Impact of storage efficiency and charging costs on storage profitability in the electricity market

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Overview

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The increasing share of intermittent renewable energy sources (iRES) in the electricity system leads to an increasing interest for investments in different electricity storage options. One metric to evaluate the profitability of possible investments is the levelized cost metric. For both dispatchable and non-dispatchable electricity generation technologies, a well-established metric is the levelized cost of electricity (LCOE) [1]. In this work three novel levelized cost metrics similar to the levelized cost of electricity but applied to electricity storage are presented and analyzed. Specific focus is on the impact of several key parameters on these new cost metrics.

Methods

Similar to the levelized cost of electricity, the levelized cost of storage could be defined as *the fictitious average electricity price during discharging needed over the lifetime of the storage plant to break even the full costs for the investor (including rate of return)* [2]. Since storage uses the same commodity (electricity) as input (to charge) and as output (to discharge), an additional metric can be defined which focus on the price difference of input and output electricity rather than on the absolute value of the generated, or discharged, electricity. To make a clear distinction between both cost metrics, their naming is focused on the electricity prices, and like the LCOE for generation, one can reformulate the definitions in terms of the required electricity prices for break even. As a result, for storage, we define the *Required Average Discharge Price* (RADP) and the *Required Average Price Spread* (RAPS). An overview of the mathematical formulation of each metric is given in Eqs. (1) and (2). The derivation of these expressions can be found in [2].

$$\mathrm{RADP} = \frac{\sum(Capital_t + O\&M_t + TCC_t)\cdot(1+r)^{-t}}{\sum MWh_t^d(1+r)^{-t}} \quad (1)$$

$$\mathrm{RAPS} = RADP - ACC \quad (2)$$

$\mathrm{Capital}_t$	= Total capital expenditures in year t
$\mathrm{O\&M}_t$	= Fixed operation and maintenance costs in year t
TCC_t	= Total charging cost in year t
ACC	= Average charging cost
MWh^d_t	= Amount of electricity discharged in MWh in year t
$(1+r)^{-t}$	= The discount factor for year t

From Eqs. (1)-(2), it is clear that the total charging cost and average charging cost have a major impact on the value of the required average discharge price (RADP) and the required average price spread (RAPS). The total charging cost, which is equal to the average charging cost per unit of charged electric energy multiplied by the total amount of charged electric energy, is in turn influenced by the round-trip efficiency, which determines the total amount of energy which needs to be charged. Therefore, a sensitivity analysis is presented which analyzes both the influence of the average cost per unit of charged electric energy (the average charging cost, ACC) and the influence of the round-trip efficiency on the values of the RADP and RAPS.

Results

The required average discharge price and required average price spread are determined for different average charging costs and round-trip efficiencies and are shown in Figures 1 and 2. The slopes of the sensitivity can be calculated as the partial derivatives of Eqs. (1) and (2) with respect to the ACC as given below in Eqs. (3) and (4) and with respect to the efficiency in Eqs. (5) and (6).

$$\frac{\partial \mathrm{RADP}}{\partial \mathrm{ACC_t}} = \frac{\sum(1+r)^{-t}}{\eta_{RT}} \quad (3)$$

$$\frac{\partial \mathrm{RAPS}}{\partial \mathrm{ACC_t}} = \frac{(1-\eta_{RT})\sum(1+r)^{-t}}{\eta_{RT}} \quad (4)$$

$$\frac{\partial \mathrm{RADP}}{\partial \eta_{RT}} = \frac{-\sum ACC_t\cdot(1+r)^{-t}}{\eta_{RT}^2} \quad (5)$$

$$\frac{\partial \mathrm{RAPS}}{\partial \eta_{RT}} = \frac{-\sum ACC_t\cdot(1+r)^{-t}}{\eta_{RT}^2} \quad (6)$$

From Eqs. (3) and (4) and Figure 1, it is clear that both the RADP and the RAPS scale linearly with a variation of the ACC. However, both metrics scale with a different magnitude, equal to $(1 - \eta_{RT})$. This can be understood as the RADP accounts for the full cost of charged electricity, while the RAPS only covers the cost due to efficiency losses. The RAPS does not account for the cost of charged electricity which can be discharged on a later moment. Therefore, the RAPS is less sensitive to a change in ACC than the RADP. Furthermore, from the right panel of Figure 1, it can be seen that the RAPS becomes insensitive to a change in ACC when the round-trip efficiency would be 100% as in this case there would be no efficiency losses.

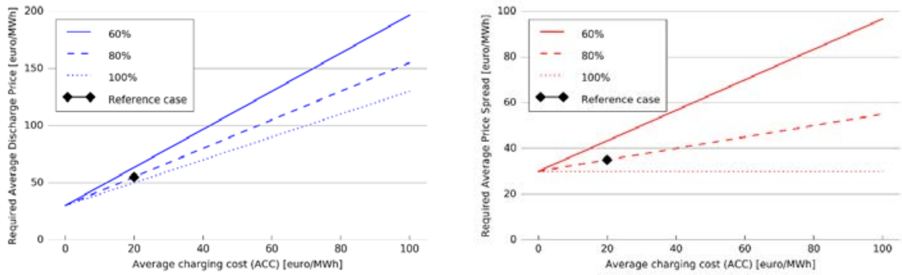

Figure 1: Sensitivity of the required average discharge price, RADP (left panel) and the required average price spread, RAPS (right panel) to different average charging costs. This is done for different round-trip efficiencies between 60% and 100%.

Eqs. (5) and (6) clearly show that the required average discharge price and the required average price spread are equally sensitive to a change in round-trip efficiency. This can be understood from the fact that both metrics account for the cost of efficiency losses. Furthermore, Figure 2 illustrates that the RADP and RAPS become equal when the average charging cost is zero.

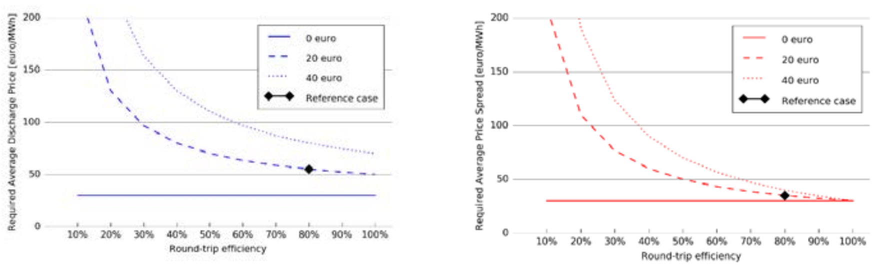

Figure 1: Sensitivity of the required average discharge price, RADP (left panel) and the required average price spread, RAPS (right panel) to different round-trip efficiencies. This is done for different average charging costs (ACC) between 0 and 40 euro.

Conclusions

The sensitivity of two levelized cost metrics applied to storage, i.e., the required average discharge price (RADP) and the required average price spread (RAPS), with respect to a change in average charging cost (ACC) and round-trip efficiency is determined. Results clearly show that the RADP is more sensitive to a change in ACC than the RAPS and that both become equal when the ACC is zero. Furthermore it is shown that the RAPS is insensitive to a change in ACC when the round-trip efficiency is 100%

References

[1] IEA, NEA, Projected Costs of Generating Electricity, Paris: OECD: IEA and NEA, 2015.

[2] Belderbos, A., Delarue, E., Kessels, K., D'haeseleer, W. 2016. The levelized cost of storage critically analyzed and its intricacies clearly explained. TME-Working Paper, WP EN2016-11, unpublished. [Online] Available at: http://www.mech.kuleuven.be/ en/tme/research/energy_environment/PublicationsEnergyandenvironment/Journalpapers.