154

The role of nuclear (in-)flexibility in the transition towards climate-neutral power systems.

Natalia Goryashchenko, Jonas Egerer, Julia Grübel, Veronika Grimm
UTN, Nürnberg, Germany

Extended Abstract

Download file

Abstract Summary

Achieving climate neutrality requires a profound transformation of electricity systems. In the European Union, nuclear power accounts for approximately 98 GW of installed capacity and around 23% of total electricity generation. Despite the rapid expansion of variable renewable energy sources (VRES), nuclear energy is expected to remain an important component of the electricity mix in several countries. This raises the question of how existing nuclear capacity should be operated and integrated into future low-carbon systems, particularly as flexibility becomes increasingly important.

This paper evaluates the system value of nuclear power under different operational flexibility assumptions. We analyze how nuclear flexibility affects capacity expansion, system operation, and market outcomes, explicitly accounting for existing nuclear infrastructure and sunk costs.

We develop a mixed-integer optimization model of a stylized energy system combining investment decisions with unit commitment constraints. The model captures key operational features of nuclear plants, including load-following and temporary shutdowns, while representing other technologies—such as VRES, gas generation, storage, and hydrogen—within a linear framework. Hydrogen demand is modeled as a flexible electricity load.

Results show that nuclear flexibility significantly alters system-wide investment, generation, and price dynamics, particularly at higher nuclear penetration and elevated hydrogen demand. Flexible operation enables greater deployment and utilization of wind and solar power while reducing the need for alternative flexibility options such as storage and peaking generation. It also dampens extreme price fluctuations under high CO_2 prices.

At the plant level, flexibility improves profitability by allowing reactors to avoid low-price periods, although these benefits decline at high nuclear penetration due to market value

cannibalization. Overall, the findings highlight that assumptions about nuclear flexibility strongly influence optimal investment pathways in decarbonized power systems.

Presenting Author Biography

Natalia Goryashchenko is a researcher at the Energy Systems and Market Design Lab at the University of Technology Nuremberg (UTN), Germany. Her research focuses on energy system modeling, electricity market design, and the integration of low-carbon technologies in decarbonizing power systems. In her work, she develops optimization models to analyze the role of flexibility, nuclear energy, and hydrogen in the transition towards climate-neutral energy systems.