COMMODITY UPDATE: ELECTRICITY

CANADIAN ENERGY RESEARCH INSTITUTE

April 2020

Using System Levelized Cost, Levelized Avoided Cost and Value-Adjusted Levelized Cost to Evaluate Electricity Generation Technologies

By Ganesh Doluweera

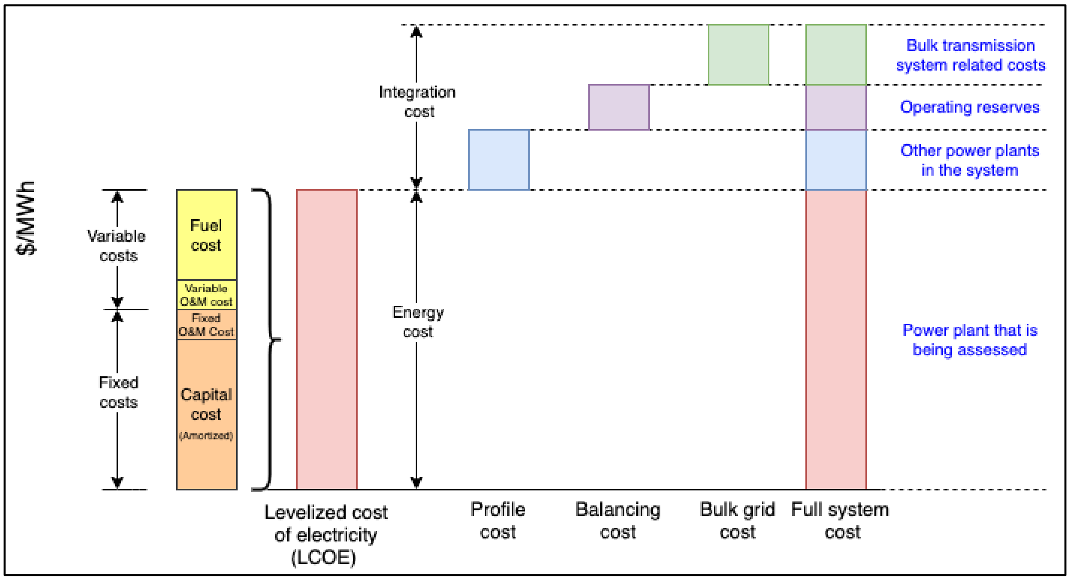
Economic evaluations of alternative electricity generating options are required to inform investment, regulatory, and policy decisions that pertain to electricity generation. The well-understood and most widely used metric for economic evaluation of alternative generating technologies is the levelized cost of electricity (LCOE). Despite its widespread usage, LCOE is now being criticized for its limitations. This article summarizes alternative methodologies in evaluating costs of electricity generation.

Background

The LCOE of an electricity generating unit is estimated by dividing the total fixed and variables costs, over the unit's financial life, by its electricity production over the same period (See [1]–[3] for full calculation details)[1]. Fixed costs include capital costs, financing costs, and fixed operating and maintenance (O&M) costs. Variable costs include variable O&M costs and fuel costs (Figure 1). LCOE estimation is based on net present value evaluation, which is a well understood economic assessment method. At the point of estimation of the LCOE of generating technology, not all information (e.g., investment and operating costs, electricity production over the financial life) is available and assumptions are made. Given the relative simplicity of the estimation procedure, detailed sensitivity assessments and uncertainty assessments can be made to manage the uncertainty introduced by the assumptions to calculate LCOE estimations. Furthermore, LCOE compresses a large amount of information pertaining to a given generating technology into a single metric.

[1] Provision of the full mathematical definitions and calculation procedure of alternative metrics described is beyond the scope of this article. Interested readers are encouraged to reference the cited literature. Publicly available references are provided for all metrics.

Figure 1 – Different Components of LCOE and Integration Costs



Note: The figure is partially adopted from [4] and prepared by CERI.

From the power generating unit owner's perspective, the LCOE represents the total revenue requirement per unit of electricity produced over its financial life. From a public/regulatory policymakers' perspective, the LCOE represents the long-run marginal cost of an incremental unit of electricity to the power system. LCOE has been used to compare alternative power generation technologies and, generally, the technology with the lowest LCOE is desired.

LCOE is now being criticized for its limitations for economic evaluations of electricity generating technologies. The main criticism of LCOE is that this metric doesn't represent the economic value or indirect costs to the system, and it is poor for comparing technologies that have different operating profiles [5], [6].

This latter limitation becomes more pronounced when comparing variable generating technologies (e.g., wind or solar) with dispatchable generating technologies (e.g., natural gas-fired combined cycle or reservoir-based hydropower). Variable generating technologies could potentially add indirect costs to the power system, while dispatchable units could potentially add capacity value. Neither is taken into account in the calculation of LCOE. As argued by Joskow in [6], a metric used for economic evaluation of a given power generating technology should capture both its costs and the economic value. For example, the ability of a merchant power plant to maximize its revenue due to its unconstrained dispatchability is not captured by LCOE.

In the past one way to address this limitation has been to build in technologies and costs to create firm or dispatchable renewable options. Storage is one approach to creating quasi-dispatchable options. Another approach is to have dispatchable stand-by generation.

The limitations of LCOE have become more apparent with the growth in the integration of variable renewable energy (VRE) based generation technologies. LCOE does not capture any potential indirect costs that would be incurred by the electricity system due to VRE integration. Alternative economic evaluation metrics are being introduced to address LCOE limitations. In general, these alternative metrics propose the estimation of an *integration cost*[2] to complement the LCOE of a given generating technology (Figure 1).

System LCOE

The integration cost is generally defined as the extra investment and operational cost of the rest of the power system when a certain generating technology is integrated [4], [7]. In [4], Ueckerdt et al. split the integration cost into three main categories, namely *profile cost*, *balancing cost*, and *grid cost* (Figure 1).[3]

The *profile cost* mainly takes into account the impact of the generating technology that is being assessed on the other units in the system, the capacity value, and the temporal correlation (or lack thereof) with the demand. For example, the addition of a VRE (e.g., a wind power plant) could potentially reduce the full-load hours of the dispatchable power plants in the system. Therefore, the average generation costs per unit of electricity produced by the residual system increases due to surplus capacity. Similarly, VRE has marginal capacity value and, due to their lower capacity credit, the addition of a VRE does not reduce the backup capacity requirements. Furthermore, at high penetration levels, there may be times where VRE generation exceeds load and overproduction may need to be curtailed, increasing the average cost of the VRE.

Balancing costs occur as a result of changes in operating reserve requirements due to the integration of a given generating unit. For example, day-ahead forecast errors and short-term variability of VRE may increase operating reserve requirements, increasing the system cost. *Grid costs* occur due to costs associated with bulk transmission investments and operational costs such as increased congestion management costs pertaining to integration and operation of a given generating technology.

By using their extended definition of the integration cost, Ueckerdt et al. develop a new metric for the economic evaluation of electricity generating technologies called the *System LCOE* (see [4] for full details and calculation methods). Ueckerdt et al. develop a mathematical definition of integration costs that directly relates to economic theory and proposes a model to estimate the profile cost. In [4], Ueckerdt et al. estimate the system LCOE of wind power and solar power in Germany. They show that the new definition of integration costs corresponds to a decrease in the market value of VRE with increasing penetration.

Levelized Avoided Cost of Electricity (LACE)

The U.S. Energy Information Administration has introduced another alternative metric called *Levelized Avoided Cost of Electricity* (LACE) to assess a given power generating unit's value to the grid [8]. LACE is estimated based on the marginal value of energy and capacity that would result from adding a unit of a given technology to a power system in its current form or its projected form at a specific future date. LACE is defined as the costs that would be incurred to provide the electricity displaced by a new generating unit. The avoided cost is interpreted as the revenue available to the new generating unit (See [3] for calculation details). The LACE estimation process requires information about how the system would operate without the new option. It accounts for both diurnal

[2] Some metrics take the integration cost as a proxy for the *system value* of a given generating technology.

[3] Ueckerdt et al. primarily look at the integration cost of VRE. This article adapts their work and provides a technology agnostic definition of integration cost.

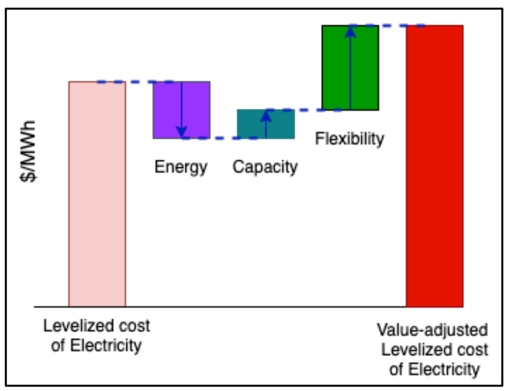
and seasonal variations in electricity demand and the characteristics of the existing generation fleet to which new capacity will be added.

LACE is a complementary metric to LCOE. The more important insight is the relative difference between the two metrics. As LACE represents the system value, a new generating unit can be considered economically attractive in a given power system if the unit's LACE exceeds LCOE. LACE only measures the energy value of a new generating unit and does not provide insights into balancing and other grid-related costs.

Value-adjusted LCOE (VALCOE)

The International Energy Agency (IEA) has developed a new metric called Value-adjusted LCOE (VALCOE) to measure the competitiveness of new generating technologies. The metric was first developed and reported in the 2019 edition of the IEA's *World Energy Outlook* report and it is intended to complement LCOE [5]. VALCOE enables comparisons of different power generation technologies by taking into account both their costs and values. As shown in Figure 2, VALCOE estimation starts with LCOE and adds three elements of a given power generating unit: energy, capacity and flexibility (See [5] for calculation details). In the IEA's estimation, the adjustments for energy, capacity, and flexibility are done by utilizing an hourly power supply simulation model.

Figure 2 – Estimation of VALCOE



Note: The figure is adopted from [5]

In Figure 2, the *energy value* represents the market value of the electricity produced by a unit of given generating technology by taking into account any applicable temporal variations and constraints in the unit's ability to produce electricity (for example, temporal variation of resource availability for VRE technologies). The *capacity value* reflects the contribution of a unit of given generating technology to system adequacy. Technology specific procedures are employed to estimate the capacity value (i.e., the procedure is differentiated for dispatchable versus VRE technologies). The *flexibility value* estimation takes into account the technology specific flexibility multiplier and the base flexibility of the system. In other words, the flexibility value measures the impact made by a new generating unit to the system flexibility. In the current form, the VALCOE does not take into account any costs or value associated with the transmission system (e.g., adjusting the value for the costs associated with transmission system expansions due to the addition of generating unit.)

Technologies with high VALCOE can be considered more competitive under the assumed technical and market conditions. The VALCOE varies by technology depending on the operating profiles and the host power system specific conditions. For example, dispatchable peaking units would have high LCOE, but also relatively high value per MWh. Baseload technologies tend to have small value adjustments and, therefore, LCOE and VALCOE would closely follow. For VRE, VALCOE depends mainly on the resource and production profile, their correlation with the demand, and the share of variable renewables already in the system.

Value of Alternative Metrics

LCOE has long been used as the metric used for economic evaluations of electricity generation technologies. However, it lacks representation of the economic value of a unit of given generating technology. Furthermore, it does not represent the indirect cost a generating unit would add to the host power system. The three alternative metrics described in this article complement the LCOE by estimating integration cost or system value. Since these are systems-level metrics, they cannot be estimated using plant-level information. Reliable estimation of those metrics requires systems-level analysis and simulation tools and, therefore, computationally expensive. Furthermore, the sophisticated procedure can introduce a higher amount of uncertainty into the estimated metric.

Nonetheless, alternative metrics for each integrated system provide valuable information for investors and policymakers. For example, System LCOE can suggest the optimal level of VRE penetration. LACE and VALCOE provide complete information about the competitiveness of a certain generating technology.

A higher level of collaboration among the energy system modeling community, government institutions, and electric power system operators is required to develop data sets and models to facilitate reliable estimations of systems-level metrics for economic evaluations of electricity generating technologies.

References

[1] D. M. Kammen and S. Pacca, “Assessing the Cost of Electricity,” *Annu. Rev. Environ. Resour.*, vol. 29, pp. 301–344, Nov. 2004, doi: 10.1146/annurev.energy.28.050302.105630.

[2] IEA/NEA, *Projected Costs of Generating Electricity - 2015 Edition*. Paris: OECD, 2015.

[3] C. Namovicz, “Assessing the economic value of new utility-scale renewable generation projects.,” presented at the EIA Energy Conference, Washington, DC, 2013.

[4] F. Ueckerdt, L. Hirth, G. Luderer, and O. Edenhofer, “System LCOE: What are the costs of variable renewables?,” *Energy*, vol. 63, pp. 61–75, Dec. 2013, doi: 10.1016/j.energy.2013.10.072.

[5] IEA, “World Energy Model Documentation - 2018,” International Energy Agency, Paris, 2018. [Online]. Available: https://www.iea.org/reports/world-energy-model/documentation.

[6] P. L. Joskow, “Comparing the Costs of Intermittent and Dispatchable Electricity Generating Technologies,” *Am. Econ. Rev.*, vol. 101, no. 3, pp. 238–241, May 2011, doi: 10.1257/aer.101.3.238.

[7] R. Sims *et al.*, “Integration of renewable energy into present and future energy systems,” 2011.

[8] EIA, “Levelized cost and levelized avoided cost of new generation resources in the annual energy outlook 2017,” Energy Information Administration, U.S. DOE, 2017. [Online]. Available: https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf.

CERI Electricity Report

Editorial Committee: Ganesh Doluweera, Dinara Millington, Allan Fogwill

About CERI

CERI provides decision-makers in government, industry and other market segments with analyses of economic and environmental issues in the energy production, transportation and consumption sectors. The institute is an independent, registered charitable organization funded by government, industry, associations, academic supporters and by individual donations.

For more information about CERI, please visit our website at www.ceri.ca or contact us at info@ceri.ca.