SYSTEM LCOE: WHAT ARE THE COSTS OF VARIABLE RENEWABLES?

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Overview

Installing variable renewable energy sources (VRE) affects the rest of the power system by reducing the full load hours of conventional power plants. This leads to higher overall costs. Standard levelized costs of electricity (LCOE) as a metric of comparing power generating technologies do not account for those costs. We introduce 'System LCOE' as the sum of standard LCOE and the system cost increase. The new metric accounts for system implications of VRE. We calculate System LCOE of wind and solar for Germany. With increasing share of VRE these costs increase because the system implications get more severe. Higher shares of VRE to an increasing extend contribute to low-price base load rather than peak or mid load. Moreover the capacity credit is further reduced. The new concept combines the social cost perspective of LCOE with the argument of electricity not being a homogenous good. The latter argument has so far been analyzed from an investor's perspective in literature focusing on market values of variable renewables (e.g. Joskow 2011). We show that System LCOE are equivalent to market values. With System LCOE we suggest an improved metric of estimating and comparing the social value of technologies especially of different types of VRE most importantly wind power and solar PV.

Methods

In this subsection System LCOE are briefly derived. In the paper this will be described in detail. We extend a method from (Green 2005) that uses screening curves and a load duration curve (LDC) to derive optimal capacities and generation of the long-term equilibrium. The concept can be easily adjusted to a short-term perspective to evaluate VRE in the transition phase.

Standard LCOE depend on the capacity factor of the respective technology. These LCOE curves correspond to the standard screening curves. An optimal capacity mix can be derived by choosing the least-cost technology for every capacity factor in the LDC (Figure 1). The average LCOE can be derived by integrating over the area of the LDC and multiplying with the corresponding LCOE value.

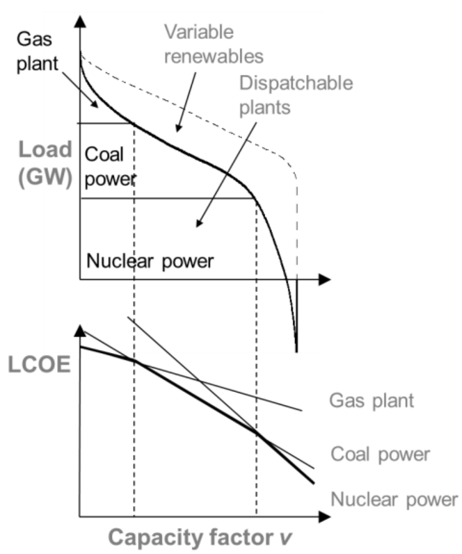

Figure 1

With VRE the LDC changes into a RLDC. The system is shifted into a new long-term equilibrium. Because VRE are introduced here exogenously, the new average LCOE of the system is higher.

VRE increase the system costs not only by their standard $LCOE_{VRE}$. Moreover they increase the specific costs of covering the residual load, because the full load hours of dispatchable plants decrease with VRE.

The absolute difference ΔC is the system cost increase due to VRE. System LCOE of VRE are defined as the sum of standard LCOE of VRE and the induced system cost increase per generated unit of VRE (equation 1).

$$SystemLCOE_{VRE} = LCOE_{VRE} + \frac{\Delta C}{G_{VRE}} \qquad (1)$$

G_{VRE} is the generation of VRE.

Results

The long-term costs of VRE for Germany are calculated using the concept of System LCOE presented in this paper.

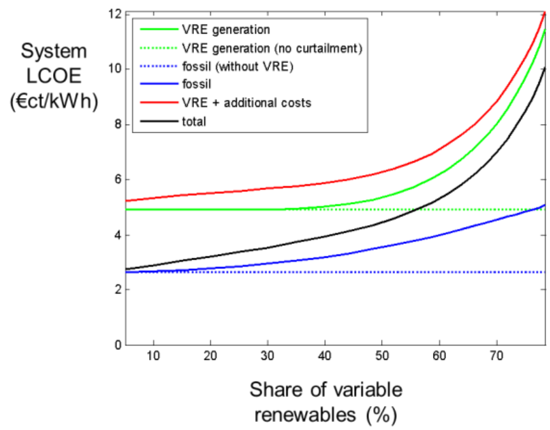

Figure 2

Costs are calculated for increasing shares of VRE (Figure). The green dashed curve shows standard LCOE. They are independent of the deployment level of VRE. The red curve corresponds to System LCOE of VRE. They significantly increase due to system implications. Hence the deficits of standard LCOE are striking. The new concept leads to a very different and more realistic cost evaluation of VRE.

However, the major cost increase is caused by the consideration of curtailment. This can be seen by comparing the solid green curve (curtailment effect) with the dashed green curve (standard LCOE). The standard concept of LCOE can be extended to account for that without necessarily applying System LCOE. The additional system costs that can be only captured by the new metric are small (~10%). This can be seen by comparing the solid red curve (System LCOE) with solid green curve (curtailment effect). These system effects already occur at low and middle VRE shares (<50%).

Evaluating VRE within transition phase leads to higher cost increases because the residual power system is not yet fully adapted to the introducing of VRE.

Conclusions

'System LCOE' is new metric for evaluating VRE in the short and long-term perspective. It accounts for system implication of VRE e.g. the reduction of full load hours of conventional power plants. Unlike standard LCOE, System LCOE account for increasing system costs due to VRE. A calculation of System LCOE of wind and solar for Germany shows that the costs of VRE significantly increase with increasing share. With System LCOE we suggest an improved metric of estimating and comparing the social value of technologies especially of different types of VRE most importantly wind power and solar PV.

References

(IPCC 2011) uses LCOE as a metric to compare VRE with fossil power plants. (Joskow 2011) argues that LCOE are not a suitable metric for evaluating VRE because their output is variable. An investor's perspective should be applied and market revenues of VRE need to be compared with their costs. (Hirth 2012) analyzes Joskow's argument in detail. He shows that the market value of VRE significantly decreases with increasing VRE share due to system effects. This paper combines the social cost perspective of the LCOE metric with the consideration of system effects. It suggests a new metric for policy makers.

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