THE POTENTIAL OF NUCLEAR ENERGY IN GERMANY'S ENERGY TRANSITION

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WePlanet DACH e.V.

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EXECUTIVE SUMMARY

Nuclear power is a virtually emission-free and cost-effective form of electricity generation, but as a result of the German nuclear phase-out, it is not part of any of the energy transition scenarios.

As a starting point for considering a possible return to nuclear, we used an illustrative scenario with simple assumptions to estimate whether economic benefits might be possible.

The results show that by including nuclear in the energy-mix costs of producing and storing renewable energy and upgrading the grid can be significantly reduced. We estimate that there are overall savings for the energy transition if initial investments in nuclear power plants (NPPs) are less than €7,400 per kW.

Over the lifetime of the NPPs, there are benefits if the total investment over this period, including fuel and upgrades, is less than €12,430 per kW.

ASSUMPTIONS

For our simple assessment of whether and to what extent the costs of the German energy system transformation could be reduced by the use of nuclear energy, we first consider an exemplary scenario: which measures could be reduced if new NPPs were built or, where still possible, decommissioned NPPs were reused for electricity generation?

The basic scenario is the T45 Electricity* by the consortium led by the Fraunhofer Institute for Systems Technology and Innovation, which was presented to the public in February 2024 and is therefore currently up to date.[1]

Assumption: Nuclear power plants of the same capacity are built (or re-commissioned) as baseload power plants at the sites of the former nuclear and lignite-fired power plants. In 2010, before the start of the nuclear and coal phase-out, these were nuclear power plants with a total capacity of 21.5 GW and lignite-fired power plants with a total capacity of 22.7 GW [2]. An average availability of 85% is assumed.

Power generation:
330 TWh per year

Average power fed into the grid:
37.6 GW

[1] ISI_WEB
[2] ISE_2010

Methodology

All individual values for electricity generation in Germany in 2045 are taken from the slide set of the webinar on energy supply [3]. However, individual cost estimates are only included in an older version [4]. In addition, data on the development of electricity generation in Germany [5] and Europe [6] were downloaded and mathematically analysed.

Replacement of wind and solar

The electricity produced in the assumed NPPs does not need to be generated in wind and solar power plants, so fewer of these plants are needed.

The main sources of renewable generation together produce 1042 TWh in the model year [7]. **The production of the assumed nuclear power plants replaces 330 TWh of this, i.e. 31.7%.** Without further optimisation, this reduction is divided between all three energy sources (onshore wind, offshore wind and photovoltaics) on a percentage basis (see Table 1).

The cost rates are based on the costs modelled for 2035, assuming that they are averaged over the entire construction period. For photovoltaics, an average cost rate corresponding to the potential for rooftop and ground-mounted systems was used.

Existing systems are not taken into account as they will all have reached their service life of around 20 years by 2045. It should also be noted that the lifetime of a nuclear power plant is about three times longer than that of solar and wind power plants. As many components are likely to be reusable in retrofits, only twice the initial investment is assumed for the long-term investment.

[3] ISI_Folien_2024
[4] ISI_Folien_2022
[5] ISI_DEU
[6] ISI_EU
[7] ISI_Folien_2024: Folie 15, T45-Strom (Update): Jahr 2045

Reduction of electricity imports

In scenario T45, electricity is imported and exported in order to balance the temporal variability of demand and the intermittent nature of renewable generation. This is surprising at first, as one would think that in a Europe that has largely switched to renewable energy supply, shortages and surpluses would occur very synchronously. However, a comparison of the dispatch curves for Germany [23] and Europe [24], for example for week 16, hour 2712, shows that this should be possible according to the scenario.

The difficulty is the necessary investments are difficult to measure and assess. In addition to battery storage and pumped storage, power-to-gas and CSP (concentrated solar power) are also used at European level. CSP uses concentrated sunlight to heat salt to a high temperature, which can then be stored and used to generate electricity at night.

As a further compensatory measure, the production of hydrogen for non-electricity applications is controlled according to the current electricity supply. With the exception of the pumped storage (PSP) plants, all the plants required for balancing have to be newly built. The power output of the European PSPs modelled is a maximum of 50 GW [25], which corresponds to the turbine output of the PSPs available today.[26]

Perhaps it can be assumed that the output of the NPPs installed in Germany would reduce the imported output in shortage situations, possibly even lead to exports, and thus replace the corresponding installed output of either CSP or PtG plants. In the case of PtG, the electrolysers and CCGTs for conversion to electricity could be omitted.

[23] ISI_DEU, Einstellung Woche 16
[24] ISI_EU, Einstellung Woche 16
[25] ISI_EU, eigene Auswertung
[26] ENTSOE_2022

IIt's not easy to determine the extent to which renewable generation can also be omitted, as the timing of electricity imports and exports would need to be taken into account. Assuming an initial investment of €1,300 per kW for electrolysers and power plants to convert to electricity, or €1,700 per kW for long-term investment, **this results in savings of around €57.5 billion and €75 billion respectively, assuming an average availability of 85%**.

According to a database, Spain is currently the only European country with operational CSP plants, with a total of 51 plants totalling 2.4 GW [27]. These plants were built between 2008 and 2013 and cost between €5,000 and €6,000 per kW. In the scenario, they are expected to generate a maximum of 44 GW. If they could be partially replaced by nuclear power plants of the same nominal capacity, **the total savings would be €188 billion.**

Grid expansion savings

To make the German transmission grid fit for the energy transition, major upgrades and expansions are needed. In the past, the maximum load on the grid was around 80 GW, and only small differences in supply and demand had to be balanced over comparatively short distances. After the energy transition, large-scale electricity transport between northern and southern Germany will have to be possible for peak demand of over 200 GW.

The current Network Development Plan (NDP) identifies additional investment requirements over and above previously agreed measures, totalling €145.1 billion for the offshore grid[28] and €106.1 billion for the onshore grid[29].

[27] NREL_2024
[28] NEP_2037, Seite 98
[29] NEP_2037, Seite 132

If NPPs are deployed on the sites of former large baseload power plants, it can be assumed that the high and extra-high voltage lines for connection to the transmission grid are either still in place or can simply be rebuilt. This should greatly simplify expansion. The difficulty, however, is that the various measures listed in the NEP cannot be easily assigned to specific expansion characteristics. In addition, no transmission capacities are specified for the onshore grid measures.

However, the significant reduction in the output of offshore wind farms is likely to substantially reduce the number and size of the various installations to be built in this context. Without being able to give a more precise estimate, a reduction of 15% of the total investment is assumed here, corresponding to a total of around EUR 37 billion.

The situation in Europe outside Germany is very difficult to assess. What is clear is that the loss of generation and storage will be reflected in the need to expand the grid there. **If around 40 GW of electricity from CSP generators is to be transported from Spain to Germany, this will require a connection that is around twice as long as the southern link [30], with ten times the transmission capacity.**

Unfortunately, no documents on the planned future European transmission grid have been found to date. The long-term planning of ENTSOE (Ten Year Net Development Plan - TYNDP) does not provide any relevant information either [31], so no further estimates are possible here.

[30] Suedlink
[31] TYNDP_2024

Results

In the previous sections, an attempt was made to roughly estimate the savings resulting from the use of NPPs to cover the base load, as was the case in 2010 for NPPs and lignite-fired power plants. In total, this resulted in initial investment savings of EUR 326.3 billion and long-term savings of EUR 549.3 billion over the lifetime of an NPP.

Table 3: Savings from gas-fired power plants and electrolysers that are no longer required

	Initial savings (in billion EUR)	Long-term savings (in billion EUR)
Regenerative power	194,5	389
PtG Germany	37,3	48,3
PtG Europe	57,5	75
Grid expansion Germany	37	37
Grid expansion Europe	?	?
Total	**326,3 + x**	**549,3 + x**

This results in economic benefits from the use of NPPs, provided they cost less than about €7,400 per kW in initial investment and less than about €12,430 per kW over their lifetime, including retrofitting and nuclear fuel. This is in addition to the savings that can certainly be expected, but are very difficult to estimate, for investments in European electricity generators and transmission grids.

Concluding thoughts on the timeline

A common argument against the use of nuclear power in the energy system transformation is that the plants would not be ready in time for climate neutrality in 2045 and would therefore be too late. Although the authors do not comment on this, the scenario clearly shows that the situation simulated here is not achievable by 2045 either. The required annual expansion of generation capacity alone – around 8GW of onshore wind, 3.5GW of offshore wind and 20GW of solar PV – is many times higher than the highest expansion rates achieved to date – and these will have to be maintained over 20 years. In addition, of course, there will need to be a similarly strong shift on the consumer side.

The problem becomes clearer when you consider the physical requirements: 2045 is 20 years away, or 1,040 weeks, or about 5,000 working days. In those 5,000 working days

- 7,000 offshore wind turbines with an average capacity of 10 MW are to be erected in order to install 70 GW of nominal capacity. Assuming further technological progress, this figure could change to around 5,000 turbines with an output of 15 MW.
- 40,000 onshore wind turbines of 4 MW each would have to be erected to install 160 GW of nominal capacity.
- Even if a solar plant had an average size of 1 MW, 400,000 such plants would have to be built to achieve 400 GW of installed capacity.
- Similarly on the consumer side: 20,000,000 or more heating systems would have to be converted to heat pumps.
- Just as many home connection points for electric vehicles are needed if their batteries are to be used to compensate for fluctuations in demand.

The list goes on and on. Who will do it? Where will the skilled workers come from? Is this to be done in a country that is currently struggling to maintain its existing infrastructure?

Moreover, many of the technologies that would need to be installed on a large scale are far from fully developed and tested. The largest electrolyser currently operating in Germany has a capacity of 0.01GW [32] - but 61GW is expected to be installed by 2045. The operating experience of larger plants is not necessarily good [33].

While these are likely to be problems encountered when scaling up any technology, the causes need to be identified and solutions sought and tested. This takes time. It would be fatal to deploy an immature and untested technology on such a large scale if major systemic weaknesses were to emerge later.

The time argument is therefore not relevant when relying on proven types of NPPs.

[32] REFHYNE: https://www.refhyne.eu/, particularly interesting: Publications/Projects Lessons Learnt.
[33] Collins_2023

Conclusion

The above considerations show **the construction of new nuclear power plants (or the recommissioning of old ones) would be worthwhile if the investment costs were below €7,400 per kW**. In all likelihood (if the savings in the European grid are duly taken into account), the actual threshold is even higher, i.e. the use of nuclear power is likely to be considerably more expensive and **would still be more favourable than the currently planned energy transition**.

By way of comparison, the investment **costs for current projects in Europe are around €5,000 per kW of capacity for reactors built in series**[34]. Only non-series reactors, such as Flamanville and the first reactor at Hinkley Point C, are significantly more expensive (over €10,000 per kW). However, these NPPs are new designs, i.e. the "first of their kind", built by teams with no experience of such large-scale projects: As soon as a certain regularity returns to the construction of European nuclear power plants, costs will fall significantly. In the longer term, we are convinced that historical cost estimates are perfectly realistic.

So we are convinced:
A new course in the energy transition, including nuclear power, would lead to significant cost savings and thus to gains in prosperity.

[34] IEA https://www.iea.org/reports/projected-costs-of-generating-electricity-2020

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ABOUT US

At WePlanet DACH, our vision is to make the earth the best possible place for people and nature. To achieve this, we want to use all the resources at our disposal.

We want to provide all people with unlimited, affordable, clean and reliable energy. This will make it easier to solve problems such as resource scarcity, hunger, poverty, water shortages and climate change. Technological innovation and sufficient energy are the basis for global prosperity.

We also want to reduce humanity's land consumption, in particular through innovative alternatives to the consumption of animal products. Natural and diverse ecosystems should return to cleared areas and the land should be made available for nature and all its inhabitants.

To mitigate climate change, we aim not only to reduce our emissions but also to use all available options, including negative emission technologies, to actively remove greenhouse gases from the atmosphere. We also want to explore the opportunities and risks of geoengineering so that we can use it if the need arises.

We want to decouple growing prosperity and progress from negative environmental impacts. We want to create a prosperous future for future generations without destroying the planet.

We live in the Anthropocene, the age of humanity. How our story continues is up to us. At WePlanet we choose hope, progress and cooperation.

Let's give freedom to nature and prosperity to people!

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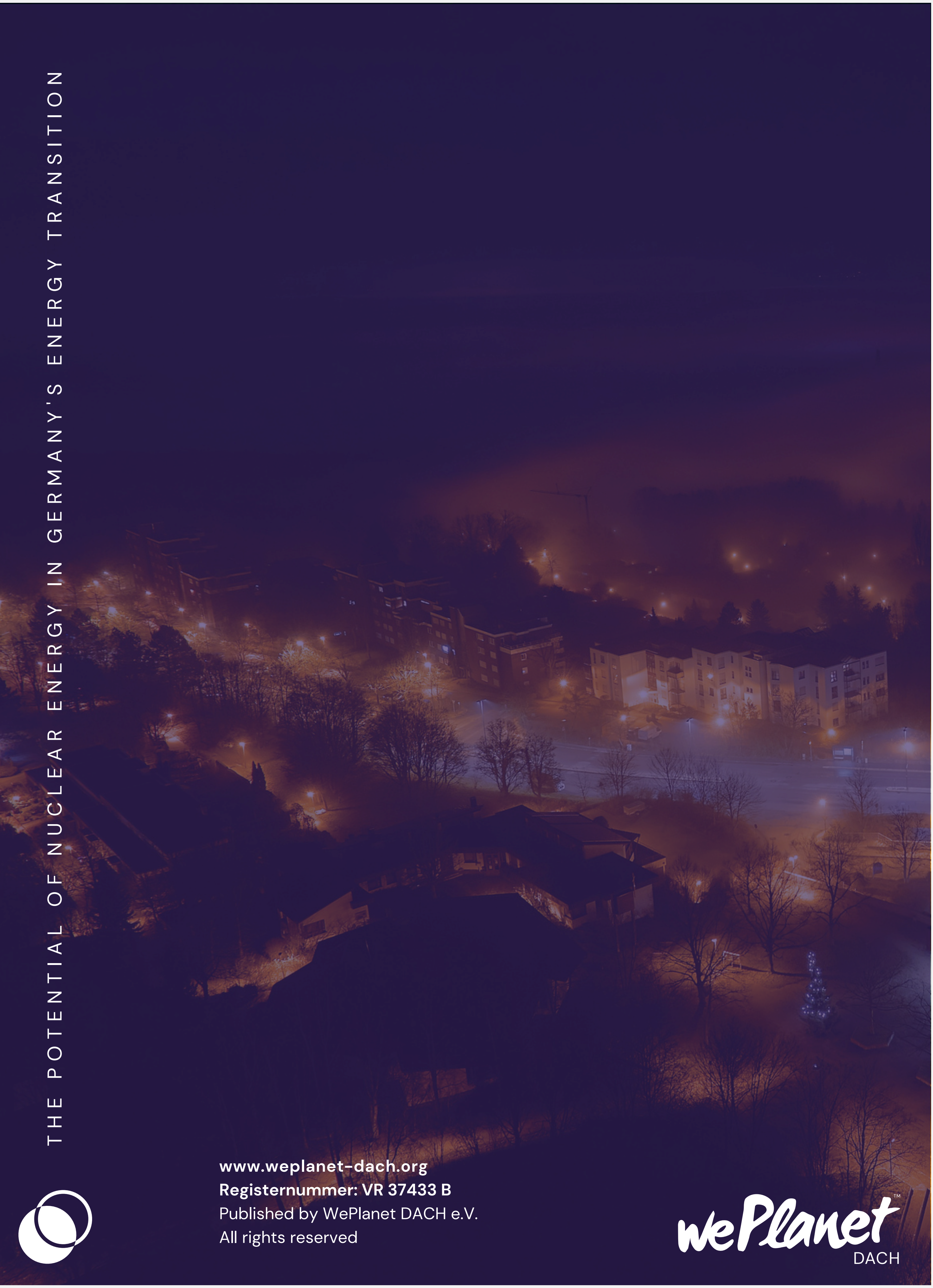

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