# STRATEGIC ENERGY INVESTMENTS AND CLIMATE POLICY IN A SMALL ECONOMY

Renata Slabe-Erker*, Miha Dominko, Kaja Primc, Darja Zabavnik

Institute for Economic Research, Kardeljeva ploscad 17, 1000 Ljubljana, Slovenia

**Abstract**

*Addressing climate change and advancing toward the European Union's climate neutrality goal by 2050 requires innovative energy investments and policies. Addressing the dual challenges of climate change and economic sustainability, this study evaluates the macroeconomic and sectoral impacts of strategic energy investments. The analysis focuses on Slovenia, a small open economy within the European Union, comparing the Energy Transition (ET) scenario to business-as-usual (BAU) scenario. The ET scenario focuses on a diverse mix of renewables, advanced nuclear technologies, and energy efficiency measures. The study applies macroeconomic methodologies with a dataset calibrated to reflect the economy's structure in a base year (2019), capturing detailed interactions between sectors and economic agents. It assumes that all agents optimize their behavior within resource constraints.*

*Results indicate significant reductions in carbon emissions, with a 35% decrease by 2030 and nearly 72% by 2040 compared to 2005 levels. Economic growth under the ET scenario is enhanced, with GDP projected to be 1.36% higher by 2050 and overall investments increasing by 3.9%. The transition drives substantial sectoral growth, notably in transport (13.1%) and construction (8.7%) by 2050, supported by expanded public transit and infrastructure investment. The importance of cross-sectoral strategies, such as workforce development and regulatory incentives, is highlighted to align infrastructure expansion with decarbonization goals. This analysis demonstrates how balanced green growth strategies can drive sustainable economic and environmental benefits, paving the way for a resilient energy future. The contribution of this work lies in demonstrating the critical role of quantitative models in assessing the broader economic impacts of energy and climate policies, offering valuable insights to policymakers, researchers, and stakeholders.*

**Keywords:** *energy transition scenario, low-carbon energy, investments, macroeconomic impacts, sectors*

## 1. INTRODUCTION

Climate change represents one of the most pressing global challenges of our time, demanding urgent and coordinated action across all levels of governance and sectors of the economy (Matthews et al. 2009). The European Union (EU) has taken a leading role in this effort by adopting ambitious targets, including a 55% reduction in greenhouse gas emissions by 2030 and climate neutrality by 2050 (Schlacke et al., 2022). These goals are particularly challenging for smaller, open economies such as Slovenia, which must balance environmental imperatives with economic stability and competitiveness. In this context, strategic energy investments emerge as a critical policy tool, offering a pathway not only to decarbonization but also to broader macroeconomic and structural transformation (McCollum et al., 2018).

This article explores how large-scale investments in low-carbon technologies, including renewable energy, advanced nuclear options, and energy efficiency improvements, can reshape economic trajectories. It highlights the importance of moving beyond aggregate-level analyses, which often overlook complex interdependencies among sectors and economic agents. By applying a computable general equilibrium (CGE) model calibrated to Slovenia's 2019 economic structure, the study captures both the macroeconomic and sector-specific impacts of an ambitious Energy Transition (ET) scenario. The ET scenario is compared to a business-as-usual (BAU) baseline, allowing for an evaluation of the incremental effects of additional clean energy investments.

The study not only estimates reductions in carbon emissions but also provides insights into changes in gross domestic product, employment, prices, and value added across various sectors. Special attention is given to how energy transition investments influence the construction, transport, manufacturing, agriculture, and service sectors—areas that are often insufficiently examined in climate policy literature. By integrating energy, environmental, and economic dimensions, this article aims to inform more holistic and forward-looking policy frameworks, demonstrating how green investment strategies can simultaneously advance sustainability, resilience, and economic prosperity.

## 2. MATERIALS AND METHODS

### *2.1. Materials*

The analysis is based on a dynamic computable general equilibrium (CGE) model tailored for the Slovenian economy. It simulates economic activity under two scenarios: the Business-as-Usual (BAU) baseline and the Energy Transition (ET) scenario with increased energy investments.

The Social Accounting Matrix (SAM) is the most important input data system used to compute the baseline solution of the CGE model, which in turn serves to estimate the macroeconomic and sectoral impacts of various scenarios (Mainar-Causapé et al., 2018). SAM provides a comprehensive data framework for the Slovenian economy. Technically, it is a square matrix—with an equal number of rows and columns—that captures the circular flow of income and expenditure within the economy. Each entry in row $i$ and column $j$ records income for account $i$ and expenditure for account $j$.

SAM summarises the structure of the economy, detailing both domestic and international linkages and highlighting the roles of different actors and sectors. Its structure includes the production account, commodity account, factor accounts, institutional accounts, capital account, and the rest of the world account (Bayar, 2018).

The year 2019 was selected as the base year due to the availability of comprehensive data and because 2020, marked by the disruptions of the COVID-19 pandemic, does not accurately reflect the structure of the Slovenian economy. The SAM for the base year was constructed using supply and use tables as well as input-output tables.

For the scenario analysis, additional data sources were incorporated, including economic growth projections from the EU Reference Scenario 2020, emission coefficients, base year energy prices, and various elasticity parameters. Among the most critical inputs were data on investment levels and.energy efficiency. Under the ET scenario, additional annual investments are expected to average EUR 3.6 billion up to 2030, increasing to EUR 8.0 billion per year in the period from 2030 to 2050.

Energy efficiency is defined as energy consumption (in terajoules) per million EUR of production output. Estimates were based on activity-specific energy consumption data from the REES-SLO model projections. Production outputs were derived from disaggregated quantitative data, which were then aggregated to align with SAM activity classifications and scaled using the growth rates from the EU Reference Scenario. Finally, energy efficiency growth rates, calculated relative to the 2019 baseline, were applied to the SAM for scenario modeling.

### *2.2. Methods*

The macroeconomic impacts of energy investments in Slovenia are evaluated using a CGE model. This model compares the ET scenario, which includes additional investments in a diverse mix of energy sources (renewables and advanced nuclear technologies) and energy efficiency improvements, with a a BAU scenario.

The model is dynamic, covering multiple sectors and households. It assumes that all economic agents (firms, households, government, foreign sector) optimise their behavior within budget constraints, and that all markets operate under the assumption of perfect competition (Bolarinwa, 2024). The core of the impact assessment model is a SAM for the year 2019, which contains data on 21 commodities and 15 sectors.

*2.2.1. Scenario design*

Two scenarios were compared to provide estimates of the impacts of additional energy investments: the BAU scenario, including the existing energy efficiency measures and the ET scenario with additional investments in renewables, advanced nuclear technology and energy efficiency.

The BAU as a benchmark for comparison with the ET scenario brings an overall consistent evolution of economic activities with exogenous projections of the main driving forces. The BAU scenario simulates the sequence of events if all the measures that have already been adopted or implemented are continued. In addition to the existing measures, the ET scenario considers investments or measures still in the preparation stages with a realistic possibility of being implemented on the central, regional or local level.

In the ET scenario, additional annual investments are projected to average EUR 3.6 billion until 2030, rising to EUR 8.0 billion per year from 2030 to 2050. Ramped-up energy investments trigger a major shift towards clean, renewable sources. By 2050, coal, natural gas, and refined oil use see substantial declines. Electrification and synthetic gas rise sharply, spotlighting their pivotal roles compared to the BAU scenario (Table 1) (cf. Keramidas et al., 2020).

| | **Changes in energy use 2030/2021 (index)** | | **Changes in energy use 2050/2021 (index)** | |
|---|---|---|---|---|
| | **BAU scenario** | **ET scenario** | **BAU scenario** | **ET scenario** |
| **Logging** | 92 | 11 | 61 | 86 |
| **Coal** | 97 | 91 | 0 | 0 |
| **Natural gas** | 106 | 94 | 175 | 15 |
| **Coke** | 57 | 48 | 0 | 0 |
| **Refined oil** | 108 | 96 | 91 | 24 |
| **Electricity** | 104 | 108 | 81 | 166 |
| **Synthetic gas** | 101 | 247 | 384 | 2672 |
| **Steam** | 102 | 99 | 96 | 93 |

**Table 1.** Changes in existing energy use (index)

In the ET scenario, emissions are reduced by 35% by 2030 and almost 72% by 2040, compared to 2005 levels (Figure 1).

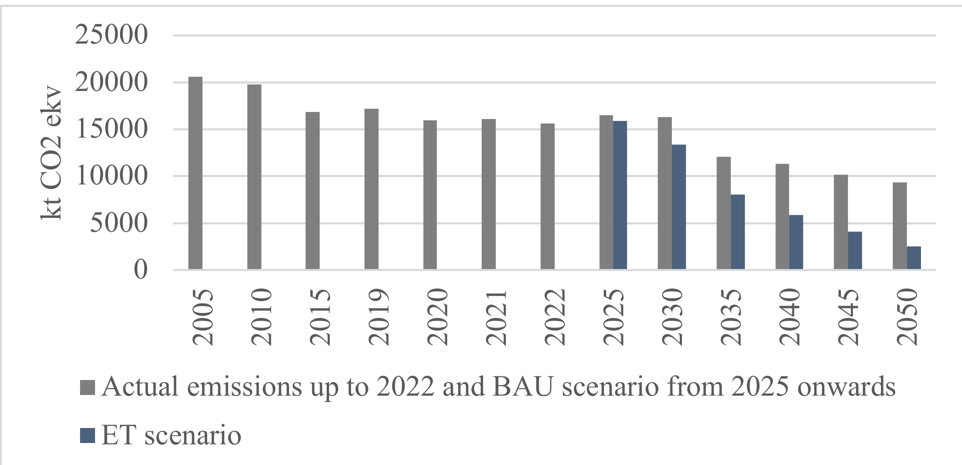


**Fig. 1.** Carbon emissions reduction in the ET scenario and BAU scenario

## 3. RESULTS AND DISCUSSION

The following section presents the macroeconomic results of the ET scenario, which incorporates additional energy investments. These results should be interpreted as the estimated impacts of the planned energy investments relative to the BAU scenario. It is important to emphasize that these estimates do not represent forecasts of the future trajectories of individual macroeconomic indicators. Rather, they reflect the marginal effects of the additional investments, assuming all other factors remain constant, while fully accounting for the complex interdependencies within the economy captured by the model.

The positive impacts of low-carbon energy investments under the ET scenario are evident in GDP, which is projected to be 0.3% higher in 2030 and 1.36% higher in 2050 compared to the BAU scenario (cf. Lyeonov et al., 2019) (Table 2). Stronger economic growth also contributes to higher savings by both households and businesses (Bhat et al., 2021). This increase in aggregate savings translates into a rise in total gross investment, which is expected to be 1.0% higher in 2030 and 3.9% higher in 2050 relative to the BAU scenario (Table 2).

Additional energy investments enhance energy efficiency, leading to a reduction in energy consumption in both intermediate and final uses. Lower energy costs have a favourable effect on labour demand, contributing to a decline in unemployment (-9.9% in 2050 compared to the BAU level). (*cf.* Omarova et al., 2025). The cost savings achieved by businesses can be redirected toward higher wages and salaries, while increased productivity boosts overall economic output.

These improvements also help to reduce relative consumer prices, driven by lower energy costs, reduced upward pressure on the prices of other goods and services, and intensified market competition resulting from technological innovation and lower production costs. As a result, the overall price level is expected to decline slightly under the ET scenario, with consumer prices projected to be 0.3% lower in 2050 compared to the BAU scenario (Table 2).

| Macroeconomic aggregates | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|
| **GDP** | 0.15 | 0.29 | 0.5 | 0.73 | 1.01 | 1.36 |
| **Unemployment rate** | -3.24 | -4.55 | -5.93 | -6.74 | -7.69 | -9.9 |
| **Gross capital formation** | 0.38 | 1.03 | 1.78 | 2.5 | 2.91 | 3.9 |
| **Prices** | -0.31 | -0.36 | -0.43 | -0.35 | -0.26 | -0.32 |

**Table. 2.** Changes in macroeconomic indicators for the ET scenario compared to the BAU scenario (in %).

By 2050, all sectors under the ET scenario show higher value added compared to the BAU scenario. The transport sector records the largest gain, with value added projected to be 13.1% higher in 2050 (Figure 2). This strong performance reflects the sector's close connection to economic growth, particularly in freight transport, which typically expands as the economy grows (Hilferink, 2005). The result is also driven by improvements in energy efficiency, both in vehicles and infrastructure, which lower operating costs for transport providers. Additionally, the growth in rail and public passenger transport contributes significantly to the sector's enhanced performance.

In the construction sector, the gap between the ET and the BAU scenarios widens over time. By 2050, the annual value added in the ET scenario is projected to be 8.7% higher than in the BAU scenario (Figure 2). This increase is primarily driven by infrastructure investments, including the construction of power plants, improvements in the energy efficiency of buildings, and the expansion of transmission networks. These developments lead to a greater volume of construction activity, resulting in higher value added for the sector. Moreover, the construction sector plays an active role in enhancing appliance efficiency and in the replacement of fossil fuel-based technologies, further contributing to its growth and transformation under the ET scenario.

A similar trend is observed in the manufacturing industry as a whole, including the chemical sector, where average annual value added is projected to be 2.7% higher in 2050 under the ET scenario.

In agriculture, the adoption of energy-efficient technologies leads to a significant reduction in energy costs (cf. Li at al., 2025), resulting in a 7.5% increase in value added by 2050 compared to the BAU scenario.

Likewise, services benefit from notable improvements in energy efficiency and new energy sources, achieving the same level of output with lower energy consumption. This reduces operating costs and boosts value added, which is expected to be 5.0% higher in 2050 under the ET scenario relative to BAU.

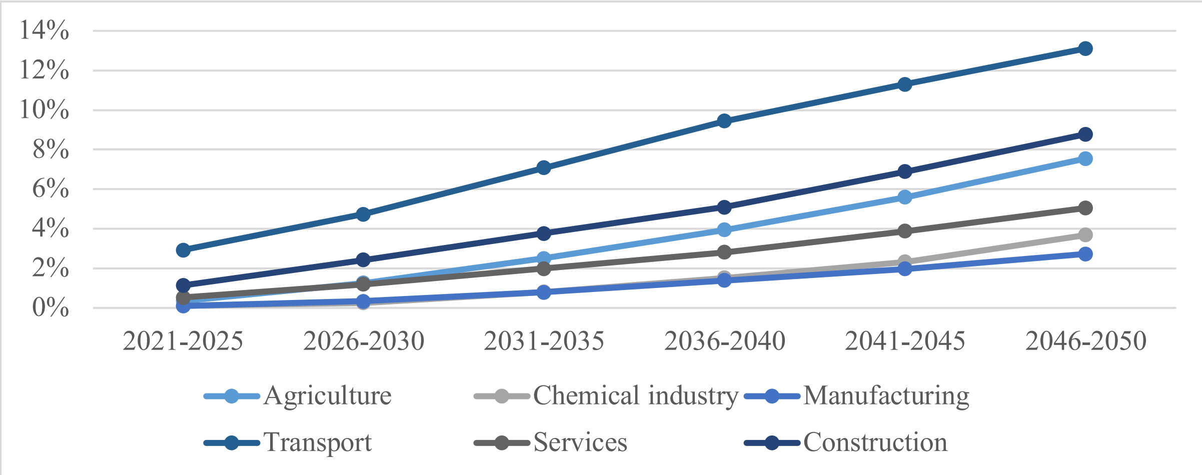


**Fig. 2.** Impacts on sectors: Added value in the ET scenario vs. BAU scenario (in % )

The ET scenario leads to a substantial reduction in fossil fuel dependence, while simultaneously driving up the demand for metals essential for the development of modern energy infrastructure. This shift is primarily the result of the transition to alternative energy sources, the implementation of energy efficiency measures, and the electrification of transport, including a significant expansion of public transit systems. At the same time, the scenario contributes to a marked decline in the demand for petroleum products, reflecting structural changes in energy consumption patterns across sectors (Table 3).

| **Homogeneous product group** | **Domestic demand (2030/2050)** | **Intermediate demand (2030/2050)** | **Import (2030/2050)** |
|---|---|---|---|
| **Paper** | ☹/☹ | ☹/☺ | ↓/↑ |
| **Refined petroleum** | ☹/☹ | ☹/☹ | ↓/↓ |
| **Chemicals** | ☹/☺ | ☹/☺ | ↓/↑ |
| **Non-metallic mineral products** | ☺/☺ | ☺/☺ | ↑/↑ |
| **Metal products** | ☺/☺ | ☺/☺ | ↑/↑ |

**Table 3.** Effects on homogeneous product groups in the ET scenario vs. BAU scenario (2030, 2050)

## 4. POLICY IMPLICATIONS AND CONCLUSION

This study offers a valuable contribution to the broader understanding of how strategic energy investments can influence macroeconomic performance and sectoral development paths in small open economies. While much of the existing literature relies on partial models that isolate specific sectors or markets, this analysis employs a CGE model, enabling a holistic, economy-wide perspective. This approach captures the complex inter-sectoral dynamics and behavioral responses that arise from large-scale energy transitions, an essential consideration for policy design and long-term planning.

A key strength of this study lies in its focus on meso-level impacts, which remain relatively underexplored. By examining sector-specific outcomes, the analysis provides a nuanced view of how different areas of the economy respond to the introduction of low-carbon energy investments. These insights are particularly relevant for aligning climate goals with industrial strategy, regional development, and labor market policies.

The findings from the ET scenario are both environmentally and economically significant. Notably, the scenario achieves a 72% reduction in carbon emissions by 2040, relative to 2005 levels—an ambitious target aligned with broader climate commitments. At the same time, it triggers a fundamental reconfiguration of energy use patterns. Reliance on fossil fuels, including coal, natural gas, and refined petroleum, is substantially curtailed, while electrification and the use of synthetic gases emerge as core elements of the future energy system. This transformation also leads to a surge in demand for industrial metals, reflecting the infrastructure-intensive nature of clean energy deployment and technological modernization.

Beyond environmental and structural impacts, the study emphasizes the importance of integrating energy investment strategies with workforce development, innovation, and infrastructure planning. The results highlight how a diversified energy investment portfolio, supported by coherent regulatory frameworks and targeted fiscal incentives, can enhance a country's economic resilience, strengthen energy security, and boost long-term competitiveness. These insights serve as a call to action for policymakers to adopt integrated, forward-looking approaches that align decarbonization efforts with sustainable economic transformation.

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