100 % Renewables in Germany's Electricity Mix by 2035? Neither a Realistic, nor a Desirable Outcome

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To achieve its ambitious goal of becoming climate neutral in 2045, Germany has set an even more ambitious goal for its electricity sector: Already by 2035, Germany strives to cover its electricity consumption almost entirely by renewable technologies. With a current share of renewables in electricity consumption of about 55%, we argue that the 2035 goal would be both overly ambitious and a suboptimal outcome.

When economists or engineers talk about mathematical optimization problems, they mean systematic ways of finding the "best possible" solution under real-world constraints—such as minimizing costs or maximizing welfare while ensuring reliability of supply. In such problems, the best solution rarely lies at the extreme, referred to as a *corner solution*. Applied to electricity, this means that a 100 % renewable share is unlikely to be optimal. As the renewable share grows, each additional percentage point becomes harder and more expensive to achieve: balancing intermittent wind and solar requires ever more backup capacity, storage, and grid expansion. These integration costs rise steeply at very high shares. Therefore, the welfare-maximizing outcome is much more likely to be an *inner solution*—a mix in which renewables play a role, but are complemented by other technologies that ensure reliability and flexibility at reasonable cost.

This intuition is supported by Hirth's (2015) work on optimal renewable shares in Northwestern Europe, published in *The Energy Journal*. Even under the unrealistic assumption of constant winds, he finds the optimal share to be only 60%. Under the more realistic assumption of intermittent wind, the share drops to as low as 20%, illustrating the dramatic impact of wind variability on the results. Moreover, today's actual costs for electricity production from onshore wind power in Germany are typically around 6–7 Eurocent per kilowatt-hour (kWh) and, hence, are often higher than Hirth's "optimistic" assumption of 5 Eurocent/kWh, which is still at the lower bound of current estimates.

Solar power fares even worse in Northwestern Europe. For countries such as Germany, Belgium, Poland, the Netherlands, and France, Hirth finds the optimal solar share to be close to zero, even under the assumption of significant further cost reductions. This outcome reflects the relatively low solar radiation intensity in these countries, compared to Southern Europe. For instance, the average solar intensity amounts to about 1,825 kWh per square meter in Spain, compared to roughly 1,100 kWh/m² in Germany (Frondel, Ritter, Schmidt 2008). With over 3,000 solar hours per year in Spain—almost double Germany's 1,600 hours—the economic case for solar power is much stronger in southern than in northern Europe.

The consequences of heavy reliance on renewables in Germany are already visible today: While sufficient storage capacities as well as electricity demand are lacking, the massive expansion of photovoltaics regularly leads to surplus electricity on sunny days, as exemplified by Figure 1 for the time period from June 17 to June 22, 2025. Nevertheless, the production of solar and wind power is rewarded through feed-in tariffs, even when the electricity is not needed. Increasingly, this pushes prices on the electricity exchange into negative territory to attract additional demand from abroad, as supply and demand for electricity must always be in balance to avoid the extreme case of a blackout.

The scale of the problem is becoming ever clearer. In 2024, there were already 457 hours with negative electricity prices, about half again as many as in the previous record year 2023, when this number of hours amounted to 301 (BHKW info 2025). In addition, there were 62 hours with a price of exactly zero, more than twice as many as in the previous year. And in 2025 we are already heading for a new record: by the end of June, 389 hours of negative prices had been recorded—almost 75 percent more than in the same period in 2024. Negative prices mean that the producers have to pay for selling their product, rather than getting money for it — a clear indication for inefficiencies that cost German taxpayers and consumers billions of Euros.

For Germany, this is increasingly turning into a losing proposition. The difference between the guaranteed feed-in tariffs for feeding green electricity into the grid and the actual market prices is borne by taxpayers. The more often prices fall into negative territory, the more expensive it becomes for German taxpayers. In the end, it is no surprise that Germany's residential electricity prices are among the highest in the European Union (Eurostat 2025).

The broader lesson is that technology choice should be guided by regional conditions and cost-effectiveness. After two and a half decades of large-scale subsidization of photovoltaics through Germany's Renewable Energy Act— by far exceeding 200 billion euros (Andor et al. 2017, Frondel et al. 2010)—further subsidization should be abandoned, a conclusion that Frondel, Schmidt, and Vance (2014) already drew more than a decade ago. Instead of narrowing the electricity mix to renewables and natural gas backup plants, Germany could benefit from reassessing the role of other low-carbon technologies. This might include reintroducing climate-neutral nuclear power, which, despite its phase-out in Germany in 2023, could provide a reliable, zero-carbon complement to variable renewables in an optimal technology portfolio.

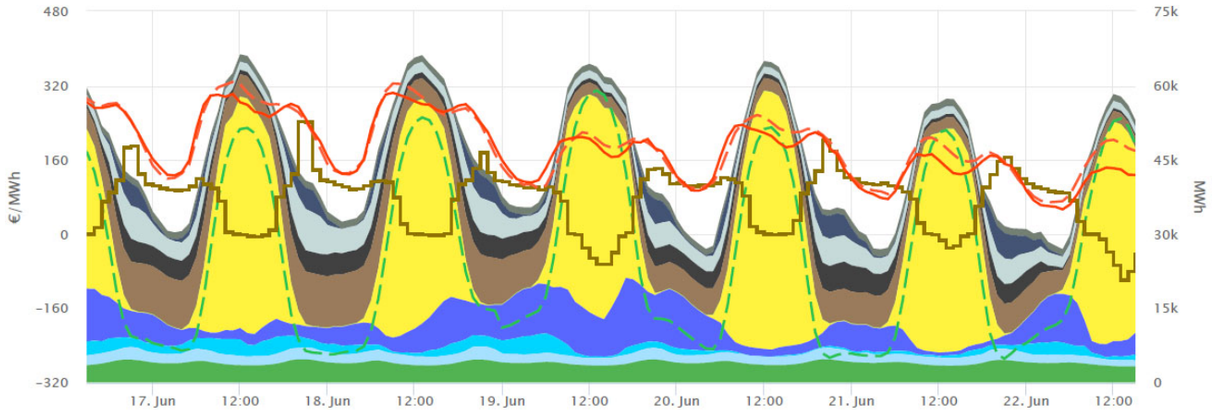

Figure 1: Electricity Demand (Red line) in Megawatthours (MWh), Spot Market Prices (Brown line) in Euros per Megawatthour, and Production in Megawatthours (MWh) from Photovoltaics (Yellow), Onshore Wind Power (Dark Blue), Off-shore Wind Power (Light Blue), Water Power (Very Light Blue), Other Renewables (Green), Lignite (Brown), Hard Coal (Black), Natural Gas (Light grey) in the Period from June 17 to June 22, 2025. Source: Smard, Federal Network Agency, Germany.

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