What realistic role for nuclear to support climate neutrality in Germany: electrification, storage optimization and energy balance.

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Overview

Germany's energy transition maybe one of the most controversial in recent history. Germany, which until 2006 enjoyed a fleet of 22 GW of low carbon, safe, reliable and efficient nuclear reactors providing 1/4th of the country's power, decided to achieve its energy transition targets without it, by, adopting a policy aiming at replacing it progressively by a 100% renewable electricity mix, which soon targeted the full energy mix. Doing so, the country spent the past 20 years growing the total carbon-free electricity production by only 20 TWh. Indeed, despite the unique conjunction of largely favourable public opinion, determined political will and policies, abundant financing, plenty available skills, technological and industrial resources, all coherently organized and on a sufficiently long time to make it significant, the decarbonization targets Germany has set for itself have repeatedly been missed, as other key indicators regarding the electricity mix health have progressively degraded (Bundesrechnungshof 2024).

What other path could have Germany take to achieve deep decarbonization, and, more importantly, what path can it take now to correct its trajectory?

Based on the share of fossil fuels in each sector, and on the known efficiency gains gotten via electrification, the experience gathered from other advanced economies shows that the decarbonization requires generally a doubling of the electricity consumption.

Germany's consumption, however, contracted by more than 10% in the 7 last years (BDEW), partly reflecting the industrial sector suffering from high energy prices.

Based on a large set of experience feedback, there would seem to be no other realistic path for Germany to achieve true decarbonization than to increase consumption by around 700 TWh and low-carbon production by around 1000 TWh. In addition, if this decarbonization is to be reached in 2045, it further means adding 50 TWh/year of new carbon-free generation, or 4 times as much as what Germany already managed during the last 15 years.

It is unlikely for wind and solar alone to be able to grow quickly enough to achieve that goal. Thus, a return to the use of nuclear power must be considered. First in the form of the restart of recently closed reactors, then by seeking an ambitious construction program.

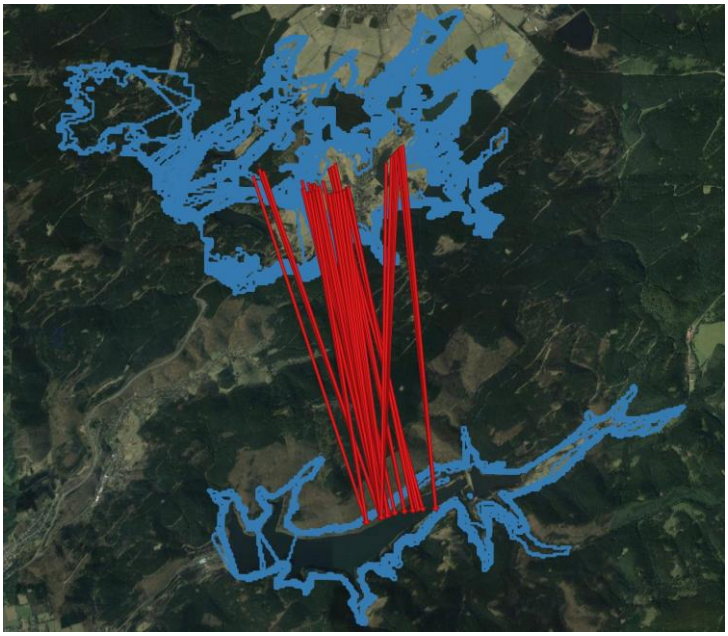
The aim of this study is to determine if a realistic nuclear redeployment program in Germany could help achieve the country's climate goals or at least alleviate the burden of not reaching them.

Methods

This works intends to determine a realistic decarbonisation trajectory for Germany using as a starting point the current energy situation of the country. After an extensive bibliographical review of past and recent deployment experiences and industry experts' interviews, a plausible rate of deployment for various technologies is being determined, considering the grid constraints (which are already extremely prevalent in Germany and likely to be the main bottleneck of the transition).In parallel, sector-specific hourly demand profiles (residential, transport, industry, etc.) have been extracted from the literature

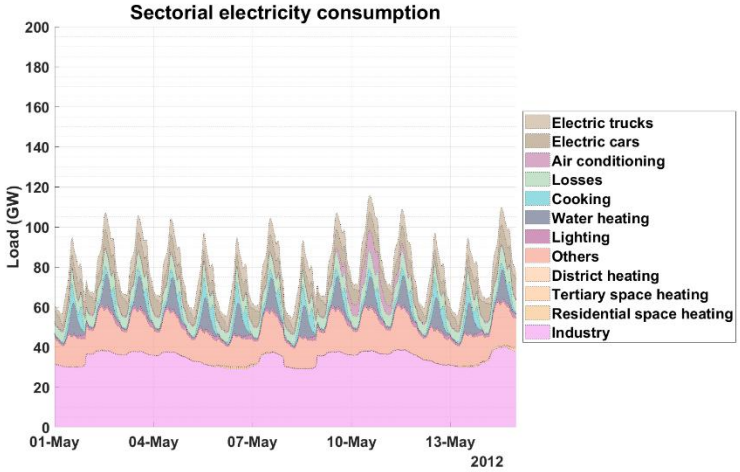
and applied to model electricity consumption under an electrification scenario. We also determine an electrification path based on sectorial analysis of the decarbonization needs to build an evolutive synthetic load curve.

As this study is primarily driven by the aim of minimizing assumptions, it limits itself to already mature and off-the-shelf technologies. Following this tenet, an extensive search of large and very large pump-storage site, specifically those above 50 GWh and meeting the most favourable geographical condition, has been conducted thanks to our partner ActaPower, with the objective to limit as much as possible the use of thermal power plants for managing the renewables' intermittency, as successfully demonstrated in our French scenario. We also intend to limit as much as possible energy imports, for reasons of independence and resilience, as well as limit demand-side flexibilities to daily static forms, due to societal acceptability concerns.

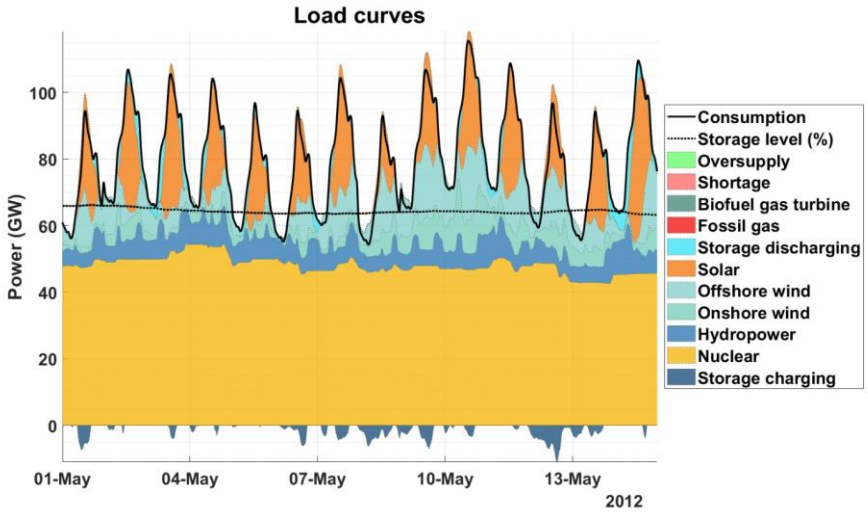


Example of a large pump-storage site identified with an automatic software provided by our partner ActaPower. The multiple blue contours, and red lines represent the various combinations computed by the software.

This philosophy of relying on as few technological, geopolitical, and societal breakthroughs as possible, was first developed and applied in the French TerraWater scenario published in November 2022 in response to the government-commissioned Energy Futures 2050 report by the French TSO RTE. With it, we demonstrated the feasibility of achieving a very high level of decarbonization and security of supply at a moderate cost, provided that systematic electrification is pursued and that well-proven technologies are not prematurely dismissed. For example, the following two graphs illustrate our approach in the TerraWater France scenario, an approach we're now replicating for Germany.



Simulation of the hourly sectorial consumption over the first two weeks of May (preliminary results of the 2nd version currently underway



Supply-demand balance calculation showing how the different energy sources interact within the scenario over the first two weeks of May (preliminary results of the 2nd version currently underway)

A trajectory for the restart of the most promising shut down nuclear reactors, based on current dismantling state and nuclear experts' insight, has been constructed. In addition to that, an analysis has been conducted on the best strategy to reinstate a nuclear new build program. This includes choosing the most suitable reactor model (i.e. the one than can provide the highest amount of electricity in the shortest amount of time), estimating as precisely as possible what construction duration and cost could be expected, and determining an adequate pace of construction taking into account the supply chain bottlenecks.

All economic and political considerations are however set aside, the objective of this study being to provide a purely technical rigorous assessment of what is possible or not.

Finally, all these data have been put together into a self-developed model to compute the real time supply-demand equilibrium and iteratively adjust the amount of flexibility (and of low carbon production when possible) needed to ensure security of supply.

Results

Based on our preliminary results, it seems Germany, with its current level of energy consumption, will be highly unlikely if at all to ever reach climate neutrality without a significant (~200 TWh/year) deployment of new nuclear and the restart of some recently closed ones.

Even if we account for a significant return of nuclear into the German energy landscape, the preliminary results of the study demonstrates that it will be impossible to reach climate neutrality by 2050, a fortiori by 2045, without considerable amounts of energy imports, in the order of magnitude of 200 TWh/year.

The reinstatement of nuclear energy into the German grid would however help reduce the amount of these imports from "definitely unachievable" to "maybe manageable with a strong European cooperation".

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