



LCOE calculation methodology

Methodology for the LCOE web calculator.

June 28, 2022

Félix Ignacio Pérez Cicala

Mario Bennekers Vallejo



Abstract

The Levelized Cost of Energy (LCOE) is an economical metric which represents the cost of producing electricity. It takes into account the raw energy output of the plant, the cost of building the plant, the cost of operating the plant, and the number of years the plant will operate for. It also considers the discount rate associated with future costs and cash inflows.

It is used as a metric for benchmarking and comparing the cost-effectiveness of different energy generation technologies¹. Additionally, it is also used in the design process of PV plants to evaluate the impact of technical decisions in the cost of electricity.

This methodology defines a calculation model which is used in the "LCOE calculator tool". The simplifications concern the calculation of the energy output of the PV plant.

¹"A review of solar photovoltaic levelized cost of electricity," *Renewable and Sustainable Energy Reviews*, vol. 15, no. 9, pp. 4470–4482, 2011. DOI: <https://doi.org/10.1016/j.rser.2011.07.104>.

Inputs

The following inputs are required from the user for this calculation:

- Latitude and longitude where the PV plant is located.
- The type of mounting structure, either SAT (single axis tracker), fixed structure, or east west structure.
- Peak DC capacity of the plant.
- Specific CAPEX, the cost of building the PV plant per peak capacity watt, usually given in \$/kWp.
- Specific OPEX, the cost of operating the PV plant per peak capacity watt, usually given in \$/kWp.
- The return rate, usually given in percentage points.

The following inputs for the calculation are internal:

- A database of global horizontal irradiation.
- Transposition gain value for the selected structure type, see Appendix 1.
- Performance ratio value for the selected structure type, see Appendix 2.

Calculation process

The calculation process to obtain the LCOE is described in this section.

The first is to get the global horizontal irradiation (GHI) for the location. The calculator tool uses an internal GHI database for this purpose, but there are tools which are publicly available^{2, 3}.

To obtain the plant production, the plant efficiency is required. An estimate of the specific production will be used, which represents the raw output per kW peak of plant capacity. Use equation (1) to calculate the specific production of the PV plant. Equation (1) was derived from the equation for the performance ratio⁴, and the equation for the specific capacity, which is the division of plant production by plant peak power.

$$E_{\text{spec}} = \text{GHI} \cdot \text{TG} \cdot \text{PR} \quad (1)$$

Where:

- E_{spec} is the specific production in kWh/kWp.
- GHI is the global horizontal irradiation in kWh/m².
- TG is the performance gain due to transposition to the plain of the array, in parts per one. See Appendix 1.
- PR is the performance ratio of the PV plant, in parts per one. Default value can be found in Appendix 2.

With the specific production, the raw output of the plant can be calculated using equation (2).

$$E_{\text{grid}} = E_{\text{spec}} \cdot W_{\text{peak}} \quad (2)$$

Where:

- E_{grid} is the raw output of the plant, energy injected to the grid in kWh.
- E_{spec} is the specific production in kWh/kWp.
- W_{peak} is the peak capacity of the PV plant, in kW.

To calculate the cost of building the PV plant, known as capital expenditure (CAPEX), use equation (3). This equation assumes that the cost of building the PV plant is paid upfront in the year zero. Financing costs could be indirectly included as part of the specific CAPEX value.

$$\text{CAPEX} = \text{CAPEX}_{\text{spec}} \cdot W_{\text{peak}} \quad (3)$$

²Prediction Of Worldwide Energy Resources (POWER) project. "Nasa power data access viewer." (2022), [Online]. Available: <https://power.larc.nasa.gov/data-access-viewer/> (visited on 06/28/2022).

³European Commission. "Pvgis photovoltaic geographical information system." (2022), [Online]. Available: https://re.jrc.ec.europa.eu/pvg_tools/en/ (visited on 06/28/2022).

⁴I. E. Commission, "Photovoltaic system performance monitoring - guidelines for measurement, data exchange and analysis," IEC 61724, 1998.

Where:

- CAPEX is the cost of building the PV plant, in dollars.
- CAPEX_{spec} is the specific CAPEX, the cost of building the PV plant per kW peak of plant capacity, in dollars per kWp.
- W_{peak} is the peak capacity of the PV plant, in kW.

To calculate the costs associated with operating the plant, known as operation expenditures (OPEX), use equation (4).

$$\text{OPEX}_u = \sum_{i=0}^n \frac{\text{OPEX}_{\text{spec}} \cdot W_{\text{peak}}}{(1+r)^{1+i}} \quad (4)$$

Where:

- OPEX_u is the updated OPEX to n years, in dollars.
- n is the number of years for the calculation.
- i is the year, zero-based (the first year is year zero, 25th year is year 24).
- OPEX_{spec} is the specific OPEX, the cost of operating the plant per peak capacity watt, in dollars per kWp.
- W_{peak} is the peak capacity of the PV plant, in kW.
- r is the rate of return, in parts per one.

The energy output of the pv plant over the years of the calculation, updated with the return rate, can be obtained using equation (5). This formulation does not consider PV module degradation.

$$E_{\text{grid},u} = \sum_{i=0}^n \frac{E_{\text{grid}}}{(1+r)^{1+i}} \quad (5)$$

Where:

- E_{grid,u} is the updated energy production to n years, in kWh.
- n is the number of years for the calculation.
- i is the year, zero-based (the first year is year zero, 25th year is year 24).
- E_{grid} is the raw output of the plant, energy injected to the grid in kWh, calculated using equation (2).
- r is the rate of return, in parts per one.

Finally, use equation (6) to calculate the LCOE. Equation (6) is a simplification of the LCOE calculation⁵ which does not consider the residual value of the PV plant.

⁵E. Vartiainen et al., "Impact of weighted average cost of capital, capital expenditure, and other parameters on future utility-scale pv levelised cost of electricity," *Progress in Photovoltaics: Research and Applications*, vol. 28, no. 6, pp. 439–453, 2020. doi: <https://doi.org/10.1002/pip.3189>.

$$\text{LCOE} = \frac{\text{CAPEX} + \text{OPEX}_u}{E_{\text{grid},u}} \quad (6)$$

Where:

- LCOE is the levelized cost of energy, in dollars per kWh.
- CAPEX is the cost of building the PV plant, in dollars, calculated using equation (3).
- OPEX_u is the updated OPEX to n years, in dollars, calculated using equation (4).
- $E_{\text{grid},u}$ is the updated energy production to n years, in kWh, calculated using equation (5).

Appendix 1

To calculate the theoretical transposition gain, empirical formulas were derived from simulations ran with pvDesign.

To calculate the transposition gain of SAT, use equation (7).

$$TG_{\text{sat}} = \begin{cases} 1.173 + 0.012 \cdot |x| - 3.27 \cdot 10^{-4} \cdot |x|^2 + 2.88 \cdot 10^{-6} \cdot |x|^3 & \text{if } |x| < 60 \\ 1.3378 & \text{if } |x| \geq 60 \end{cases} \quad (7)$$

Where:

- TG_{sat} is the performance gain due to transposition to the plain of the array for trackers, in parts per one.
- x is the latitude of the PV plant, in degrees.

To calculate the transposition gain of fixed structures, use equation (8).

$$TG_{\text{fixed}} = \begin{cases} 1.00294 + 2.33 \cdot 10^{-3} \cdot |x| + 3.28 \cdot 10^{-5} \cdot |x|^2 & \text{if } |x| < 60 \\ 1.26 & \text{if } |x| \geq 60 \end{cases} \quad (8)$$

Where:

- TG_{fixed} is the performance gain due to transposition to the plain of the array for fixed structures, in parts per one.
- x is the latitude of the PV plant, in degrees.

To calculate the transposition gain of east west structures, use equation (9).

$$TG_{\text{ew}} = 1.0 \quad (9)$$

Where:

- TG_{ew} is the performance gain due to transposition to the plain of the array for east west structures, in parts per one.

Appendix 2

The following performance ratios are used as default values in the calculator tool. Please note that the same values are used for all locations. These values are only meant as an initial estimate.

- For single axis trackers, the default performance ratio will be 0.85.
- For fixed structures and east west structures, the default performance ratio will be 0.8.