Impact of Residual Emissions from Non-CO_2 Sources on Greenhouse Gas-neutral Energy Systems

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Motivation and objectives

Many energy system models, such as in Hofmann et al. [1], analyze transformation strategies for European energy systems, but only model CO_2 emissions and neglect other greenhouse gases such as CH_4 or N_2O from sectors like agriculture in their emission balance. This could potentially lead to energy system designs which fail to achieve the set climate targets, as the majority of residual emissions of greenhouse gas-neutral energy systems is likely originating from agriculture [2]. Furthermore, the sector Land Use, Land-use Change and Forestry (LULUCF) is typically not included in energy system models, while significant carbon removal is expected from it in the future [3]. Thus, this work analyzes the impact of residual emissions from non-CO_2 emission sources and the LULUCF sector on national energy system transformations, using Germany as a case study.

Methodology

In this work we use the integrated energy system model ETHOS.NESTOR [4] which depicts the entire German energy system with its sectors energy supply, industry, buildings and mobility. Additionally, the optimization model includes non-CO_2 emission sources and the LULUCF sector as exogenous emission pathways in the emission balance. To assess the uncertainty of the future development of emissions in these sectors, we develop a range of scenarios, ranging from pessimistic scenarios with high emissions to optimistic scenarios, in which negative emissions are provided via the exogenous emission pathways.

Results and conclusions

Our optimization results for the year 2045, in which Germany becomes greenhouse gas-neutral, show that in the pessimistic scenario residual emissions of 166 Mt CO_2eq lead to a 6.8% increase in system costs compared to the reference scenario with zero residual emissions (see Fig. 1). In this scenario, around 200 Mt CO_2 need to be permanently stored in geological formations each year, with more than 90% of that being negative emissions to offset the residual emissions from agriculture and LULUCF. In contrast, 58 Mt CO_2eq of negative emissions in the optimistic scenario result in 3.2% lower system costs compared to the reference scenario and make permanent CO_2 storage unnecessary. Furthermore, the residual emissions significantly affect electricity demand, varying between 1067 (optimistic) to 1412 TWh (pessimistic), and installed capacities of wind energy, ranging from 313 to 437 GW. This shows that emissions from agriculture and LULUCF have a significant impact on the transformation of the energy system towards greenhouse gas-neutrality and should be included in energy system models.

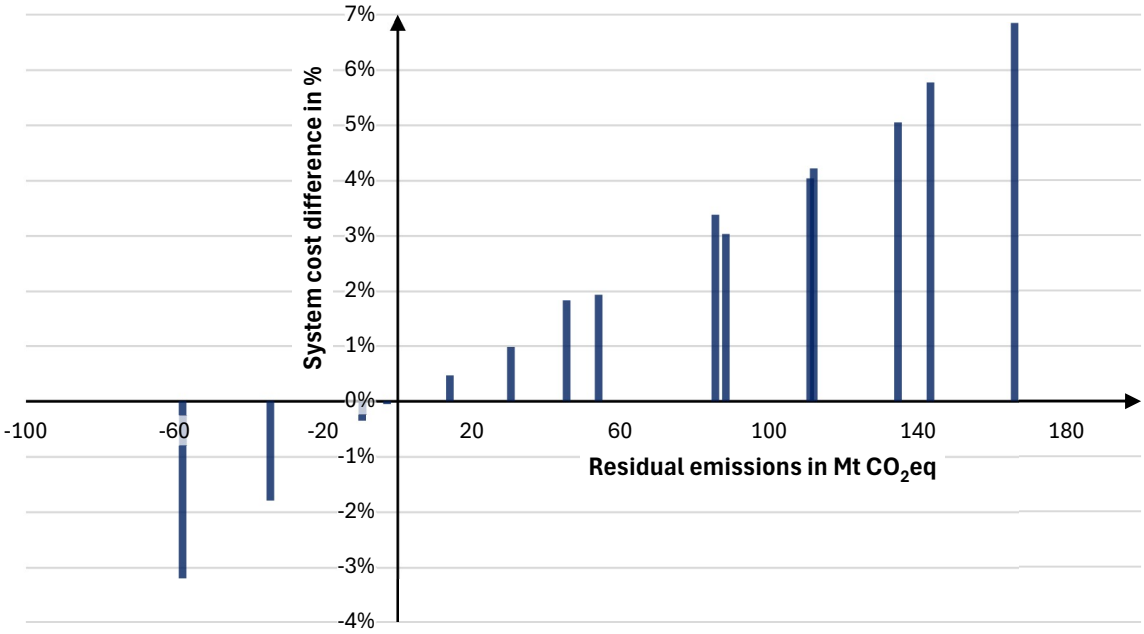

Fig. 1: Impact of residual emissions from agriculture, non-CO_2 sources and the LULUCF-sector on energy system costs in the year 2045

References

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