Overview
Carbon pricing has gained a lot of traction in recent years, either in the form of national carbon prices or emission trading schemes [1]. Currently, the EU is developing the EU ETS 2, which will include the building and transport sector [2], while Germany has introduced its own carbon pricing scheme for these sectors in 2021 [3]. The level of carbon pricing to achieve the climate targets are a topic of ongoing discussions. Energy Systems Models can be used to assess the effect of different carbon price paths [4–6]. However, when assessing the effects of policy measures such as carbon pricing, the model architecture and the role of the foresight of the model should be taken into account [7]. Analysis of different CO₂-price paths under different levels of foresights show that perfect foresight models might overestimate the effect of CO₂-prices on the decarbonization of the energy system.

Method
To analyze the effectiveness of carbon prices, the TIMES PanEU energy systems model is used. TIMES PanEU is a technology rich, bottom-up, linear optimization model that includes all relevant energy sectors for the EU27, Switzerland, Norway and the UK [8]. The model solves milestone-years every 5 years until 2050. The model typically is solved under perfect foresight (PF), meaning the model knows all parameters in advance, but can be switched to a time-stepped or myopic solution, where the so-called myopic window determines the length of model foresight. CO₂-price-paths are implemented for all sectors, the global discount rate is set to 5% and the prices for fossil fuel inputs are chosen from the WEO 2022, APS Scenario [9]. The focus of this analysis is on the buildings and transport sector, as the majority of investment decisions in these sectors are made by private households, which might not have a lot of knowledge about energy policies or future carbon prices [10]. No additional policy measures are considered besides the CO₂-price. The results are analyzed as a case study of the building and transport sector in Germany. Three different price paths (low, medium, high) are implemented with either perfect foresight or myopia (_myo) with a myopic window of 10 years (Table 1). The results are compared to a reference scenario, which achieves carbon neutrality in Germany by 2045 (ref).

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<tr>
<th>Scenario</th>
<th>€2020/t CO₂</th>
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<tr>
<td></td>
<td>2020</td>
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<td>low</td>
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<td>medium</td>
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<td>high</td>
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Results
When comparing the scenario results under myopia and perfect foresight, it becomes clear that under myopia, the intended effect of CO₂-prices (reducing CO₂-emissions) is smaller over the whole timeframe. Especially in the early period, the myopic scenarios delay investment in climate-neutral technologies, and fail to catch up once CO₂-prices rise. Under myopia, the model avoids long-term investments with high investment costs that will pay off later, and opts for technologies with lower investment, but higher operation costs. In the case of medium and especially high CO₂-prices in later periods, the model then tries to decarbonize as fast as possible, but has to rely on more expensive technologies like e-fuels to make up for the delayed investments. Thus, total system costs
also increases under myopia. In addition, the cumulative CO\textsubscript{2}-emissions over the whole timeframe increase by 6-17%.

Figure 1 shows the CO\textsubscript{2}-emission pathways of the buildings sector in Germany for different scenarios. Under perfect foresight, the high CO\textsubscript{2}-price path is almost able to reduce the CO\textsubscript{2}-emissions to the levels that would be required if the reference scenario is seen as a relevant benchmark to reach the german climate targets in this sector. However, under myopia, emissions are significantly higher. The same effect can be observed with the medium and low CO\textsubscript{2}-price path.

![Figure 1: Development of CO\textsubscript{2}-emissions in the german buildings sector for the different scenarios.](image)

Similar effects can also be observed in the transport sector, where the failure to invest in fossil free propulsion technology in time (e.g. BEV or fuel-cell vehicles) requires the model to use e-Fuels in later periods, while overall CO\textsubscript{2}-emissions under myopia are significantly higher. These effects also extend to the installment of renewable energies or electrolyzers, as well as a delay in investment in electricity, hydrogen or district heat grids under myopia.

**Conclusions**

The results of the scenario analysis shows that the effect of CO\textsubscript{2}-prices on the decarbonization of the energy system are much higher under perfect foresight then under myopia. This hints at a possible overestimation of the usefulness of CO\textsubscript{2}-pricing using models with perfect foresight. Therefore, effects such as myopia should ideally be taken into account when using energy systems models to determine the effectiveness of policy measures. Otherwise, implemented CO\textsubscript{2}-prices could not yield the expected CO\textsubscript{2}-emissions reductions. If myopia of decision makers is assumed, especially low CO\textsubscript{2}-prices in the early periods (until 2030) cause a big delay in the ramp-up of technologies such as electric vehicles or heat pumps. This would hint at the practicality of rising CO\textsubscript{2}-prices early on (in contrast to the proposed price mechanisms in the EU ETS 2) and of communicating the expected rise of CO\textsubscript{2}-prices and its consequences to the public effectively and transparently, so that short-sighted (= myopic) investment decisions can be avoided. In this paper, only carbon pricing has been considered, however an effective policy mix would ideally combine regulations and taxation to generate better outcomes. Depending on the policy measure, myopia of decision makers might still represent a hurdle for the effectiveness of climate policy, and thus requires more thorough examination in energy system models.

**References**


