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Opinion

Low cost, uncertain value: Why cheap PV may still not become UK's main power source

Claude Klöckl,[1,*] Sebastian Wehrle,[1] and Johannes Schmidt[1]
[1]Institute of Sustainable Economic Development, University of Natural Resources and Life Sciences, Vienna, Austria
*Correspondence: claude.kloeckl@boku.ac.at
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We contrast a recent assessment by Mandys et al. that dropping PV LCOE in the UK will lead to photovoltaics becoming the most competitive renewable energy technology by 2030, by arguing that (1) strong seasonal variation, (2) too little demand correlation, and (3) highly concentrated production periods still lead to overall more competitiveness and less system cost of wind power production.

A recent paper by Mandys et al.,[1] published in this issue of *Patterns*, predicted future levelized costs of solar photovoltaic electricity (PV LCOE).[1] For large-scale projects, Mandys et al.[1] project LCOE to decrease to 34 $\frac{£}{MWh}$ (39.4 $\frac{€}{MWh}$) by 2035, and therefore, Mandys et al.[1] expect PV to possibly become "even cheaper than onshore and offshore wind energy, which are predicted to cost 44 $\frac{£}{MWh}$ (51 $\frac{€}{MWh}$) and 43 $\frac{£}{MWh}$ (50 $\frac{€}{MWh}$) respectively in 2035." The article foresees a steep decline in the cost of PV projects. Consequently, the future expansion of PV in the UK is seen very optimistically, culminating in the strong claim that PV *will be the most competitive renewable energy technology by 2030*. While a cost decline of solar PV could lead to a more significant role for PV in a decarbonized energy system, the overall predictions for the future of solar PV in the UK may be overly optimistic.

The LCOE is not the only relevant factor for the market penetration of renewable energy technologies. Private investment incentives depend on PV's overall profitability, which depends on revenue and cost. If a technology delivers electricity mainly at times of low electricity market prices, it might be uncompetitive even when generation costs are low. Moreover, competitiveness will also depend on the extent to which a generation technology must bear the (indirect) cost it imposes on the power system.

Assessing the system value of intermittent renewable energy technologies is a complex task, as the system value depends on temporal generation patterns and on the residual system. However, some generalizations are in order. The value of electricity generated by intermittent renewable energy technologies decreases the penetration rate of that technology.[2,3] On the other hand, the availability of low-cost flexibility options, such as pumped hydropower, can stabilize the value of variable generation. Hence, the socially optimal deployment of renewable energy technologies should be assessed with power system models. Comparing different technologies by LCOE does not suffice.

Analyses based on power system models show that solar PV typically has a substantial value disadvantage compared to wind power in northern regions. First, a disadvantage arises from large seasonal fluctuations in PV generation, which dwindles in northern winters. In comparison, wind power typically exhibits smaller seasonal variations. Second, solar PV's summer peak in generation tends to be anti-correlated with the winter demand peaks typically observed in northern regions. Third, electricity generation from solar PV is concentrated in fewer hours than wind power generation. Consequently, requirements for grid infrastructures and electricity storage tend to be higher for solar PV than for wind power.

The first two points erode solar PV's market value compared to wind power, while the third point induces higher system costs when significant quantities of solar PV are introduced into an electricity system. Therefore, energy system modeling studies consistently show that the system cost-optimal share of solar PV in the overall electricity system is below that of wind power in fully or almost-fully decarbonized systems at higher latitudes.

A detailed analysis of this effect can be found in a previous publication,[4] to which two of us contributed. In this publication we analyze the effect of substituting solar PV and wind power in a future German-Austrian electricity system. We find a significant opportunity cost of replacing wind turbines with solar PV. Our analysis suggests that the opportunity cost of replacing wind capacity with solar capacity gradually rises from 10,000 $\frac{€}{MW}$ to 70,000 $\frac{€}{MW}$ when assuming a CO_2 price of 100 $\frac{€}{tCO_2}$. The more wind power is replaced by PV, the higher the resulting additional system cost. This system cost advantage of wind power over solar PV holds for a wide range of cost assumptions for solar PV, including very-low-cost solar PV (see Figure 1). Moreover, for a realistic picture of the CO_2 price consider that in the European Emission Trading Scheme the CO_2 price is currently at about 90 $\frac{€}{tCO_2}$.

The capital cost on the right of the figure will result in LCOE slightly above the lower bound found in Mandys et al.[1] To see this, consider the spreadsheet accompanying Mandys et al.,[1] where we found the lowest capital costs to be 469 £/kWh in 2021. This corresponds to 534 €/kWh in 2021. The steepest decline in LCOE between 2021 and 2030 is 42%. Hence, 2030 costs are 58% of 2021 costs, leaving us with an approximate capital cost projection of 534 × 0.58310 €/kWh in 2030. Consequently, the lowest LCOE projection of Mandys et al.[1] is comparable to the right side of capital cost of PV given in Figure 1, where costs vary between 650 and 250 €/kWh.

There is a considerable difference in opportunity cost between partial and total replacement of wind power by PV. This

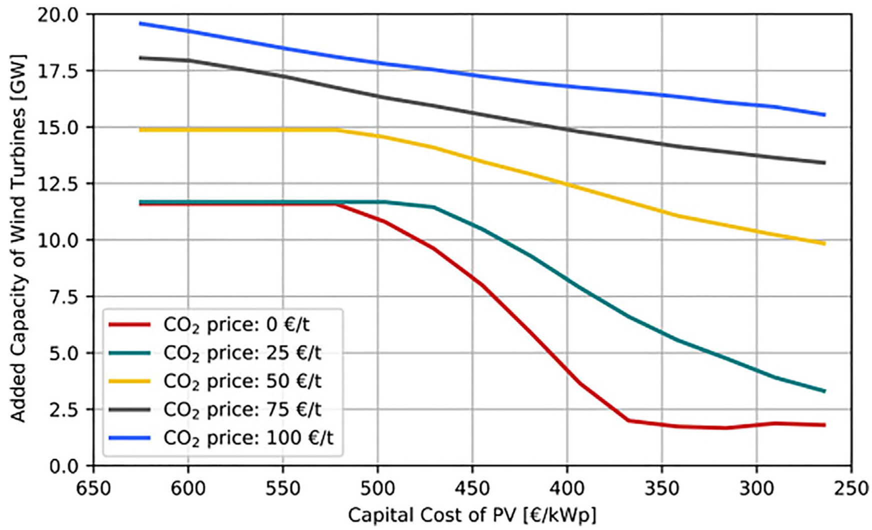

Figure 1. Optimal deployment of wind power in Austria conditional on the capital cost of solar PV

illustrates that the higher the penetration of solar PV, the higher the additional system cost. Thus, there may be room for some solar PV in the UK grid, but very high shares are costly. While the analysis in Wehrle et al. was conducted for the German-Austrian electricity market, we are confident that the analysis also holds for the UK, which has slightly worse solar resources than Austria. At the same time, available system flexibility, which benefits PV integration, is high in Austria due to the ample availability of hydropower reservoirs.

An analysis of the Brazilian electricity system shows that the value of electricity from intermittent renewable energy technologies strongly depends on local meteorological conditions. Schmidt et al.[5] have shown that, in Brazil, the optimal solar PV share is much higher than the wind share under the implicit assumption of equal LCOE, as differences between seasonal generations are lower, while the existing large-scale hydropower reservoirs support the integration of intermittent generation.

On a global level, an analysis of the reliability of electricity supply shows that, the higher the latitude of a region, the more wind power is in the optimal, reliability-maximizing generation mix.[6] While the fall in solar PV costs will positively contribute to decarbonizing the UK grid, an optimal mix of renewable energy technologies will likely contain substantial shares of wind power in addition to solar PV.

These results contrast the view that plummeting PV capital costs will lead to PV becoming the most competitive renewable electricity source in the UK by 2030. Solar PV will be the second-best option regarding systemic needs and overall system cost, as long as wind power can be expanded.

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DECLARATION OF INTERESTS

The authors declare no competing interests.

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About the authors

Claude Klöckl is a mathematician working on energy economics, energy forecasting, and modeling the green transition. After a PhD from Universitat Autonoma de Barcelona, he worked for the Austrian Academy of Sciences, the University of Natural Resources and Life Sciences, Vienna, and the Austrian Power Grid.

Sebastian Wehrle pursues a doctoral degree in energy economics at the University of Natural Resources and Life Sciences, Vienna. His research centers on the external effects relevant for the planning of future power systems. Before his academic career, he has worked for more than a decade in strategic positions for major Austrian utilities.

Johannes Schmidt is assistant professor at the Institute for Sustainable Economic Development, at the University of Natural Resources and Life Sciences, Vienna (BOKU). His main research interests are the integrated modeling of energy systems with high shares of renewables and developing a comprehensive approach to the assessment of renewable energies, including technical, economic, social, and ecological aspects. In 2017, he won the ERC Starting Grant for the reFUEL project, which deals with a global, integrated analysis of trade with renewable energy carriers and associated impacts on land-use.