Policy Note 2019.6 – The Benefits of RES Curtailment in Ukraine

WITH an increasing integration of renewable energy sources (RES), system operators across the world are faced with the challenges to balance the weather-dependent and thus fluctuating generation from wind and solar plants with dispatchable plants or energy storage. At the same time, the share of dispatchable plants in the system, such as coal plants, is declining due to higher RES shares.

This balancing challenge can be addressed by adding flexible generation or storage, increasing transmission capacity as well as improving demand-response abilities.

Another administrative flexibility measure is to temporarily limit the output of RES plants when the safe operation of the system is threatened or when local transmission lines cannot absorb additional electricity. This is called "curtailment".

Curtailment as a flexibility option in the short and long run

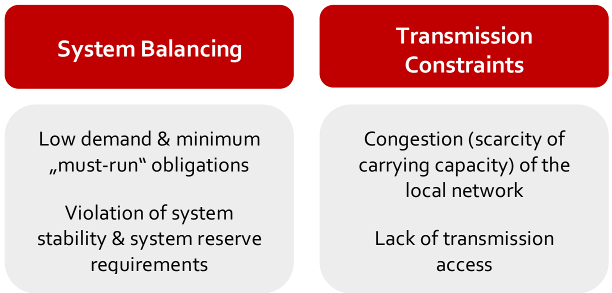
In the short term, curtailment "buys time" until new flexible generation, storage and transmission capacities are deployed. With flexible capacity still lacking in Ukraine today, curtailment could ease the pressure to substitute low-emission baseload generation such as nuclear for reserve-providing thermal capacity as a means of integrating higher RES shares – and would therefore mitigate the so-called "green-coal paradox" to some extent. Once the necessary infrastructural, operational and institutional changes to increase system flexibility have been made, curtailment ratios will likely settle down.

But even in highly flexible electricity systems, curtailment may still be the most cost-efficient option in some cases: Instead of absorbing the last kWh of a short-lived peak in wind generation with expensive storage or transmission investment, curtailing local and/or short-term generation peaks may be cheaper.

As of now, the day-ahead dispatch process of Ukraine's TSO Ukrenergo does not foresee the curtailment of renewable electricity generation. Based on weather forecasts, the expected RES generation during the next day is taken as given. When determining the necessary operating reserves to be held in order to balance spontaneous imbalances in electricity supply and demand and to cover contingency events such as the loss of a large generator, the day-ahead forecast error of RES as well as their inherent variability are taken into account. The more renewable energy is in the system, the larger the fluctuations and thus the larger the necessary reserves. In Ukraine, those reserves are provided by thermal power plants (TPPs) and big hydro plants. If 100% of potential RES electricity are used in Ukraine's electricity system, the limited amount of available operating and contingency reserves sets a natural limit to the further deployment of renewables.

If, however, Ukrenergo could order RES producers to decrease or stop their production in times where reserve requirements leave no room for further infeed of RES electricity or when the grid is locally congested, a significantly higher RES share would be feasible already today without having to invest into additional flexibility options. In the long-run, a more flexible electricity system with increased fast-responding capacities and energy storage would then help to reduce curtailment to its optimal low level.

The two main reasons for curtailing RES electricity



Source: own visualisation

Mitigating the green-coal paradox through curtailment

A concern associated with an increasing share of renewables in Ukraine is that due to the electricity system's inflexibility, more renewables with priority dispatch could perversely increase both system-wide emissions and costs – the so-called "green-coal paradox". We argue that temporary curtailment poses a feasible option to deal with rising shares of fluctuating renewables in the short run.

With rising RES penetration, an increasing amount of operating reserves (upwards and downwards) needs to be held in the system to be able to balance fluctuations in RES generation (and load). If there is less wind and sunlight than forecasted, reserve units are ordered to increase their power generation to avoid a frequency drop. The opposite holds if RES electricity generation exceeds its forecast – downwards reserves are activated, i.e. plants that are "online" are decreasing their output. Everything else equal, more renewable capacity means larger absolute forecast errors and thus larger reserve requirements.

In the Ukrainian electricity system, this could lead to a higher share of coal and a lower share of nuclear generation: In order to provide the necessary operating reserves, a large number of old coal-fired units with minimum stable loads of more than 70% have to work in the middle of their operating range to provide sufficient leeway up- and downwards. These "must-run" obligations imply that coal plants partly take over the base-load generation originally provided by nuclear plants, eventually leading to an increase in system-wide emissions and operating costs.

However, curtailment can help to alleviate this problem in a scenario where RES deployment is faster than the installation of more flexible gas turbines or batteries – hence bridging the time gap until investments into flexibility options are completed. But also in the long run, allowing curtailment can reduce the costly demand for storage to a more efficient level.

Curtailment experiences across the world

A comparison of RES penetration and curtailment figures shows that high shares of RES are almost always associated with a certain degree of curtailment.

While some countries, including Germany, still prefer to implement curtailment through DSOs and TSOs, other countries such as Denmark have made the dispatch-down of RES a part of the regular balancing market. While such a market-based approach might be economically most efficient as the compensation for dispatching down RES is determined through the interaction of supply and demand for electricity rather than a lump sum compensation, curtailment ratios close to 0% should not be interpreted as if RES plants would always work at full output. Instead, they voluntarily decide not to produce if prices for electricity turn negative. The following table shows curtailment and wind/solar penetration (RES electricity generation/Total demand) for selected countries.

Curtailment & penetration for selected countries in 2017

Country	Total production, TWh	Penetration		Curtailment	
		Wind	PV	Wind	PV
China	6313	5%	2%	12%	6%
Germany	654	18%	7%	5%	1%
Ireland	31	26%	n.a.	4%	n.a.

Sources: China National Renewable Energy Centre (CNREC); Bundesnetzagentur, (BMWi), Statistisches Bundesamt, Eirgrid, Soni, seai

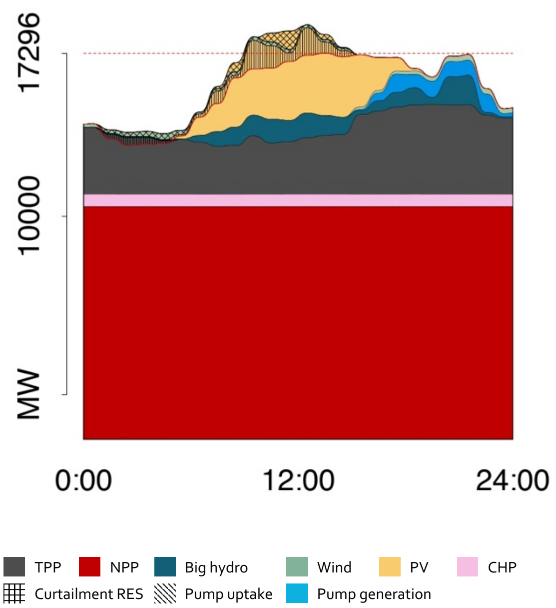
The high levels of curtailment in China can be explained by the rapid expansion of renewable capacity, a suboptimal geographic distribution of load centers and renewable energy generation as well as insufficient transmission capacity between load and generation centers. Especially in China's north, where most RES capacity is located, electricity demand is low and a lack of transmission capacity prevents a significant share of renewable electricity to be transported to load centers. Must-run obligations for coal plants, a lack of flexible generation capacity and the need to keep CHPs generation for district heating in winter are further aggravating factors.

Ireland shows that even with a high penetration of renewables, modest levels of curtailment are achievable in a flexible system. In 2017, where wind plants covered 26% of electricity demand, only 4% of total available wind energy was curtailed. Dispatch-down due to system balancing typically occurs in times of low electricity consumption from 11pm to 9am when minimum generation levels are imposed on conventional plants, whereas dispatch-down due to local network congestion is more likely throughout the day.

Curtailment vs. hardware solutions

The current discussion in Ukraine on how to deal with growing RES shares is focused on the appropriate hardware solutions – i.e. gas turbines and battery storage. We argue that Ukraine's electricity system must indeed become most flexible on the generation side. However, modernising plants and increasing storage capacity is only one of many flexibility options. Curtailment, should be considered too. The economic trade-off between curtailment and hardware solutions can moreover be determined by electricity system models that minimise the cost of system operation. In a forthcoming policy paper, Low Carbon Ukraine will employ its Optimal Dispatch Model of the Ukrainian electricity system to quantify curtailment under different scenarios. The graph below shows the cost-optimal dispatch for a working day in summer, based on the 2018 load trajectory.

Power flow of a working day in summer with 7.5 GW RES and curtailment



Source: own results

The figure indicates, that curtailment is an important component to a cost-optimal dispatch of Ukraine's electricity system. Hence more work on how it can be properly introduced and remunerated is needed.