iea wind

Task 25 Design and Operation of Energy Systems with Large Amounts of Variable Generation

Fact Sheet

WIND AND SOLAR ENERGY CURTAILMENT

Curtailment of wind and solar sometimes occurs in surplus periods when electricity demand is low or when network capacity is congested. Curtailing wind and solar is not necessarily a bad thing as it may enable larger shares of renewables through making them flexible. Although a moderate amount of curtailed energy can be tolerated, huge amounts of wasted energy from near-zero operating cost renewable energy sources would be inefficient and unprofitable.

Is wind and solar curtailment required?

If curtailment of wind and solar would be strictly prohibited in a power system, only limited amounts of wind and solar could be installed and connected to the system. Not everyone needs electricity exactly when the wind blows and the sun shines, so sometimes the power generated from wind and solar is excessive. Zero curtailment may represent a sub-optimal solution.

Figure 1 illustrates the duration curve (energy values sorted in descending order) of net load, or residual load, that is the difference between total demand and total output from wind and solar. Surplus situations occur when the net load turns negative, meaning wind and solar output exceeds demand. At higher shares of renewables, such periods will become more common, and the amount of surplus energy tends to increase with the installed capacity of wind and solar. Surplus energy can be caused by local constraints, leading to curtailments at some parts of the system before system-wide limits. Building transmission helps export the supply to high-demand areas.

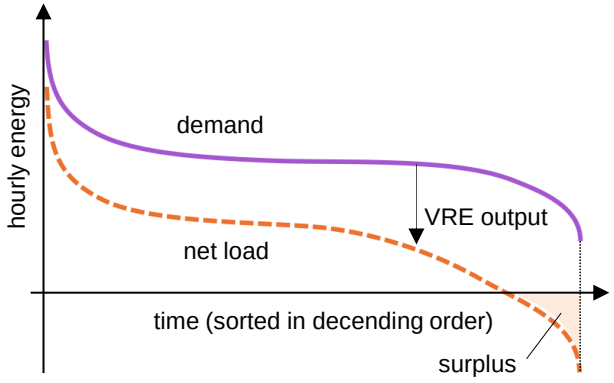

Figure 1. *Conceptual illustration of surplus energy in duration curve of net load with large amounts of VRE (wind + solar).*

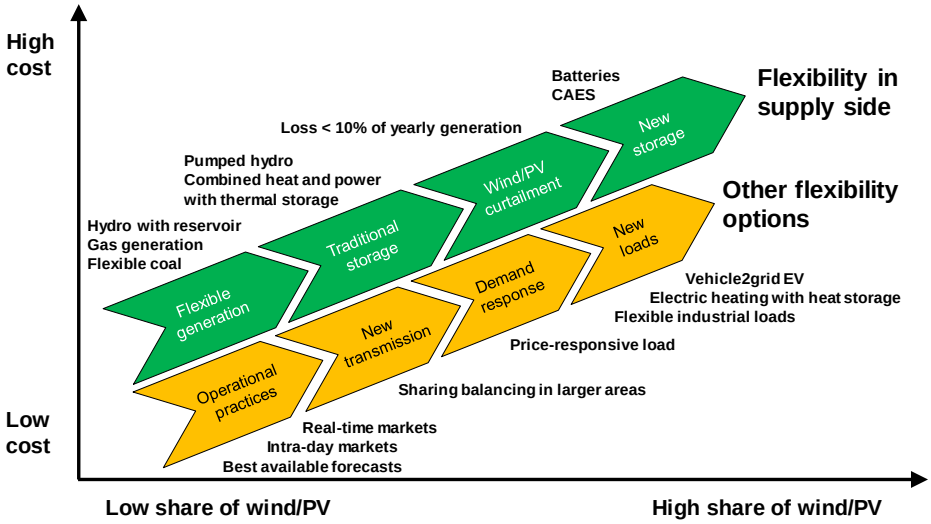

Figure 2. *Methods to increase flexibility in power systems. (The relative order of options is illustrative only).*

Options to reduce surplus energy are: output reduction of conventional power plants, export to other areas, demand side management, and energy storage. If these options are costly or have been exhausted, curtailment could be appropriate to manage the surplus energy of wind and solar. Large amounts of curtailment, however, show lack of system flexibility or appropriate market design.

Wind and solar operators can provide upward reserves when a part of the available energy from wind or solar resource is curtailed, where the lost energy provides the basis for the provision of these valuable system services. Curtailment is a way for wind and solar to provide flexibility (Figure 2).

Evaluation and comparison of curtailment

The level of curtailment depends on system being analysed. It also varies depending upon the time of year, such as by hour, day, week and month. Hence, comparisons of annual curtailments in different systems are more insightful than those made based on an arbitrary period.

Figures 3 and 4 illustrate wind and solar curtailment, respectively, in selected countries or areas in the form of C-E maps (correlation maps between energy share of wind/solar/wind+solar and annual curtailment ratio). Figure 5 illustrates total wind and solar curtailment.

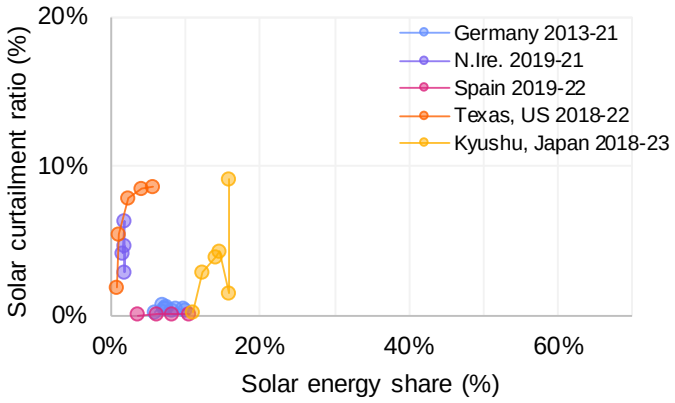

Figure 3. *C-E map of solar in selected countries/areas. (Source: adapted from Yasuda et al., 2023).*

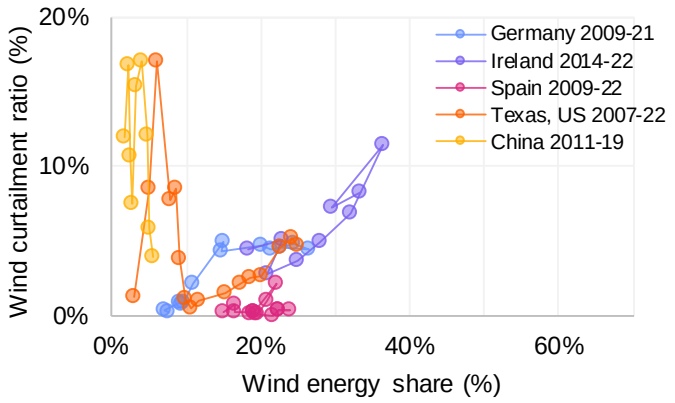

Figure 4. *C-E map of wind in selected countries/areas. (Source: adapted from Yasuda et al., 2023).*

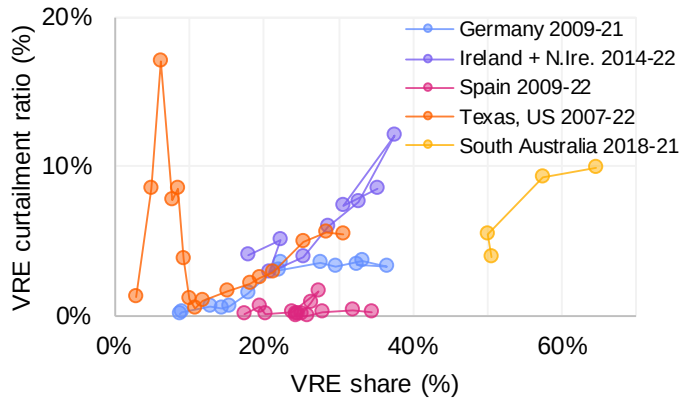

Figure 5. *C-E map of VRE (wind + solar) in selected countries/areas. (Source: adapted from Yasuda et al., 2023).*

The three graphs show that there are several countries/areas where the curtailment ratio is large, despite the small energy share. The sharp decline in some countries/areas, such as China and Texas, is likely to be due to the rapid development of transmission lines following large curtailments, which means that the curtailment problem could be quickly resolved through appropriate measures. The Irish curtailments in Figure 4, where large wind share is managed in a small synchronous zone, gives a reference on how curtailments develop as wind share increases in the future.

Remark on Figures 3–5: Note that curtailment in some of the countries, such as Australia and US, may include "economic dispatch" that is voluntary market behaviour, which should be distinguished from the curtailment that is forced by transmission system operators. Note also that evaluating the C-E map by the total volume of wind and solar could be misleading as it may result in an underestimation/overestimation of the levels of individual wind/solar curtailment in some countries/areas where the share of one of the two sources is very large and the other very small.

Associated publications

- Holttinen, H. et al. (2021). **Design and operation of energy systems with large amounts of variable generation**. Final summary report, IEA WIND TCP Task 25. https://doi.org/10.32040/2242-122X.2021.T396
- Yasuda, Y. et al. (2022). **C-E (curtailment – Energy share) map: An objective and quantitative measure to evaluate wind and solar curtailment**. Renewable and Sustainable Energy Reviews, 160 (2022) 112212. https://doi.org/10.1016/j.rser.2022.112212
- Yasuda, Y. et al. (2023). **Latest wind and solar curtailment information: statistics and future estimations in various countries/areas**. 22nd Wind and Solar Energy Workshop. https://iea-wind.org/task25/t25-publications/

More information

This Fact Sheet draws from the work of IEA Wind TCP Task 25, a research collaboration among 17 countries. The vision in the start of this network was to provide information to facilitate the highest economically feasible wind energy share within electricity power systems worldwide. IEA Wind TCP Task 25 has since broadened its focus to analyze and further develop the methodology to assess the impact of wind and solar power on power and energy systems.

See our website at

https://iea-wind.org/task25/

See also other fact sheets

Flexibility for Power Systems
Balancing Power Systems with Large Shares of Wind and Solar Energy
Storage for Power Systems
Wind and Solar Integration Issues