THE TRADITIONAL "LEVELISED COST OF ENERGY" [LCOE] IS NOT AN INDICATOR FOR GRID PARITY

Ulrich Nissen, Niederrhein University of Applied Sciences, Phone +49 2161 186 6386, E-mail: ulrich.nissen@hs-niederrhein.de
Nathanael Harfst, Niederrhein University of Applied Sciences, Phone +49 2161 186 6464, E-mail: nathanael.harfst@hs-niederrhein.de

Overview

The "Levelised Cost Of Energy" [LCOE] is a widespread indicator that is used in order to determine whether or not a renewable energy supply technology is profitable. It is traditionally calculated by dividing the net present value (NPV) of the capital investment of a technology by the discounted energy yields generated by that technology resulting in costs per kWh (e.g. €/kWh) as shown in formula 1.

Formula 1: $$LCOE = \frac{\sum_{t=0}^{T} \frac{P_t}{q^t}}{\sum_{t=0}^{T} \frac{E_t}{q^t}} \left[\frac{€}{kWh} \right].$$

The evaluation of a technology by using the LCOE is quite simple. It is done by comparing the calculation result with the relevant specific costs of the conventional energy that might be replaced (e.g. LCOE of 0.22 €/kWh for a photovoltaic system vs. 0.26 €/kWh for conventional electricity). If the LCOE is lower than these specific costs, the investment is assumed to be profitable, and vice versa. The moment in which the LCOE is equal to the relevant specific energy costs is called "grid parity" because energy can be generated at the same costs as it can be bought.

The derivation of the LCOE formula results from the idea that grid parity is achieved as soon as all payments in and out (including the energy yields) lead to a positive net present value (NPV). If the NPV equals zero, we have a break-even situation. This would mean that grid parity has exactly been reached as shown in formula 2.

Formula 2: $$NPV = \sum_{t=0}^{T} \frac{E_t \cdot p_t - P_t}{q^t} \stackrel{!}{=} 0$$

with:
P_t := payment in period t [€]
q := interest factor (1 + i) with i := reference interest rate
p_t := specific price for sold or saved energy [€/kWh] in period t
p := specific price for sold or saved energy (constant) [€/kWh]
E_t := energy supply or energy saving in period t [kWh]

This formula can be rearranged as follows:

Formula 3: $$NPV = \sum_{t=0}^{T} \frac{E_t \cdot p_t}{q^t} - \sum_{t=0}^{T} \frac{P_t}{q^t} \stackrel{!}{=} 0$$

Formula 4: $$\sum_{t=0}^{T} \frac{E_t \cdot p_t}{q^t} \stackrel{!}{=} \sum_{t=0}^{T} \frac{P_t}{q^t}.$$

The variable, that has to be determined, is p_t, which is the – fictive – specific price of the replaceable energy that would lead to a grid parity situation (and therefore is congruent with the LCOE).

Therefore we may put p_t in front of the sigma sign as follows …

Formula 5: $$\overline{p} \cdot \sum_{t=0}^{T} \frac{E_t}{q^t} \stackrel{!}{=} \sum_{t=0}^{T} \frac{P_t}{q^t} \quad ...$$

…, but only if this specific price is **constant** over the whole lifetime of the investment. Only in that particular case can the index "t" be taken away. The result of the next formula transformation would then be …

Formula 6: $$p \overset{!}{=} \frac{\sum_{t=0}^{n} \frac{P_t}{q^t}}{\sum_{t=0}^{n} \frac{E_t}{q^t}} = LCOE$$

... in which we may call the right side "LCOE" and which makes clear that the beak-even point is reached when the specific price "p" of replaceable energy exactly coincides with the LCOE of an evaluated (renewable) energy technology.

And right at this point of the derivation there is an essential limitaton that needs to be pointed out. As mentioned before, the extraction of p_t out of the sigma can only be done **if the specific price of the replaceable energy is constant over the whole lifetime of the project.** This is correct if – for instance – feed-in tariffs are given (these are usually constant). But as more and more self-generated energy is used direcly, the value of a kWh is not determined by a given feed-in tariff but instead by the relevant energy market price. Looking at the development of energy prices over the last decade we see that those specific prices are not constant over time.

Methodology

Hypothesis test, deductive approach.

Results

In our paper we show that a positive NPV can be generated (and therefore grid parity be achieved) with case data that would lead to a "traditional LCOE" which is higher than the specific costs of the energy that might be replaced. This is contradictory to the definition of grid parity (see above) and makes clear: The <u>traditional</u> LCOE is not an indicator for grid parity and should therefore be adjusted.

The following formula is the result of our work and can be used for calculating LCOEs considering both volatile energy prices (at constant rates) and degradation:

Formula 7: $$Energy\ price\ adjusted\ LCOE = \frac{\sum_{t=0}^{T} \frac{P_t}{q^t}}{\bar{E} \cdot \sum_{t=1}^{T} \frac{(1+epr)^t \cdot (1-\mathrm{d})^{t-1}}{q^t}}$$

with: E := initial annual energy yield, epr := energy price rise rate [%/a], d := degradation rate [%/a].

It is derived from the NPV and allows the analyst to adjust – besides degradation rates (d) – annual energy price changes (epr) as well as OPEX price changes (incorporated in P_t). As long as the energy price rise rates epr are assumed to be constant over time in reality the "Energy price adjusted LCOE" delivers accurate decision-oriented indicator values.

In order to improve the accuracy of the calculation even more, the "Energy price adjusted LCOE" can be modified further so that it incorporates volatile – not constant – energy price rise <u>rates</u>, volatile discount rates, volatile degradation rates and volatile OPEX price rise rates. As such a modified scheme enables the user to adjust all relevant parameters we call it "Total LCOE" or "TLCOE".

Formula 8: $$Total\ LCOE = \frac{CAPEX_0 + \sum_{t=1}^{T} \frac{OPEX_t \bullet aopr_t}{aq_t}}{\sum_{t=1}^{T} \frac{aepr_t \bullet E_1 \bullet ad_t}{aq_t}}.$$

In our paper we derive these new LCOE calculation approaches from their origin (the Net Present Value), explain all adjustment parameters ($aopr_t$, aq_t, $aepr_t$, E_t and ad_t), and exemplify the application of the LCOE formulas in spreadsheet tables.

Conclusions

The traditional LCOE is not an indicator of grid parity. Therefore it is incorrect to believe that in general a public promotion of renewable energy systems is necessary as long as the traditional LCOE of a particular system lies above the price of conventional energy that shall be replaced. The traditional LCOE is not appropriate for that. It does not fit. We need a new formula which allows us to calculate the LCOE and grid parity by taking rising energy prices into account. Such a formula will be presented in Bergen.