# Powering Down Nuclear: A Multidimensional Impact Evaluation of the German Case

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## Extended Abstract

## 1 Policy Background and Literature

On April 15$^{th}$ 2023, the last three German nuclear reactors stopped, marking the end of the nuclear power phase-out initiated 12 years ago. Indeed, Germany adopted the 13$^{th}$ Atomic Energy Act in 2011, which plans the phase-out of nuclear power by 2022. It establishes the immediate and permanent shutdown of half of the country's nuclear reactors and the gradual closure of the remaining ones. This policy is exogenous as it follows the Fukushima nuclear accident and a political setback for the government in the context of anti-nuclear German public opinion. Moreover, the phase-out is unlikely to be anticipated by agents considering the multiple back and forths in the country's nuclear policy in recent years. Many countries have already decided on a phase-out - Belgium, Germany, Italy, South Korea, Spain, Sweden, and Switzerland, for instance - and globally, more nuclear power reactors have closed than opened in recent years, even if the overall generation capacity has increased. Such ambitious energy transitions raise public concerns regarding their unintended consequences, concerns that can, in turn, affect their political acceptance. Empirical work assessing the effects of large-scale

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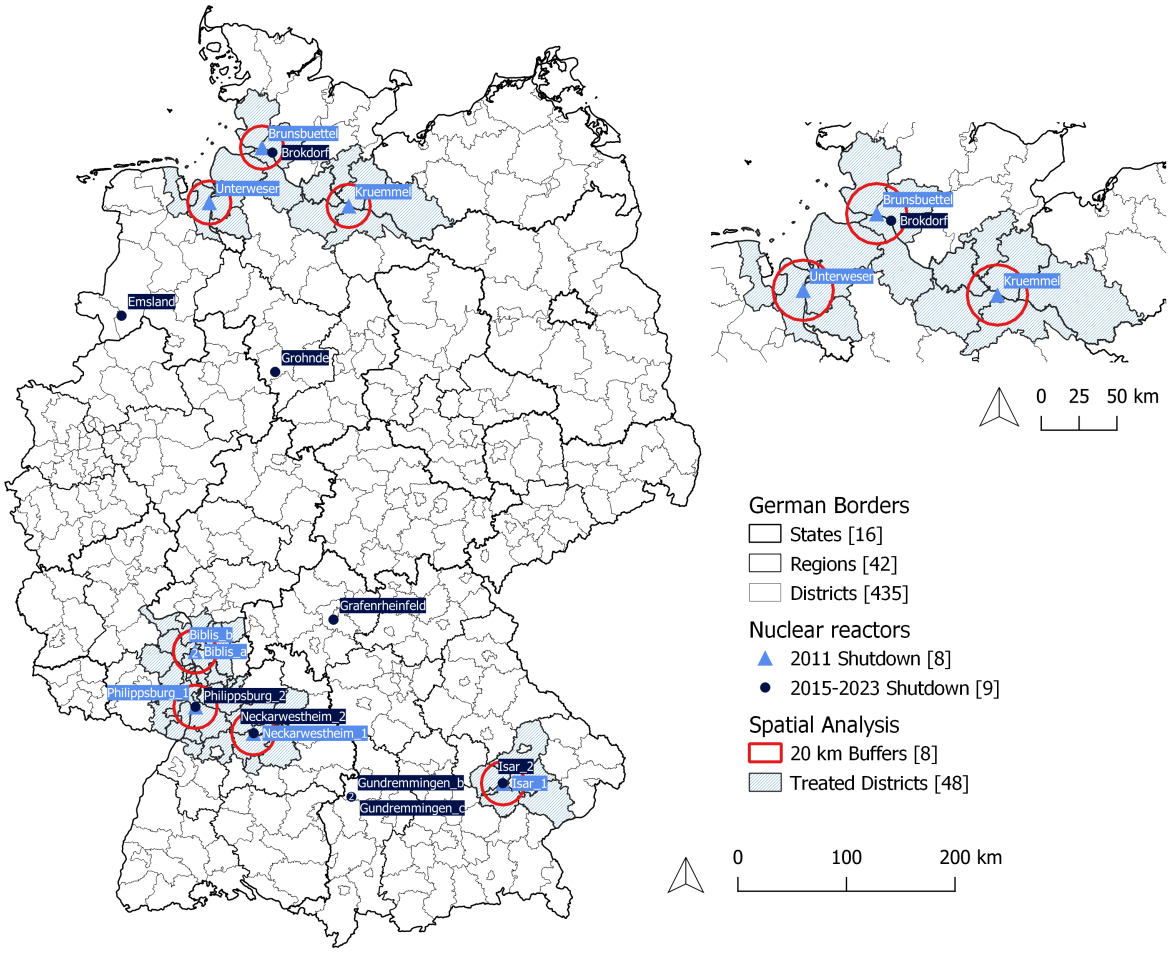
nuclear shutdowns can address these concerns and help design fair and efficient energy policies.

Hence, this paper links the impact assessment literature of energy transitions with labour and urban economic research studying the local consequences of mass layoffs. vom Berge and Schmillen (2023) enters the second category and finds that local spillovers lessen the direct effect of significant dismissals on municipal labour markets. Yet, sectoral characteristics of the energy and nuclear industry might cause different patterns. Part of the first category, Davis (2011) quantifies the housing-market consequences of nuclear reactors opening in the United States and de Faria et al. (2017) evaluate the social impacts of hydropower development in Brazil. They both assess the local socio-economic consequences of energy transitions but focus on power plant commissioning instead of closure. Rud et al. (2022) is at the crossroads of the two literature, studying the phasing-out of coal in the United Kingdom and the resulting job displacement. Again, a nuclear shutdown may display particular features, considering its highly-skilled workforce and differences in risk perception. To my knowledge, few studies evaluate the impacts of nuclear closures. Davis and Hausman (2016) and Severnini (2017) estimate how small-scale, sometimes temporary, nuclear shutdowns affect the US electricity market and air pollution. The German nuclear phase-out is a national energy transition, a policy of an entirely different level. Some authors investigate this ambitious German measure, including Traber and Kemfert (2012), Bruninx et al. (2013) and Knopf et al. (2014) using *ex-ante* evaluation with mixed economic-engineering models, and *ex-post* employing quasi-experimental and machine learning approaches as Grossi, Heim, and Waterson (2017) and Jarvis, Deschênes, and Jha (2022). However, they focus on national energy markets and air pollution consequences. This previous research shows that the phase-out entails a significant transformation of the German energy market, with considerable changes in the electricity mix, trade and prices. There is a consensus on the primarily increased resort to fossil fuels, the resulting air pollution, and the rise of net power imports and wholesale electricity prices. Hence, the socio-economic impacts of the German nuclear shutdown seem overlooked in the economic literature. Yet, since the nuclear power sector employs a significant labour force, there might be "direct", "induced" and "indirect" employment effects from the shutdown. Indeed, according to Alexeeva et al. (2018), total employment in the nuclear energy industry represents about 200,000 labour years over the life cycle of a gigawatt of nuclear-generating capacity for a given country. As underlined by Chay and Greenstone (2005) and Currie et al. (2015), air pollution can also negatively influence real-estate market value, and thus, the policy

may have real-estate fallouts as well. Coulomb and Zylberberg (2021) and Bauer, Braun, and Kvasnicka (2017) estimate how the Fukushima accident decreased real-estate prices in the neighbourhood of nuclear power plants in the United Kingdom and Germany, respectively. The first paper studies the impact on housing prices through a variation in risk perception. While the other attributes the effect to adverse economic conditions rather than changes in local amenities. The former accounts for sale values only, and both papers primarily assess the impact of the Fukushima accident rather than the nuclear phase-out *per se*.

# 2 Data and Empirical Strategy

Figure 1: Spatial Analysis



I contribute to this literature by quantifying the overlooked local socio-economic impacts of the nuclear phase-out in Germany. I study the consequences of this ambitious energy transition on labour, health and housing outcomes. Thus, I exploit a rich multidisciplinary panel data set at the district scale, the GSOEP (German Socio-Economic Panel 2022), of 30,000 individuals, between 2006 and 2014. I use Difference-in-Differences, coupled with spatial analysis, to compare changes in outcomes before and after the phase-out between treated districts near a closed nuclear reactor; and control districts further away. In particular, I focus on the 2011 initial shutdown for which individuals have no time to prepare. To test for the "Parallel Trend Assumption" and determine the timing and longevity of the impacts, I also compute a panel event study. I consider two types of local effects: the "direct" local effect on energy workers employed in the districts of the closed nuclear power plants, and the "induced" local effect on the surrounding localities whose economic activity heavily relies on those power plants. To disentangle the two, I perform a heterogeneous analysis by industry, contrasting outcomes between the energy sector and the others.

# 3 Results and Conclusions

I observe no local effect of the German nuclear phase-out on the energy labour supply at the extensive margin (on the total number of workers). Yet, I find a significant, sizeable and persistent increase at the intensive margin (on the hours worked per worker), with the corresponding growth in wages and loss in public transfers. The energy industry largely drives this result, corresponding to a positive "direct" local effect on labour. I see two potential mechanisms for these findings: (1) the dismantling of the nuclear power plants; (2) the adjustments required in the energy industry to compensate for the loss in electricity generation and changes in electricity supply. On the contrary, I get a negative "induced" impact on the other local economic activities revolving around the nuclear power plants *via* a rise in self-employment. These precarious work conditions may stem from the adaptive behaviour of local businesses to economic uncertainty, reflecting their concerns for the future district's dynamism and attractiveness following the sudden shutdown. I obtain a significant change in self-rated health, life and health satisfaction in treated districts after the phase-out, but no variation in the number of visits to the doctor or hospital, suggesting a psychological health impact. Again, I find a positive "direct" effect on energy workers, possibly explained by the beneficial employment outcomes. Energy employees also probably feel safer with the cessation of nuclear power generation. Workers in other

industries suffer from psychological health degradation, consistent with unfavourable employment results. This negative "induced" effect corroborates the "anxiety with respect to uncertainty" channel. Finally, I observe no statistically significant effect of the nuclear power plant closure on income from rental and leasing in affected districts. Nonetheless, my estimates suggest a trade-off between energy workers, positively impacted, and the rest of the local population, on the losing side, regarding employment and health outcomes of the 2011 German nuclear phase-out.

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