balanced. Until 2040, the revenue from surcharges is sufficient to finance the subsidies (€3,000/household). This stability can be explained by the low rate of decline in the gas supply, which leads to a constant rate of replacement. This scenario is therefore characterised by a more spread-out and relatively neutral budgetary effort.

Finally, in scenario 1, no subsidy is paid for households switching from gas (those switching from heating oil are not included in this analysis). The budgetary balance is therefore virtually zero, but the same applies to the associated environmental benefits.

4.5 Sensitivity analysis

In any cost-benefit analysis (CBA), the robustness of the results depends on the reliability of the underlying assumptions. However, some of these assumptions are inherently uncertain, particularly in the context of prospective analyses concerning long-term energy infrastructure. Sensitivity analysis thus constitutes an indispensable tool, allowing for the assessment of the extent to which the results are sensitive to reasonable variations in certain key parameters.

By way of illustration, a sensitivity analysis was conducted here on the shadow price of CO_2, a central parameter in the valuation of avoided emissions.

This analysis shows that, even though the variation in the CO_2 price within a realistic range (±20% around the reference value) does not change the hierarchy between indeed the scenarios the rapid phase-out of gas with subsidies remaining the most favourable but it strongly influences the magnitude of the net benefits.

The two graphs below illustrate this effect: the first presents the results with a shadow price reduced by 20%, the second with an increase of 20% We observe that, in all cases, scenario 3 remains the most advantageous. However, the gap between this scenario and the others widens with a high carbon price and narrows when it is reduced.

Figure 8: Net welfare with a shadow price of CO_2 reduced by 20% [M€]

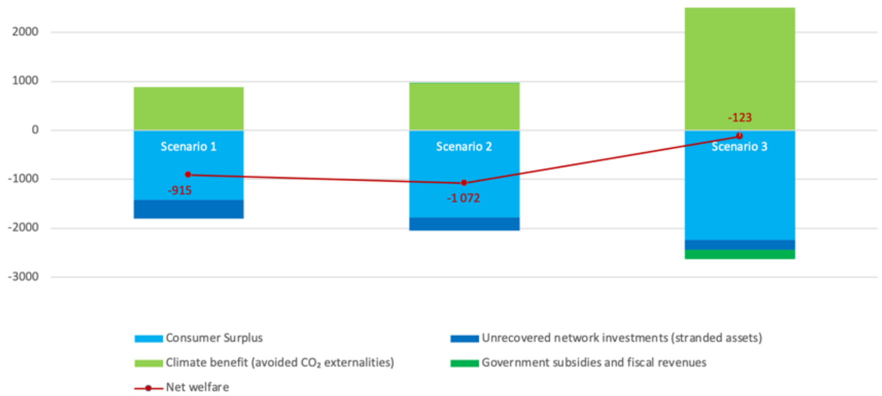
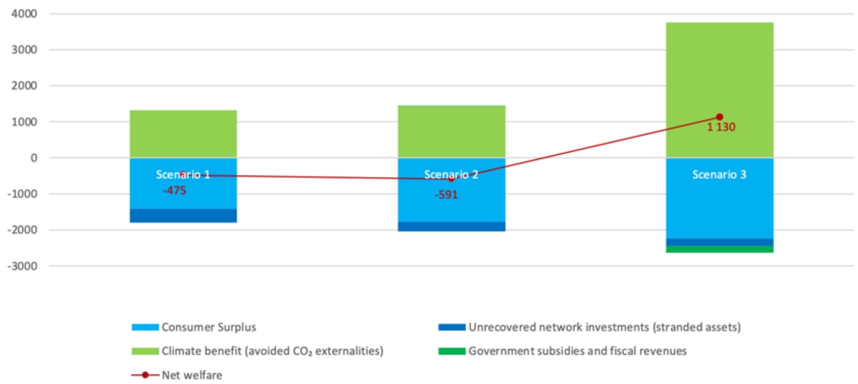


Figure 9: Net welfare with a shadow price of CO_2 increased by 20% [M€]



The choice of this parameter for the sensitivity analysis is arbitrary, motivated by its visibility in the results. It does not claim to cover all the uncertainties of the model. A more in-depth analysis would be necessary to rigorously assess the robustness of the conclusions, particularly by testing other influential variables such as energy prices, the pace of disconnection, or residual investments in the network.

4.6 Limits and discussion

This section aims to explain the main limitations of the model, starting with its static nature, which makes it impossible to model the adjustment of household behaviour in response to price changes. This is followed by a discussion of the key assumptions and methodological choices made.

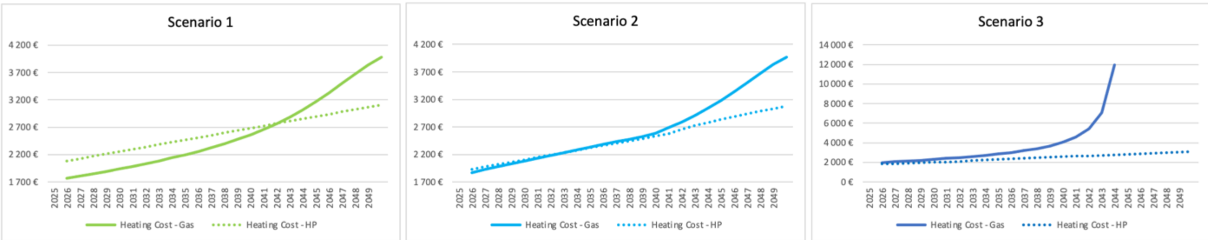
4.6.1 Limitations of the static model and underestimation of substitution dynamics

As mentioned earlier, the model is based on a completely static structure, with no functional link between economic signals and adoption behavior. This choice runs counter to recommended best practice in cost-benefit analysis, which stresses the importance of anticipating the price elasticity effects of demand.

The figure below illustrates the change in the total annual cost of heating for households according to the two technologies used: natural gas ('full line') and heat pumps (dotted line), for each of the three scenarios analysed. These graphs illustrate the moment, in each scenario, at which the cost of gas heating becomes higher than that of heat pumps. It isa tipping point that would directly influence household choices in a dynamic framework.

In a realistic framework, any rational consumer has an incentive to opt for the least expensive heating option. This has a decisive impact on the dynamics of substitution between technologies. However, in the current model, which is static in nature, these behavioural adjustments are not taken into account.

Figure 10: Annual cost evolution of heating with gas and heat pumps (2025-2050)



In scenario 1, we see that from 2044 the annual cost of gas heating exceeds that of heat pumps. From that year onwards, a rapid switch to heat pumps would be expected.

In scenario 2, this crossing of the curves occurs much earlier, in 2033, suggesting that the annual rate of adoption of heat pumps would be even more pronounced in this configuration.

Finally, in scenario 3, the investment grants (€5,000 per installation) make the heat pump immediately more advantageous. This would lead, in practice, to a substitution rate higher than the 5% annual rate assumed, and would enable a more rapid phase-out of gas, with beneficial effects on the CO_2 emissions avoided.

It is also important to emphasise that a feedback loop effect reinforces this dynamic: the more households disconnect from gas, the more the unit distribution costs increase for the remaining users, which in turn increases the economic incentive to disconnect.

Following the integration of this feedback loop, scenario 3 can be expected to remain the best-performing scenario, with a wider gap between the first 2 scenarios. The static nature of the model undoubtedly leads to an underestimation of substitution effects. Further work incorporating price-sensitive behavioural dynamics would be required to refine these results.

4.6.2 Other limitations

Firstly, the model assumes a homogeneous housing stock, based on a typical profile of single-family homes with intermediate insulation. This assumption masks the considerable heterogeneity of the buildings on Resa sector, particularly the large proportion of multi-family dwellings, older dwellings and dwellings located in dense urban areas. In these configurations, the installation of a heat pump may be technically complex, economically dissuasive or even impossible. This simplification could therefore lead to an overestimation of the general feasibility of electrifying heating.

The gas and electricity price projections are based on linear trend using inflation-adjusted historical data. This method, while guaranteeing the readability of the assumptions, does not reflect the structural volatility expected on the energy markets, nor the impact of transition policies on long-term prices. In particular, the potential increase in the cost of electricity as a result of the investments needed to green the mix, or the effects of possible gas crises, are not taken into account.

The estimation of stranded assets is based on a simplified approximation, assimilating the residual book value to an economic cost. However, this approach does not allow the actual loss to be measured and gives only a simple estimation. Nor does it take into account income already recovered or expectations made at the time of investment.

Scenario 3 assumes the generalised granting of investment subsidies, financed entirely by the public authorities, with no budgetary constraints. However, such a system would require a significant financial effort, specific governance and strong political acceptability. Although these transfers are treated here as neutral in terms of collective well-being, their institutional and financial feasibility merits discussion.

Finally, the model deliberately focuses on the direct effects for households, the network operator and the environment, without incorporating the wider macroeconomic effects. For example, it does not measure the effects on employment, the impact on the balance of trade via the reduction in gas imports, or the potential spillover effects on the local industries. As mentioned in the literature these dimensions are also impacting by the asset stranding (van der Ploeg & Rezai, 2020; Caldecott et al., 2013).

4.6.3 Discussion

From a reflective standpoint, one of the main challenges encountered in developing this model was to define a scope that is both coherent, methodologically sound and practically implementable. The wide range of potential impacts related to the gas phase-out, including economic, social, fiscal and environmental dimensions, makes it particularly difficult to determine which effects to include. Methodological trade-offs were therefore necessary to isolate the most measurable and policy-relevant variables. This process of narrowing the analytical focus, although inherently reductive, was essential to ensure internal consistency and interpretability of the results. Several aspects would benefit from further research, such as the inclusion of redistributive effects, differentiated technology adoption pathways or network-level interactions. However, the main limitation remains the static nature of the model. Allowing household behaviour to respond to changing prices and policy signals would be a critical step towards improving the robustness and relevance of the analysis.

5 Conclusion

The economic evaluation carried out in this work concerns the transition away from residential gas in Wallonia, based on a cost-benefit analysis applied to Resa's distribution network. Among the three scenarios considered, only the rapid phase-out with targeted public support yields a positive net welfare outcome by 2050. The progressive and business-as-usual scenarios fail to fully capture the environmental benefits and lead to growing inefficiencies either through delayed electrification or persistent underutilisation of the gas infrastructure.

Beyond the numerical results, a central insight emerges: achieving carbon neutrality by 2050 requires a gas phase-out strategy that is clear, credible, and well signalled. Stranded asset risk is not a future shock, but a structural consequence of delayed or poorly communicated decisions. Without visibility, network operators cannot adjust investment plans, households postpone their switch to low-carbon alternatives, and decarbonisation efforts lose momentum. Managing stranded assets is not solely a financial matter it is a long-term governance challenge that calls for consistent planning, coherent regulation, and early coordination between public and private actors.

In this context, policy unpredictability represents the worst-case scenario: it deters investment in sustainable alternatives, increases user costs, and undermines climate targets. A well-defined phase-out trajectory grounded in transparent regulatory signals, appropriate compensation mechanisms, and stable governance is essential to align climate ambition with economic and social outcomes. With twenty-five years remaining, there is still time to build a robust and coordinated transition but delay would make that path narrower, costlier, and less equitable.

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Appendixes

Appendix 1: Modelling the adoption curve for heat pumps using the Bass model

The Bass model suggests that the adoption of an innovation is driven by two factors:

- external innovation (parameter p)
- social imitation (parameter q)

To estimate the quantity adopted in a given year, the model is based on the following formula:

$$S(t) = \left(p + \frac{q \cdot Y(t)}{M}\right) \cdot \left(M - Y(t)\right)$$

With
$S_{(t)}$ = number of heat pumps installed during the year
$Y_{(t)}$ = cumulative stock installed in the year
M = maximum number of potential adopters
p = innovation coefficient
q = imitation coefficient

This equation is used to determine the number of HP installed each year, i.e. the "HP simulated sales" column of table 2. To establish the unknow parameters p and q, historical data were used, calibrating the "projected" data to the actual data using a solver that minimises the squared error between these two values.

The excel solver was used to automatically adjust the parameters; p, q and M with variable cells "HP simulated sales" and "HP simulated stock". The constraints are as follows:
$p \geq 0$
$q \geq 0$
$M \geq 31\,398$ (actual stock in 2024)
$M \leq 532\,076$ (total number of households projected for 2050 on Resa territorial sector)

Calibration produced the following parameters:

p = 0,0059
q = 0,2
M = 532 076

These parameters have been used to generate the heat pump adoption curve, from 2012 to 2070.

Figure 1: Stock of heat pumps in the Resa sector (2024-2070), according to the Bass diffusion model

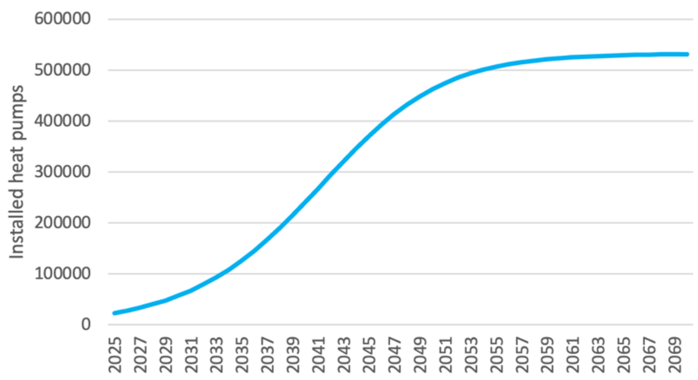


Table 2: Historical data and simulation of the adoption of heat pumps (Bass model)

Year	HP Sales	HP cumulative stock [6]	HP simulated cumulative stock	HP simulated sales	Error 2
2012	810	810	810	810	0
2013	810	1620	1285	475	112122
2014	720	2340	1855	570	235532
2015	1080	3420	2537	682	779493
2016	1170	4590	3354	817	1526473
2017	1350	5940	4333	979	2582245
2018	1440	7380	5504	1171	3519599
2019	1980	9360	6904	1400	6032069
2020	1980	11340	8577	1673	7636069
2021	2520	13860	10573	1996	10803342
2022	5490	19350	12953	2380	40916399
2023	7535	26885	15787	2834	123163492
2024	4513	31398	19156	3368	149886245
2025			23151	3996	
2030			56695	8974	
2040			240316	25794	
2050			462325	14185	
2060			523404	2121	
2070			531135	236	

Sources: HP stock (European Commission, 2024)

[6] The national historical figures have been adjusted for RESA using a double weighting:

- Wallonia represents around 30% of the Belgian households
- RESA covers around 30% of Wallonia

This approximation is necessary in the absence of more precise territorial data about heat pump adoption. It is likely that the distribution of sales will not be uniform across the Regions, with faster take-up in Flanders due to a more favourable regulatory and socio-economic context. This assumption is therefore a conservative one for estimating the dynamics in Wallonia.

Appendix 2: Average renovation rate in Wallonia

The renovation rate used in scenario 2 is based on regional data on the number of residential buildings and annual renovations between 2002 and 2024. The rate is obtained by dividing the number of renovations each year by the total housing stock. The average over the period gives an annual rate of 0.55%, used as an assumption for gradual gas disconnection.

Table 3: Renovation rate of residential buildings in Wallonia (2002-2024)

Year	Number of residential buildings in Wallonia	Number of residential rennovation in Wallonia	Rennovation Rate [%]
2002	1 531 542	7 022	0,45849216
2003	1 540 012	8 109	0,526554339
2004	1 548 494	8 740	0,564419365
2005	1 555 900	8 686	0,558262099
2006	1 564 342	9 337	0,596864369
2007	1 573 229	9 021	0,573406669
2008	1 582 328	9 323	0,589195161
2009	1 592 035	9 129	0,573417042
2010	1 601 070	9 374	0,585483458
2011	1 609 809	9 013	0,559880085
2012	1 617 569	9 154	0,565910944
2013	1 626 262	9 174	0,564115745
2014	1 634 163	9 224	0,564447977
2015	1 641 150	9 854	0,600432623
2016	1 648 759	9 642	0,584803479
2017	1 655 928	9 510	0,574300332
2018	1 664 006	9 393	0,564481138
2019	1 671 874	8 897	0,532157328
2020	1 679 424	8 746	0,520773789
2021	1 687 007	10 450	0,619440228
2022	1 695 472	8 828	0,520680967
2023	1 702 592	7 739	0,454542251
2024	1 710 141	7 400	0,432712858
Average			**0,549372016**

Appendix 3: Residential heating mix

The table below presents the estimated distribution of households by primary heating system in 2024, based on national statistics adjusted to Resa's territorial sector.

Table 4: Residential heating technology mix on Resa territory in 2024

Technology	Number of Households	Share (%)	Source
Natural gas	228,558	49.0 %	(Resa, 2022)[7]
Oil heating	206,250	44.2 %	(Wallonie, 2023)[8]
Heat pumps	31,398	6.7 %	(European Commission, 2024)

In Wallonia, the number of private households is expected to increase by 2050 to 1 773 487 (Iweps, 2024). As Resa covers approximately 30% of the Walloon territory, the estimated number of private households in 2050 on the Resa territory is 532 076. We estimate that this increase will be linear over the period.

These tables 5 show, for each scenario, the annual change in the breakdown of households according to their main heating system: natural gas, oil-fired boiler or heat pump (HP).

Although all the heat pumps installed contribute to the energy transition, only some of them replace a gas-fired boiler. For the purposes of this study, which looks specifically at the economic impact of natural gas leaving the Resa network, we consider only switches from gas to the heat pump.

Table 5: Scenario 1 - Breakdown of households by heating technology (2024-2050)

SCENARIO 1 – Baseline					
Year	**Heat pump**	**Gas boiler**	**Oil boiler**	**TOTAL**	**Households that switched from gas to HP**
2024	31398	228558	206250	466206	0
2025	23151	247588	198000	468739	0
2026	27880	253643	189750	471273	0
2027	33462	258845	181500	473806	0
2028	40027	263063	173250	476340	0
2029	47721	266153	165000	478873	0
2030	56695	267962	156750	481407	0
2031	67106	268334	148500	483940	0
2032	79109	267115	140250	486474	0

[7] Based on the total number of Resa gas connections (252 712) , 90.44% of which are residential. This estimate is based on data from CWaPE, which indicates 788,986 customers connected to the gas network in Wallonia, including 713,428, which represents approximately 90% (CWaPE, 2024a)

[8] Based on the assumption that Resa covers an area representing 30% of the Walloon population.

2033	92845	264162	132000	489007	0
2034	108433	259358	123750	491541	0
2035	125950	252624	115500	494074	0
2036	145417	243941	107250	496608	0
2037	166780	233361	99000	499141	0
2038	189896	221029	90750	501675	7529
2039	214522	207186	82500	504208	21372
2040	240316	192176	74250	506741	36382
2041	266843	176432	66000	509275	52126
2042	293603	160455	57750	511808	68103
2043	320062	144780	49500	514342	83778
2044	345694	129932	41250	516875	98626
2045	370022	116386	33000	519409	112172
2046	392657	104535	24750	521942	124023
2047	413317	94659	16500	524476	133899
2048	431838	86922	8250	527009	141636
2049	448168	81375	0	529543	147183
2050	532076	0	0	532076	228558

Table 6: Scenario 2 - Breakdown of households by heating technology (2024-2050)

SCENARIO 2 – Gradual phase-out					
Year	**HP**	**Gas**	**Oil**	**TOTAL**	**Households that switched from gas to HP**
2024	31398	228558	206250	466206	
2025	43439	227301	198000	468739	1257
2026	55479	226044	189750	471273	2514
2027	67520	224787	181500	473806	3771
2028	79560	223530	173250	476340	5028
2029	91601	222273	165000	478873	6285
2030	103641	221016	156750	481407	7542
2031	115682	219759	148500	483940	8799
2032	127722	218501	140250	486474	10057
2033	139763	217244	132000	489007	11314
2034	151803	215987	123750	491541	12571
2035	163844	214730	115500	494074	13828
2036	175884	213473	107250	496608	15085
2037	187925	212216	99000	499141	16342
2038	199965	210959	90750	501675	17599
2039	215779	205929	82500	504208	22629
2040	241573	190919	74250	506741	37639
2041	268100	175175	66000	509275	53383
2042	294860	159198	57750	511808	69360
2043	321319	143523	49500	514342	85035

2044	346951	128675	41250	516875	99883
2045	371280	115129	33000	519409	113429
2046	393915	103278	24750	521942	125280
2047	414574	93401	16500	524476	135157
2048	433095	85664	8250	527009	142894
2049	449425	80118	0	529543	148440
2050	532076	0	0	532076	228558

Table 7: Scenario 3 - Breakdown of households by heating technology (2024-2050)

SCENARIO 3 – Planned break-up					
Year	**HP**	**Gas**	**Oil**	**TOTAL**	**Households that switched from gas to HP**
2024	31398	228558	206250	466206	
2025	53609	217130	198000	468739	11428
2026	75821	205702	189750	471273	22856
2027	98032	194274	181500	473806	34284
2028	120243	182846	173250	476340	45712
2029	142455	171419	165000	478873	57140
2030	164666	159991	156750	481407	68567
2031	186878	148563	148500	483940	79995
2032	209089	137135	140250	486474	91423
2033	231300	125707	132000	489007	102851
2034	253512	114279	123750	491541	114279
2035	275723	102851	115500	494074	125707
2036	297934	91423	107250	496608	137135
2037	320146	79995	99000	499141	148563
2038	342357	68567	90750	501675	159991
2039	364568	57140	82500	504208	171419
2040	386780	45712	74250	506741	182846
2041	408991	34284	66000	509275	194274
2042	431203	22856	57750	511808	205702
2043	453414	11428	49500	514342	217130
2044	475625	0	41250	516875	228558
2045	486409	0	33000	519409	228558
2046	497192	0	24750	521942	228558
2047	507976	0	16500	524476	228558
2048	518759	0	8250	527009	228558
2049	529543	0	0	529543	228558
2050	532076	0	0	532076	228558

Appendix 4 : Estimation of future energy prices and surcharges

This appendix outlines the methodology used to project the evolution of key energy price components over the 2025-2050 period. These projections feed into the cost calculations of consumer surplus across all scenarios.

The analysis focuses on three components:

- the energy-only price of gas (excluding distribution tariffs and taxes),
- the surcharges applied to gas (excise duties, VAT, etc.),
- the all-in electricity price (including energy, transport, distribution and taxes).

Table 8 presents the historical values used for the estimation. Data were collected from CWaPE reports (2014–2023), and nominal prices were converted into constant €2024 using consumer price index (CPI) data. The inflation index used is based on Belgian national CPI figures (Statbel, 2025)

Table 8: Historical energy prices by component (2014 – 2024)

Year	Gas energy price [$€_{2024}$/kwh]	Surcharges on gas [$€_{2024}$/kwh]	Electricity price all includes [$€_{2024}$/kwh]	Sources	Discount factor
2014	0,0525	0,0022	0,4443	(CWaPE, 2016)	1,2004
2015	0,0466	0,0024	0,4737	(CWaPE, 2017)	1,1806
2016	0,0375	0,0022	0,5078	(CWaPE, 2017)	1,1682
2017	0,0401	0,0021	0,5199	(CWaPE, 2017)	1,1467
2018	0,0484	0,0020	0,5840	(CWaPE, 2020)	1,1173
2019	0,0369	0,0020	0,5564	(CWaPE, 2020)	1,0952
2020	0,0314	0,0021	0,4818	(CWaPE, 2021)	1,0570
2021	0,0938	0,0020	0,7209	(CWaPE, 2022)	1,0319
2022	0,1732	0,0017	0,8841	(CWaPE, 2023a)	1,0172
2023	0,0715	0,0099	0,7104	(CWaPE, 2025)	1,0080
2024	0,0699	0,0101	0,6375	(CWaPE, 2025)	1

To extrapolate future values from 2025 to 2050, a linear regression was applied to the inflation-adjusted historical data. The year 2022 was excluded due to the exceptional impact of the energy crisis. The resulting equations allow for a forward projection of each component under a trend-based assumption.

The figures 12, 13 and 14 illustrate the applied linear regressions, along with the resulting trend lines and formulas.

Figure 11: Evolution of natural gas prices [$€_{2024}$/kWh]

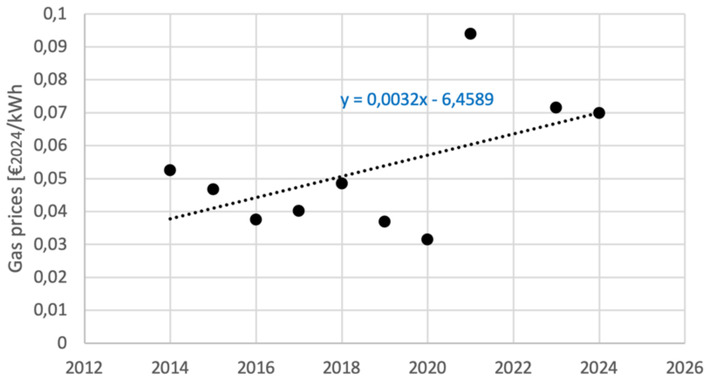


Figure 12: Evolution of surcharges prices on natural gas [$€_{2024}$/kWh]

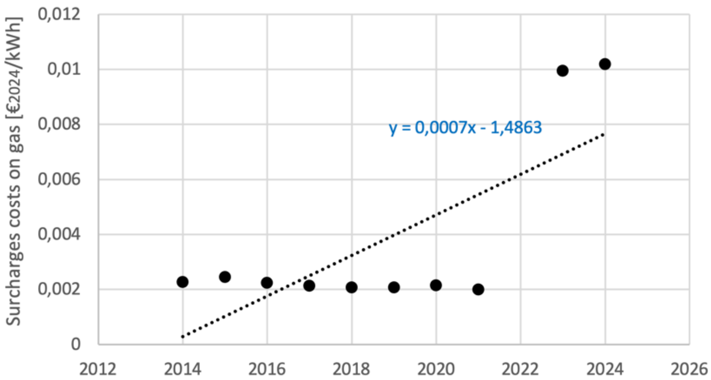
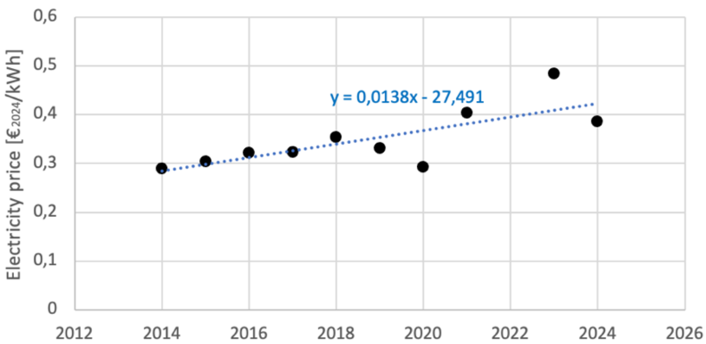


Figure 13: Evolution of electricity price all included [$€_{2024}$/kWh]



Using the regression equations from figures 13 to 14, we estimate the evolution of the gas price, gas surcharges, and electricity price between 2025 and 2050. The annual values obtained through this method are reported in the table below.

Table 9: Projected values of gas energy price, surcharges, and electricity price (2025–2050)

Year	Projection of energy price of gas [€$_{2024}$/kWh]	Projection Surcharge cost [€$_{2024}$/kwh]	Projection of Price of electricity all included [€$_{2024}$/kWh]
2025	0,0732 €	0,0084 €	0,4359 €
2026	0,0765 €	0,0091 €	0,4496 €
2027	0,0797 €	0,0099 €	0,4634 €
2028	0,0829 €	0,0106 €	0,4772 €
2029	0,0861 €	0,0114 €	0,4910 €
2030	0,0894 €	0,0121 €	0,5048 €
2031	0,0926 €	0,0128 €	0,5186 €
2032	0,0958 €	0,0136 €	0,5324 €
2033	0,0991 €	0,0143 €	0,5462 €
2034	0,1023 €	0,0150 €	0,5600 €
2035	0,1055 €	0,0158 €	0,5738 €
2036	0,1087 €	0,0165 €	0,5876 €
2037	0,1120 €	0,0173 €	0,6013 €
2038	0,1152 €	0,0180 €	0,6151 €
2039	0,1184 €	0,0187 €	0,6289 €
2040	0,1216 €	0,0195 €	0,6427 €
2041	0,1249 €	0,0202 €	0,6565 €
2042	0,1281 €	0,0209 €	0,6703 €
2043	0,1313 €	0,0217 €	0,6841 €
2044	0,1345 €	0,0224 €	0,6979 €
2045	0,1378 €	0,0232 €	0,7117 €
2046	0,1410 €	0,0239 €	0,7255 €
2047	0,1442 €	0,0246 €	0,7393 €
2048	0,1474 €	0,0254 €	0,7530 €
2049	0,1507 €	0,0261 €	0,7668 €
2050	0,1539 €	0,0269 €	0,7806 €

Note that gas overloads depend on the scenario, so the data presented in the table above are those used in scenario 1. In scenario 2 the data is increased by a factor of 1.1 and in scenario 3 by a factor of 1.5.

Appendix 5: Consumer surplus calculations

This appendix provides the detailed annual calculations of the consumer surplus for each group of households, as well as the aggregated total. These calculations are based on a set of technical and economic assumptions summarised in the table below.

Table 10: Key parameters for the consumer surplus calculation

Parameter	Value
Willingness to pay (WTP)	2000€/year
Average gas consumption	11 523 kWh/year
Average HP electricity consumption	3 100 kWh/year
Gas boiler investment cost	6 890€ (344,5€/year)
Heat pump investment cost	14 630€ (731,5€/year)
Subsidy for HP	1800€ in sceanrio 1, 3000€ in scenario 2 and 5000€ in scenario 3
Gas & electricity prices	Linear regression on historical data
Gas surcharges	Follow price regression (time 1,1 in scenario 1 and times 1,5 in scenario 3)
Gas DSO tariffs	Dynamic evolution based on Resa costs and number of customers (see appendix X)

The first block of table 11, 12 and 13 present the consumer surplus (CS) for a representative household that remains connected to the gas distribution network for each scenario.

The consumer surplus is calculated each year as:

$$CS_{gas,t} = \text{WTP} - (17000 \times (\text{gas price}_t + \text{surcharges}_t + \text{DSO tariffs}_t) + CAPEX\ )$$

The value of the CS in 2050 (except for scenario 3) reflects the stranded asset impact for gas users still connected in 2049. It represents the non-amortised residual value of the gas boiler, assumed to be on average 35% of the purchase price per household.

The second block of table 11, 12 and 13 present the consumer surplus (CS) for households that have switch to heat pump in each scenario. The calculation includes both energy expenditure and annualised investment costs, while distinguishing between households that have received subsidies and those that have not.

The total annual heating cost is calculated as:

- the product of the all-inclusive electricity price (€/kWh) and the average annual consumption (3,100 kWh), and
- the annualised capital expenditure (CAPEX) of the heat pump.

The full investment cost of a heat pump is assumed to be 14 630€, amortised linearly over 20 years, resulting in a base CAPEX of 731,5€ per year for households that did not benefit from subsidies.

For households that receive a subsidy, the amount of the subsidy is deducted from the total investment cost, and the resulting reduced CAPEX is then amortised over the same period (20 years). This approach reflects the long-term economic benefit of the subsidy, rather than treating it as a one-off reduction in the year of purchase.

The amount and availability period of the subsidy differ across scenarios and are defined in the respective scenario assumptions. Households that installed a heat pump during the eligible period continue to benefit from the lower CAPEX throughout the amortisation period, while households that installed a heat pump outside the subsidy window bear the full CAPEX.

As a result, the model distinguishes each year between:

- $N_{HP,sub,t}$: the number of households with heat pumps installed during the subsidised period, and
- $N_{HP,no\_sub,t}$: the number of households with heat pumps installed without subsidy.

The consumer surplus for each group is calculated as follows:

$$CS_{HP,sub,t} = WTP - (3100 \times P_{elec,t} + CAPEX_{sub})$$
$$CS_{HP,no\_sub,t} = WTP - (3100 \times P_{elec,t} + CAPEX_{no\_sub})$$

With:

$$CAPEX_{no\_sub} = \frac{14{,}630}{20} = €731.5$$
$$CAPEX_{sub} = \frac{14{,}630 - \text{Subsidy amount}}{20}$$

The average individual consumer surplus for all HP households in year t is then computed as a weighted average:

$$CS_{HP,t} = \frac{N_{HP,sub,t} \times CS_{HP,sub,t} + N_{HP,no\_sub,t} \times CS_{HP,no\_sub,t}}{N_{HP,total,t}}$$

The last column 13,14 and 15 aggregate the consumer surplus across all households in the Resa area for each scenario, taking into account:

- The number of clients using gas or HP in each year,
- The individual consumer surplus for each category (from tables X).

The total is calculated each year as:

$$CS_{total,t} = (N_{gas,t} \times CS_{gas,t}) + (N_{HP,t} \times CS_{HP,t})$$

With:
$N_{gas,t}$ = Number of households connected to the gas network in year t
$N_{HP,t}$ = Number of households using a heat pump in year t

Table 11: Scenario 1 - Consumer surplus

SCENARIO 1 - Baseline											
Year	**Gas price [€2024/kWh]**	**Surcharges [€2024/kWh]**	**DSO tarrifs [€2024/kWh]**	**CAPEX [€2024]**	**CS of a client with gas boiler [€2024]**	**Electricity prices (all included) [€/kWh]**	**Subsidies [€2024]**	**Capex without subsidies**	**Number of HP with subsidies**	**CS of a client with HP**	**Consumer Surplus [M€2024]**
2025	0,073	0,008	0,042	344,5	235,9	0,436	1800	641,5	0	-82,66	58,41
2026	0,076	0,009	0,041	344,5	193,0	0,450	1800	641,5	0	-125,41	48,95
2027	0,080	0,010	0,041	344,5	150,8	0,463	0	641,5	0	-168,16	39,02
2028	0,083	0,011	0,041	344,5	108,0	0,477	0	641,5	0	-210,91	28,42
2029	0,086	0,011	0,041	344,5	63,1	0,491	0	641,5	0	-253,67	16,80
2030	0,089	0,012	0,041	344,5	16,1	0,505	0	641,5	0	-296,42	4,33
2031	0,093	0,013	0,041	344,5	-32,7	0,519	0	641,5	0	-339,17	-8,79
2032	0,096	0,014	0,042	344,5	-84,1	0,532	0	641,5	0	-381,92	-22,46
2033	0,099	0,014	0,042	344,5	-138,3	0,546	0	641,5	0	-424,67	-36,52
2034	0,102	0,015	0,043	344,5	-195,8	0,560	0	641,5	0	-467,42	-50,78
2035	0,106	0,016	0,045	344,5	-257,3	0,574	0	641,5	0	-510,18	-65,01
2036	0,109	0,017	0,046	344,5	-323,6	0,588	0	641,5	0	-552,93	-78,93
2037	0,112	0,017	0,049	344,5	-395,5	0,601	0	641,5	0	-595,68	-92,29
2038	0,115	0,018	0,052	344,5	-474,2	0,615	0	641,5	0	-638,43	-109,61
2039	0,118	0,019	0,055	344,5	-561,0	0,629	0	641,5	0	-681,18	-130,78
2040	0,122	0,019	0,060	344,5	-657,3	0,643	0	641,5	0	-723,93	-152,66
2041	0,125	0,020	0,065	344,5	-764,9	0,657	0	641,5	0	-766,69	-174,92
2042	0,128	0,021	0,071	344,5	-885,4	0,670	0	641,5	0	-809,44	-197,19
2043	0,131	0,022	0,079	344,5	-1019,9	0,684	0	641,5	0	-852,19	-219,05
2044	0,135	0,022	0,088	344,5	-1168,9	0,698	0	641,5	0	-894,94	-240,14
2045	0,138	0,023	0,098	344,5	-1331,1	0,712	0	641,5	0	-937,69	-260,10
2046	0,141	0,024	0,109	344,5	-1502,5	0,725	0	641,5	0	-980,44	-278,67
2047	0,144	0,025	0,120	344,5	-1675,9	0,739	0	641,5	0	-1023,20	-295,64
2048	0,147	0,025	0,131	344,5	-1840,2	0,753	0	641,5	0	-1065,95	-310,93
2049	0,151	0,026	0,139	344,5	-1982,5	0,767	0	641,5	0	-1108,70	-324,51
2050	0,154	0,027		344,5	-196235799,4	0,781	0	641,5	0	-1151,45	-263,17

Table 12: Scenario 2 - Consumer surplus

SCENARIO 2 – Gradual phase-out											
Year	**Gas price [€2024/kWh]**	**DSO tarrifs [€2024/kWh]**	**Surcharges [€2024/kWh]**	**CAPEX [€2024]**	**CS of a client with gas boiler [€2024]**	**Electricity prices (all included) [€/kWh]**	**Subsidies [€2024]**	**Capex without subsidies**	**Number of HP with subsidies**	**CS of a client with HP**	**Consumer Surplus [M€2024]**
2025	0,073	0,050	0,009	344,5	131,3	0,436	3000	581,5	1257	67,34	29,94
2026	0,076	0,051	0,010	344,5	76,4	0,450	3000	581,5	2514	24,59	17,32
2027	0,080	0,051	0,011	344,5	23,9	0,463	3000	581,5	3771	-18,16	5,30
2028	0,083	0,051	0,012	344,5	-27,2	0,477	3000	581,5	5028	-60,91	-6,38
2029	0,086	0,052	0,012	344,5	-78,5	0,491	3000	581,5	6285	-103,67	-18,11
2030	0,089	0,052	0,013	344,5	-129,8	0,505	3000	581,5	7542	-146,42	-29,80
2031	0,093	0,053	0,014	344,5	-180,5	0,519	3000	581,5	8799	-189,17	-41,34
2032	0,096	0,053	0,015	344,5	-230,9	0,532	3000	581,5	10057	-231,92	-52,79
2033	0,099	0,053	0,016	344,5	-281,0	0,546	3000	581,5	11314	-274,67	-64,16
2034	0,102	0,054	0,017	344,5	-330,8	0,560	3000	581,5	12571	-317,42	-75,44
2035	0,106	0,054	0,017	344,5	-380,3	0,574	3000	581,5	13828	-360,18	-86,64
2036	0,109	0,054	0,018	344,5	-429,5	0,588	3000	581,5	15085	-402,93	-97,76
2037	0,112	0,054	0,019	344,5	-478,4	0,601	3000	581,5	16342	-445,68	-108,81
2038	0,115	0,054	0,020	344,5	-527,0	0,615	3000	581,5	17599	-488,43	-119,78
2039	0,118	0,056	0,021	344,5	-586,9	0,629	3000	581,5	22629	-531,18	-132,89
2040	0,122	0,060	0,021	344,5	-681,4	0,643	3000	581,5	37639	-573,93	-151,70
2041	0,125	0,065	0,022	344,5	-786,8	0,657	0	581,5	40434	-653,07	-172,70
2042	0,128	0,071	0,023	344,5	-904,8	0,670	0	581,5	40434	-721,99	-194,11
2043	0,131	0,078	0,024	344,5	-1036,3	0,684	0	581,5	40434	-780,86	-215,14
2044	0,135	0,087	0,025	344,5	-1181,9	0,698	0	581,5	39177	-836,11	-235,59
2045	0,138	0,097	0,025	344,5	-1340,0	0,712	0	581,5	37920	-887,55	-254,95
2046	0,141	0,107	0,026	344,5	-1506,9	0,725	0	581,5	36663	-936,55	-272,96
2047	0,144	0,118	0,027	344,5	-1675,1	0,739	0	581,5	35406	-983,90	-289,44
2048	0,147	0,127	0,028	344,5	-1834,0	0,753	0	581,5	34149	-1030,10	-304,30
2049	0,151	0,135	0,029	344,5	-1970,8	0,767	0	581,5	32892	-1075,46	-317,54
2050	0,154		0,030	344,5	-193204377,5	0,781	0	581,5	31635	-1130,69	-451,63

Table 13: Scenario 3 - Consumer surplus

SCENARIO 3 – Planned Break-up													
Year	**Gas price [€2024/kWh]**	**DSO tarrifs [€2024/kWh]**	**Surcharges [€2024/kWh]**	**Average consumption [kwh]**	**CAPEX [€2024]**	**CS of a client with gas boiler [€2024]**	**Electricity prices (all included) [€/kWh]**	**Average consumption of a HP [kwh]**	**Subsidies [€2024]**	**Capex without subsidies**	**Number of HP with subsidies**	**CS of a client with HP**	**Consumer Surplus [M€2024]**
2025	0,073	0,057	0,013	11523	344,5	14,7	0,436	3100	5000	481,5	11428	167,34	5,10
2026	0,076	0,059	0,014	11523	344,5	-59,2	0,450	3100	5000	481,5	22856	124,59	-9,33
2027	0,080	0,061	0,015	11523	344,5	-136,5	0,463	3100	5000	481,5	34284	81,84	-23,72
2028	0,083	0,064	0,016	11523	344,5	-217,9	0,477	3100	5000	481,5	45712	39,09	-38,06
2029	0,086	0,067	0,017	11523	344,5	-304,2	0,491	3100	5000	481,5	57140	-3,67	-52,35
2030	0,089	0,071	0,018	11523	344,5	-396,3	0,505	3100	5000	481,5	68567	-46,42	-66,59
2031	0,093	0,075	0,019	11523	344,5	-495,6	0,519	3100	0	481,5	75814	-102,24	-81,81
2032	0,096	0,080	0,020	11523	344,5	-603,9	0,532	3100	0	481,5	75814	-174,61	-98,78
2033	0,099	0,086	0,021	11523	344,5	-723,5	0,546	3100	0	481,5	75814	-240,39	-115,67
2034	0,102	0,093	0,023	11523	344,5	-857,8	0,560	3100	0	481,5	75814	-301,57	-132,49
2035	0,106	0,102	0,024	11523	344,5	-1011,7	0,574	3100	0	481,5	75814	-359,40	-149,23
2036	0,109	0,114	0,025	11523	344,5	-1192,4	0,588	3100	0	481,5	75814	-414,72	-165,88
2037	0,112	0,128	0,026	11523	344,5	-1411,4	0,601	3100	0	481,5	75814	-468,10	-182,45
2038	0,115	0,148	0,027	11523	344,5	-1687,9	0,615	3100	0	481,5	75814	-519,96	-198,92
2039	0,118	0,176	0,028	11523	344,5	-2056,2	0,629	3100	0	481,5	75814	-570,61	-215,30
2040	0,122	0,217	0,029	11523	344,5	-2585,0	0,643	3100	0	481,5	75814	-620,28	-231,58
2041	0,125	0,287	0,030	11523	344,5	-3435,0	0,657	3100	0	481,5	75814	-669,13	-247,76
2042	0,128	0,426	0,031	11523	344,5	-5087,5	0,670	3100	0	481,5	75814	-717,30	-263,83
2043	0,131	0,843	0,033	11523	344,5	-9950,1	0,684	3100	0	481,5	75814	-764,90	-279,79
2044							0,698	3100	0	481,5	75814	-812,01	-185,59
2045							0,712	3100	0	481,5	60651	-871,35	-199,15
2046							0,725	3100	0	481,5	45488	-930,69	-212,72
2047							0,739	3100	0	481,5	30325	-990,02	-226,28
2048							0,753	3100	0	481,5	15163	-1049,36	-239,84
2049							0,767	3100	0		0	-1108,70	-253,40
2050							0,781	3100	0		0	-1151,45	-263,17

Appendix 6: Projection of Resa's regulated revenue base (2025–2050)

These tables show the yearly breakdown of RESA's regulated revenue components under each scenario. The estimates include depreciation, investments, OPEX, other regulated charges, and the return on capital. They are used to approximate Resa's financial needs and the corresponding distribution tariffs.

Table 14: Scenario 1 – Annual regulated revenue base of Resa (2025–2050) [M€2024]

SCENARIO 1 - Baseline							
Year	**Net book value at start**	**Depreciation**	**Investments**	**OPEX**	**Other expenses**	**Return on capital**	**Regulated revenue base**
2025	809,78	20,24	60,3	58	16	24,29	118,54
2026	849,84	21,25	50	58	16	25,50	120,74
2027	878,59	21,96	44	58	16	26,36	122,32
2028	900,63	22,52	45,2	58	16	27,02	123,53
2029	923,31	23,08	44,9	58	16	27,70	124,78
2030	945,13	23,63	42,5	58	16	28,35	125,98
2031	964,00	24,10	41,09	58	16	28,92	127,02
2032	980,99	24,52	39,68	58	16	29,43	127,95
2033	996,14	24,90	38,27	58	16	29,88	128,79
2034	1009,51	25,24	36,86	58	16	30,29	129,52
2035	1021,13	25,53	35,45	58	16	30,63	130,16
2036	1031,05	25,78	34,04	58	16	30,93	130,71
2037	1039,32	25,98	32,63	58	16	31,18	131,16
2038	1045,97	26,15	31,22	58	16	31,38	131,53
2039	1051,04	26,28	29,81	58	16	31,53	131,81
2040	1054,57	26,36	28,4	58	16	31,64	132,00
2041	1056,61	26,42	26,99	58	16	31,70	132,11
2042	1057,18	26,43	25,58	58	16	31,72	132,14
2043	1056,33	26,41	24,17	58	16	31,69	132,10
2044	1054,09	26,35	22,76	58	16	31,62	131,98
2045	1050,50	26,26	21,35	58	16	31,52	131,78
2046	1045,59	26,14	19,94	58	16	31,37	131,51
2047	1039,39	25,98	18,53	58	16	31,18	131,17
2048	1031,93	25,80	17,12	58	16	30,96	130,76
2049	1023,26	25,58	15,71	58	16	30,70	130,28
2050	1013,38	25,33	0	0	0	0,00	0,00

Table 15: Scenario 2 – Annual regulated revenue base of Resa (2025–2050) [M€2024]

SCENARIO 2 – Gradual phase-out							
Year	**Net book value at start**	**Depreciation**	**Investments**	**OPEX**	**Other expenses**	**Return on capital**	**Regulated revenue base**
2025	805,56	28,19	45,23	58	16	28,19	130,39
2026	822,59	28,79	37,50	58	16	28,79	131,58
2027	831,30	29,10	33,00	58	16	29,10	132,19
2028	835,21	29,23	33,90	58	16	29,23	132,46
2029	839,87	29,40	33,68	58	16	29,40	132,79
2030	844,15	29,55	31,88	58	16	29,55	133,09
2031	846,48	29,63	30,82	58	16	29,63	133,25
2032	847,67	29,67	29,76	58	16	29,67	133,34
2033	847,76	29,67	28,70	58	16	29,67	133,34
2034	846,80	29,64	27,65	58	16	29,64	133,28
2035	844,80	29,57	26,59	58	16	29,57	133,14
2036	841,82	29,46	25,53	58	16	29,46	132,93
2037	837,89	29,33	24,47	58	16	29,33	132,65
2038	833,03	29,16	23,42	58	16	29,16	132,31
2039	827,29	28,96	22,36	58	16	28,96	131,91
2040	820,70	28,72	21,30	58	16	28,72	131,45
2041	813,27	28,46	20,24	58	16	28,46	130,93
2042	805,05	28,18	19,19	58	16	28,18	130,35
2043	796,06	27,86	18,13	58	16	27,86	129,72
2044	786,32	27,52	17,07	58	16	27,52	129,04
2045	775,87	27,16	16,01	58	16	27,16	128,31
2046	764,73	26,77	14,96	58	16	26,77	127,53
2047	752,92	26,35	13,90	58	16	26,35	126,70
2048	740,46	25,92	12,84	58	16	25,92	125,83
2049	727,39	25,46	11,78	58	16	25,46	124,92
2050	713,71	0,00	0,00	58	16	24,98	98,98

Table 16: Scenario 3 – Annual regulated revenue base of Resa (2025–2050) [M€2024]

SCENARIO 3 – Planned break-up							
Year	**Net book value at start**	**Depreciation**	**Investments**	**OPEX**	**Other expenses**	**Return on capital**	**Regulated revenue base**
2025	793,91	39,70	10	58	16	27,79	141,48
2026	764,21	38,21	10	58	16	26,75	138,96
2027	736,00	36,80	10	58	16	25,76	136,56
2028	709,20	35,46	10	58	16	24,82	134,28
2029	683,74	34,19	10	58	16	23,93	132,12
2030	659,55	32,98	10	58	16	23,08	130,06
2031	636,58	31,83	10	58	16	22,28	128,11
2032	614,75	30,74	10	58	16	21,52	126,25
2033	594,01	29,70	10	58	16	20,79	124,49
2034	574,31	28,72	10	58	16	20,10	122,82
2035	555,59	27,78	10	58	16	19,45	121,23
2036	537,81	26,89	10	58	16	18,82	119,71
2037	520,92	26,05	10	58	16	18,23	118,28
2038	504,88	25,24	10	58	16	17,67	116,91
2039	489,63	24,48	10	58	16	17,14	115,62
2040	475,15	23,76	10	58	16	16,63	114,39
2041	461,39	23,07	10	58	16	16,15	113,22
2042	448,32	22,42	10	58	16	15,69	112,11
2043	435,91	21,80	10	58	16	15,26	111,05
2044	424,11			58	16		
2045				58	16		
2046				58	16		
2047				58	16		
2048				58	16		
2049				58	16		
2050				58	16		

Appendix 7: Projection of gas distribution tariffs

Under the Belgian regulatory model, distribution tariffs are based on the principle of full cost recovery. For each year, the regulated revenue base (see appendix 7) is divided by the total gas volume distributed, which is derived from the number of households connected to the network and their average consumption. As the number of gas customers declines over time, the distributed volume decreases, mechanically increasing the unit tariff (€/kWh) to ensure cost recovery.

Table 17 : Scenario 1 - Gas distribution tariffs (2025–2050)

SCENARIO 1 - Baseline				
Year	**Regulated revenue base [M€$_{2024}$]**	**Number of gas connection**	**Distibuted Volume [MWh]**	**Distribution tarrifs [€$_{2024}$/kWh]**
2025	118,54	247588	2852957,8	0,0415
2026	120,74	253643	2922723,14	0,0413
2027	122,32	258845	2982667,41	0,0410
2028	123,53	263063	3031269,82	0,0407
2029	124,78	266153	3066875,63	0,0406
2030	125,98	267962	3087727,37	0,0408
2031	127,02	268334	3092017,4	0,0410
2032	127,95	267115	3077967,32	0,0415
2033	128,79	264162	3043938,64	0,0423
2034	129,52	259358	2988576,88	0,0433
2035	130,16	252624	2910986,77	0,0447
2036	130,71	243941	2810929,23	0,0464
2037	131,16	233361	2689021,78	0,0487
2038	131,53	221029	2546914,07	0,0516
2039	131,81	207186	2387401,85	0,0552
2040	132,00	192176	2214440,35	0,0596
2041	132,11	176432	2033025,09	0,0649
2042	132,14	160455	1848927,18	0,0714
2043	132,10	144780	1668299,44	0,0791
2044	131,98	129932	1497201,82	0,0881
2045	131,78	116386	1341119,52	0,0982
2046	131,51	104535	1204553,86	0,1091
2047	131,17	94659	1090750,44	0,1202
2048	130,76	86922	1001596,98	0,1305
2049	130,28	81375	937684,063	0,1389
2050	129,74	0	0	

Table 18: Scenario 2 - Gas distribution tariffs (2025–2050)

SCENARIO 2 – Gradual phase-out				
Year	**Regulated revenue base [M€$_{2024}$]**	**Number of gas connection**	**Distibuted Volume [MWh]**	**Distribution tarrifs [€$_{2024}$/kWh]**
2025	130,39	227301	2619189	0,0415
2026	131,58	226044	2604703	0,0413
2027	132,19	224787	2590218	0,0410
2028	132,46	223530	2575733	0,0407
2029	132,79	222273	2561248	0,0406
2030	133,09	221016	2546763	0,0408
2031	133,25	219759	2532277	0,0410
2032	133,34	218501	2517792	0,0415
2033	133,34	217244	2503307	0,0423
2034	133,28	215987	2488822	0,0433
2035	133,14	214730	2474337	0,0447
2036	132,93	213473	2459851	0,0464
2037	132,65	212216	2445366	0,0487
2038	132,31	210959	2430881	0,0516
2039	131,91	205929	2372917	0,0552
2040	131,45	190919	2199955	0,0596
2041	130,93	175175	2018540	0,0649
2042	130,35	159198	1834442	0,0714
2043	129,72	143523	1653814	0,0791
2044	129,04	128675	1482717	0,0881
2045	128,31	115129	1326634	0,0982
2046	127,53	103278	1190069	0,1091
2047	126,70	93401	1076265	0,1202
2048	125,83	85664	987112	0,1305
2049	124,92	80118	923199	0,1389
2050	98,98	0	0	

Table 19: Scenario 3 - Gas distribution tariffs (2025–2050)

SCENARIO 3 – Planned break-up				
Year	**Regulated revenue base [M€$_{2024}$]**	**Number of gas connection**	**Distibuted Volume [MWh]**	**Distribution tarrifs [€$_{2024}$/kWh]**
2025	141,48	217130	2501990	0,0415
2026	138,96	205702	2370306	0,0413
2027	136,56	194274	2238623	0,0410
2028	134,28	182846	2106939	0,0408
2029	132,12	171419	1975255	0,0407
2030	130,06	159991	1843572	0,0408
2031	128,11	148563	1711888	0,0411
2032	126,25	137135	1580204	0,0416
2033	124,49	125707	1448521	0,0423
2034	122,82	114279	1316837	0,0433
2035	121,23	102851	1185153	0,0447
2036	119,71	91423	1053470	0,0465
2037	118,28	79995	921786	0,0488
2038	116,91	68567	790102	0,0516
2039	115,62	57140	658418	0,0552
2040	114,39	45712	526735	0,0596
2041	113,22	34284	395051	0,0650
2042	112,11	22856	263367	0,0715
2043	111,05	11428	131684	0,0792
2044	0,00	0	0	0,0881
2045	0,00	0	0	0,0983
2046	0,00	0	0	0,1092
2047	0,00	0	0	0,1203
2048	0,00	0	0	0,1305
2049	0,00	0	0	0,1389
2050	0,00	0	0	

Appendix 8 : Shadow price CO_2

The reference values of the shadow cost of carbon published by the European Investment Bank (EIB) are expressed in constant 2016 euros. To ensure consistency with the rest of the monetary data in the model, which are expressed in 2024 constant euros, these values were adjusted for inflation.

The Harmonised Index of Consumer Prices (HICP, base 2013 = 100) was used as the reference index. Based on Statbel data:

- The average HICP for 2016 was 102.89
- The HICP for December 2024 was 132.04

The compound annual growth rate (CAGR) of inflation over the period is calculated using the formula:

$$r = (132.04/102.89)^{(1/8)} - 1 \approx 3.17\% \; per \; year$$

The cumulative inflation factor to convert from €2016 to €2024 is:

$$Adjustment \; Factor \; = \; 102.89 \,/ 132.04 \; \approx 1.283$$

All shadow price values expressed in 2016 euros were thus multiplied by this factor to express them in constant 2024 euros. This ensures consistency across all monetary components of the cost-benefit model.

Table 20: CO2 emmissions shadow price

Year	$€_{2016}/tCO_2$ [9]	Discount factor	$€_{2024}/tCO_2$
2025	165	1,283	211,7
2030	250	1,283	320,8
2035	390	1,283	500,4
2040	525	1,283	673,6
2045	660	1,283	846,8
2050	800	1,283	1026,4

Intermediate yearly values between the reference years (2025, 2030, ..., 2050) were estimated using a linear regression applied to the six reference points in constant 2024 euros.

[9] (EIB Group, 2020)

Appendix 9 : Annual CO_2 emissions avoided and their monetary valuation

The avoided CO_2 emissions (in tonnes per year) were calculated using the following formula:

$$\text{Avoided } CO_2\ (t) = N_{HP} \times \frac{17\,000 \times EF_{gas}}{1\,000}$$

Where:

- N_{HP} is the number of heat pumps installed that year
- EF_{gas} is the gas emission factor (in kg CO_2/kWh)
- 17,000 kWh is the average annual consumption of a gas boiler
- Division by 1,000 converts kg to tonnes

The monetary value of these avoided emissions (in constant €2024) is then calculated as:

$$\text{Value of avoided } CO_2\ [€] = \text{Avoided } CO_2\ (t) \times \text{Shadow price of } CO_2$$

Table 21: Scenario 1- Annual CO_2 emissions avoided and economical valuation

SCENARIO 1 - Baseline			
Year	**Number of HP installed**	**Avoided ton of CO2 per year [tCO_2]**	**Value of CO_2 emissions avoided [$M€_{2024}$]**
2025	0	0	0
2026	0	0	0
2027	0	0	0
2028	0	0	0
2029	0	0	0
2030	0	0	0
2031	0	0	0
2032	0	0	0
2033	0	0	0
2034	0	0	0
2035	0	0	0
2036	0	0	0
2037	0	0	0
2038	7529	17178	10,534
2039	21372	48762	31,525
2040	36382	83008	55, 912
2041	52126	118928	84,806
2042	68103	155380	115,971
2043	83778	191144	149,027
2044	98626	225021	182,930

2045	112172	255926	216,712
2046	124023	282966	248,872
2047	133899	305499	278,859
2048	141636	323151	305,728
2049	147183	335806	328,877
2050	228558	521467	535,234
TOTAL		2864237	2 544 993

Table 22: Scenario 2- Annual CO_2 emissions avoided and economical valuation

SCENARIO 2 – Gradual phase-out			
Year	**Number of HP installed**	**Avoided ton of CO2 per year [tCO_2]**	**Value of CO_2 emissions avoided [M€$_{2024}$]**
2025	1257	2868	0,607
2026	2514	5736	1,226
2027	3771	8604	2,126
2028	5028	11472	3,216
2029	6285	14340	4,498
2030	7542	17208	5,519
2031	8799	20076	7,633
2032	10056	22945	9,488
2033	11313	25813	11,533
2034	12570	28681	13,769
2035	13827	31549	15,786
2036	15084	34417	18,814
2037	16341	37285	21,623
2038	17599	40153	24,623
2039	22629	51630	33,379
2040	37639	85876	57,844
2041	53383	121797	86,852
2042	69360	158248	118,112
2043	85035	194012	151,263
2044	99883	227890	185,261
2045	113429	258794	219,141
2046	125280	285834	251,395
2047	135157	308367	281,477
2048	142894	326019	308,441
2049	148440	338674	331,686
2050	228558	521467	535,234
TOTAL		3179755	2 700,557

Table 23: Scenario 3- Annual CO_2 emissions avoided and economical valuation

SCENARIO 3 – Planned break-up			
Year	**Number of HP installed**	**Avoided ton of CO2 per year [tCO_2]**	**Value of CO_2 emissions avoided [$M€_{2024}$]**
2025	11427,9	26073	5,52
2026	22855,8	52147	11,15
2027	34283,7	78220	19,33
2028	45711,6	104293	29,24
2029	57139,5	130367	40,89
2030	68567,4	156440	50,18
2031	79995,3	182514	69,40
2032	91423,2	208587	86,26
2033	102851,1	234660	104,85
2034	114279	260734	125,18
2035	125706,9	286807	143,51
2036	137134,8	312880	171,04
2037	148562,7	338954	196,58
2038	159991	365027	223,85
2039	171419	391101	252,86
2040	182846	417174	281,00
2041	194274	443247	316,08
2042	205702	469321	350,29
2043	217130	495394	386,24
2044	228558	521467	423,92
2045	228558	521467	441,57
2046	228558	521467	458,64
2047	228558	521467	476,00
2048	228558	521467	493,35
2049	228558	521467	510,71
2050	228558	521467	535,23
TOTAL		8604212	6 202,85

Appendix 10: Annual government balance from heat pump subsidies and gas surcharges

This table shows the net annual budgetary balance for the government resulting from its policy of supporting the adoption of heat pumps. These costs and benefits represent a transfer and do not actually affect overall welfare. Subsidies and surcharges affect the distribution of value between actors, but not overall efficiency or societal benefit.

On the expenditure side, public spending comes from subsidies granted to households switching from gas to heat pumps. The net public balance is the difference between these two flows.

$$\begin{aligned}&\text{Net public balance}_t\\&\qquad= (\text{Additional surcharges on gas}_t \times \text{Distributed volume}_t \times 1000)\\&\qquad- (\text{Subsidy policy in place}_t \times \text{Households enjoying subsidies}_t)\end{aligned}$$

Table 24: Scenario 1 - Annual public balance (2025–2050)

SCENARIO 1 – Baseline					
Year	**Subsidy policy in place**	**Households enjoying subsidies**	**Additional surcharges on gas [€$_{2024}$/kWh]**	**Distibuted volume [MWh]**	**Total**
2025	1800	0	0	2633674	-1570610
2026	1800	0	0	2852958	-1390522
2027	0	0	0	2922723	-1212572
2028	0	0	0	2982667	-1036760
2029	0	0	0	3031270	-863087
2030	0	0	0	3066876	-691552
2031	0	0	0	3087727	-522156
2032	0	0	0	3092017	-354898
2033	0	0	0	3077967	-189778
2034	0	0	0	3043939	-26797
2035	0	0	0	2988577	134046
2036	0	0	0	2910987	292751
2037	0	0	0	2810929	449317
2038	0	0	0	2689022	603745
2039	0	0	0	2546914	674574
2040	0	0	0	2387402	512905
2041	0	0	0	2214440	4079823
2042	0	0	0	2033025	3843133
2043	0	0	0	1848927	3586791
2044	0	0	0	1668299	3325157
2045	0	0	0	1497202	3073047
2046	0	0	0	1341120	2844544
2047	0	0	0	1204554	2651969
2048	0	0	0	1090750	2505151
2049	0	0	0	1001597	2411092

2050	0	0	0	937684	0

Table 25: Scenario 2 - Annual public balance (2025–2050)

SCENARIO 2 – Gradual phase-out					
Year	**Subsidy policy in place**	**Households enjoying subsidies**	**Additional surcharges on gas [€$_{2024}$/kWh]**	**Distibuted volume [MWh]**	**Total**
2025	3000	1257	0,00084018	2619189	-1570610
2026	3000	1257	0,00091399	2604703	-1390522
2027	3000	1257	0,00098781	2590218	-1212572
2028	3000	1257	0,00106162	2575733	-1036760
2029	3000	1257	0,00113543	2561248	-863087
2030	3000	1257	0,00120924	2546763	-691552
2031	3000	1257	0,00128305	2532277	-522156
2032	3000	1257	0,00135687	2517792	-354898
2033	3000	1257	0,00143068	2503307	-189778
2034	3000	1257	0,00150449	2488822	-26797
2035	3000	1257	0,00157830	2474337	134046
2036	3000	1257	0,00165212	2459851	292751
2037	3000	1257	0,00172593	2445366	449317
2038	3000	1257	0,00179974	2430881	603745
2039	3000	1257	0,00187355	2372917	674574
2040	3000	1257	0,00194736	2199955	512905
2041	0		0,00202118	2018540	4079823
2042	0		0,00209499	1834442	3843133
2043	0		0,00216880	1653814	3586791
2044	0		0,00224261	1482717	3325157
2045	0		0,00231642	1326634	3073047
2046	0		0,00239024	1190069	2844544
2047	0		0,00246405	1076265	2651969
2048	0		0,00253786	987112	2505151
2049	0		0,00261167	923199	2411092
2050	0		0,00268548	0	0

Table 26: Scenario 3 - Annual public balance (2025–2050)

SCENARIO 3 – Planned break-up					
Year	**Subsidy policy in place**	**Households enjoying subsidies**	**Additional surcharges on gas [€$_{2024}$/kWh]**	**Distibuted volume [MWh]**	**Total**
2025	5000	11427,9	0,004201	2501990	-46628856
2026	5000	11427,9	0,004570	2370306	-46307262
2027	5000	11427,9	0,004939	2238623	-46082867
2028	5000	11427,9	0,005308	2106939	-45955669
2029	5000	11427,9	0,005677	1975255	-45925671
2030	5000	11427,9	0,006046	1843572	-45992870
2031	0	0	0,006415	1711888	10982232
2032	0	0	0,006784	1580204	10720635
2033	0	0	0,007153	1448521	10361840
2034	0	0	0,007522	1316837	9905847
2035	0	0	0,007892	1185153	9352655
2036	0	0	0,008261	1053470	8702265
2037	0	0	0,008630	921786	7954676
2038	0	0	0,008999	790102	7109889
2039	0	0	0,009368	658418	6167904
2040	0	0	0,009737	526735	5128720
2041	0	0	0,010106	395051	3992338
2042	0	0	0,010475	263367	2758757
2043	0	0	0,010844	131684	1427978
2044	0	0	0	0	0
2045	0	0	0	0	0
2046	0	0	0	0	0
2047	0	0	0	0	0
2048	0	0	0	0	0
2049	0	0	0	0	0
2050	0	0	0	0	0

Appendix 11: Methodology for calculating overall net well-being

Annual welfare is calculated as the sum of consumer surplus, stranded asset costs, the value of avoided CO_2 emissions, and the government's financial balance. Since all components are expressed in constant euros, the total welfare is discounted at a 4% interest rate.

Table 27: Scenario 1 – Net Welfare (2025-2050) [M€]

SCENARIO 1 - Baseline					
Year	**Consumer surplus [M€$_{2024}$]**	**Stranded assets [M€$_{2024}$]**	**Value of CO_2 emissions avoided [M€$_{2024}$]**	**Annual public balance [M€$_{2024}$]**	**Net welfare [M€]**
2025	58,41		0	0	58,41
2026	48,95		0	0	47,06
2027	39,02		0	0	36,08
2028	28,42		0	0	25,27
2029	16,80		0	0	14,36
2030	4,33		0	0	3,56
2031	-8,79		0	0	-6,94
2032	-22,46		0	0	-17,07
2033	-36,52		0	0	-26,69
2034	-50,78		0	0	-35,68
2035	-65,01		0	0	-43,92
2036	-78,93		0	0	-51,27
2037	-92,29		0	0	-57,65
2038	-109,61		10,53	0	-59,51
2039	-130,78		31,53	0	-57,32
2040	-152,66		55,91	0	-53,72
2041	-174,92		84,81	0	-48,11
2042	-197,19		115,97	0	-41,69
2043	-219,05		149,03	0	-34,57
2044	-240,14		182,93	0	-27,15
2045	-260,10		216,71	0	-19,80
2046	-278,67		248,87	0	-13,07
2047	-295,64		278,86	0	-7,08
2048	-310,93		305,73	0	-2,11
2049	-324,51		328,88	0	1,70
2050	-263,17	-713,71	535,23	0	-236,08
TOTAL					-695,002

Table 28: Scenario 2 – Net Welfare (2025-2050) [M€]

SCENARIO 2 – Gradual phase-out					
Year	**Consumer surplus [M€2024]**	**Stranded assets [M€2024]**	**Value of CO_2 emissions avoided [M€2024]**	**Annual public balance [M€2024]**	**Net welfare [M€]**
2025	29,94		0,61	-1,57	28,98
2026	17,32		1,23	-1,39	16,50
2027	5,30		2,13	-1,21	5,74
2028	-6,38		3,22	-1,04	-3,74
2029	-18,11		4,50	-0,86	-12,37
2030	-29,80		5,52	-0,69	-20,52
2031	-41,34		7,63	-0,52	-27,05
2032	-52,79		9,49	-0,35	-33,18
2033	-64,16		11,53	-0,19	-38,59
2034	-75,44		13,77	-0,03	-43,35
2035	-86,64		15,79	0,13	-47,78
2036	-97,76		18,81	0,29	-51,09
2037	-108,81		21,62	0,45	-54,17
2038	-119,78		24,62	0,60	-56,79
2039	-132,89		33,38	0,67	-57,07
2040	-151,70		57,84	0,51	-51,83
2041	-172,70		86,85	4,08	-43,66
2042	-194,11		118,11	3,84	-37,04
2043	-215,14		151,26	3,59	-29,76
2044	-235,59		185,26	3,33	-22,31
2045	-254,95		219,14	3,07	-14,94
2046	-272,96		251,40	2,84	-8,21
2047	-289,44		281,48	2,65	-2,24
2048	-304,30		308,44	2,51	2,70
2049	-317,54		331,69	2,41	6,46
2050	-451,63	-713,71	535,23	0,00	236,36
TOTAL					- 813,67

Table 29: Scenario 3 – Net Welfare (2025-2050) [M€]

SCENARIO 3 – Planned break-up					
Year	**Consumer surplus [M€$_{2024}$]**	**Stranded assets [M€$_{2024}$]**	**Value of CO_2 emissions avoided [M€$_{2024}$]**	**Annual public balance [M€$_{2024}$]**	**Net welfare [M€]**
2025	5,10		5,52	-46,63	-36,01
2026	-9,33		11,15	-46,31	-42,77
2027	-23,72		19,33	-46,08	-46,66
2028	-38,06		29,24	-45,96	-48,69
2029	-52,35		40,89	-45,93	-49,05
2030	-66,59		50,18	-45,99	-51,29
2031	-81,81		69,40	10,98	-1,13
2032	-98,78		86,26	10,72	-1,37
2033	-115,67		104,85	10,36	-0,34
2034	-132,49		125,18	9,91	1,82
2035	-149,23		143,51	9,35	2,45
2036	-165,88		171,04	8,70	9,00
2037	-182,45		196,58	7,95	13,79
2038	-198,92		223,85	7,11	19,24
2039	-215,30		252,86	6,17	25,25
2040	-231,58		281,00	5,13	30,29
2041	-247,76		316,08	3,99	38,61
2042	-263,83		350,29	2,76	45,80
2043	-279,79		386,24	1,43	53,25
2044	-185,59		423,92	0	-88,18
2045	-199,15		441,57	0	110,63
2046	-212,72		458,64	0	107,92
2047	-226,28		476,00	0	105,37
2048	-239,84		493,35	0	102,86
2049	-253,40		510,71	0	100,38
2050	-263,17	-713,71	535,23	0	102,05
TOTAL					503,221

UNIVERSITÉ CATHOLIQUE DE LOUVAIN
Louvain School of Management

Place des Doyens, 1 bte L2.01.01, 1348 Louvain-la-Neuve
Boulevard Emile Devreux 6, 6000 Charleroi, Belgique
Chaussée de Binche 151, 7000 Mons, Belgique

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