Cost of Utility-Scale Solar: One Quick Way to Compare Projects

Submitted by David Feldman on Fri, 12/09/2011 - 12:37pm

How can someone compare two energy projects to determine which is more cost-effective? The levelized cost of energy (LCOE), usually measured in dollars per kWh, is an informative metric when used appropriately. LCOE allows one to compare the costs of a single technology or between different technologies as their costs change over time. He or she can simply add up all the costs of building and maintaining the electric generating system and divide by the amount of energy produced. It gets more complicated when taking into account things like the discount rate of money, taxes, and the lifetime of a project; however, if one has a general idea of a technology and a marketplace, he or she can get a rough idea of the attractiveness of a particular project.

To compare large-scale solar projects in terms of both upfront cost and LCOE, I collected publicly available data from solar-generation projects that received loan guarantees, as well as other recently installed (Dec. 2010 – Aug. 2011) utility-scale PV projects. Because I had limited information of these projects, my calculations were based on a simplistic LCOE formula (included below). If I had had more information on the details of project cost, performance over time, and financing terms, I would have used one of the National Renewable Energy Laboratory's (NREL) LCOE calculators: (System Advisor Model (SAM) or the Cost of Renewable Energy Spreadsheet Tool (CREST).

My first step to determine each project's LCOE was to make some very basic assumptions about the cost, performance and lifetime of the different types of systems under investigation.

Table 1: Large-Scale Solar: Underlying LCOE assumptions

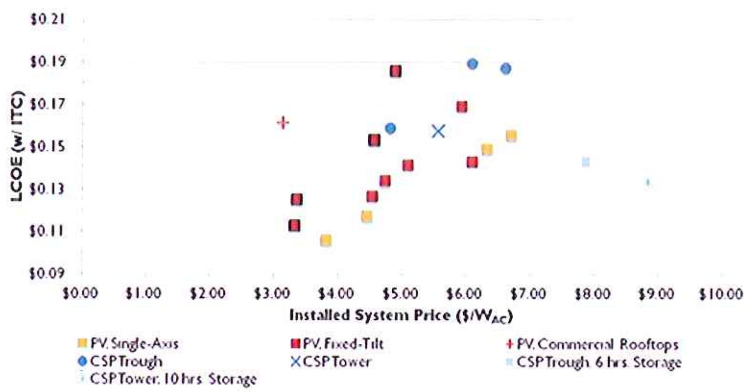
		Replacement Cost of Inverter ($/WAC)	**Replacement Year of Inverter**	**Fixed O&M ($/kWAC per year)**	**Tax Basis**	**Rate of Return (Real)***	**Lifetime (years)**
PV	Utility Scale, Fixed-Axis	$0.25	15	$15.94	38.9%	7%	30
	Utility Scale, Single -Axis	$0.25	15	$19.93	38.9%	7%	30
	Commercial Scale	$0.25	15	$25.00	38.9%	7%	30
CSP	Trough/Tower, no Storage	NA	NA	$70.00	38.9%	7%	30
	Trough/Tower, 6 hrs. Storage	NA	NA	$77.00	38.9%	7%	30
	Trough/Tower, 10 hrs. Storage	NA	NA	$87.50	38.9%	7%	30

Table 1 shows the generic assumptions used in performing the LCOE analysis.
**This is a standard DOE assumption. By holding this constant we can better compare non-financing aspects of the projects.*

With the above assumptions as my starting point, all I needed to calculate the LCOEs was the cost of the systems and their expected energy output (capacity factor). Fortunately the U.S. Department of Energy (DOE) Loan Program Office (LPO) makes these two numbers publicly available. For other utility-scale solar projects, I went on-line and found available details.

There are some uncertainties using this method of LCOE calculation. "Total project costs" may not include several elements of a system's cost, such as upfront payment on an O&M contract or transmission interconnection. In addition, the expected electricity output for each system is only an estimate. There can also be variations in a project's underlying costs for O&M and taxes. Lastly, and most importantly, financing terms can vary dramatically between projects. Companies may have applied to the loan guarantee program to receive more favorable financing terms than they would have gotten in the marketplace. To better compare their non-financing aspects, this analysis holds the discount rate constant between projects. For these reasons, the calculated LCOEs for each project should be taken as illustrative only. The results, however, proved interesting.

Figure 1: LCOE v. Installed System Price

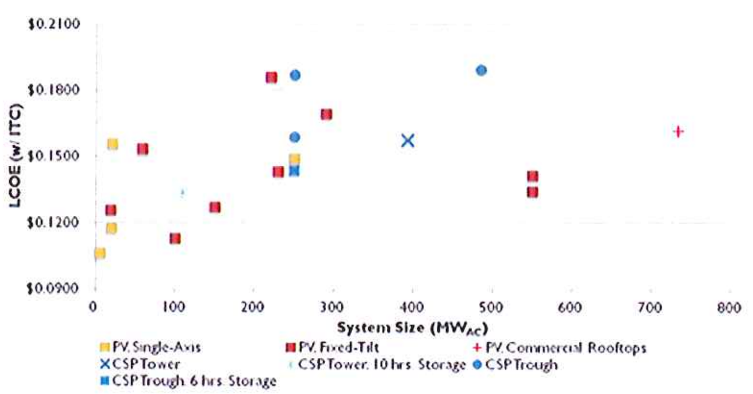


Source: Publicly available data from the DOE Loan Program Office, Xcel Energy, Greenfiretimes, Tristate Generation, Getsolar, California PUC, Business Wire, US Air Force Academy, Juwi Solar, Winston-Salem Journal, iStockAnalyst, EarthTechling, Environmental Leader, and PV-Magazine.

Categorized by technology, Figure 1 shows the LCOE of specific projects versus their system installed price (per watt). A 30% ITC and 5-year MACRS were included in this analysis, however state and local incentives were excluded. It illustrates the wide range of LCOEs, even within the same class of technology, due to different costs and expected performance. One surprising result from the analysis is that comparing system prices is not a good indicator of whether a project will have a lower LCOE. In fact, the CSP project with 10 hours of storage has an equivalent LCOE as a project that has half its reported price. With storage, the CSP project can produce energy over more hours of the day (i.e., even after the sun goes down). Thus, the LCOE of the CSP project decreases because the denominator of the equation, expected energy production, increases.

You might wonder why every CSP project doesn't have storage as storage lowers LCOE (provided the additional cost of building storage is not greater than the value of additional energy generated). The rate structures in which a project is paid may be one possible reason. One of the disadvantages of LCOE is that it does not take into account time-of-use pricing, which values energy differently depending on when it is purchased. A project's LCOE of $0.13/kWh may look good compared to daytime pricing of $0.15/kWh but not to nighttime pricing of $0.10/kWh. Typically, time-of-use pricing favors solar because it produces energy during peak demand periods. This can be particularly true of CSP with storage, which has the ability to generate energy during the peak energy usage period when people are coming home from work. However, if electricity is produced after this peak period, when the price of energy drops, the additional storage may not justify the added cost. In the end, the economics of a project are largely dependent on the rate structure in which a project operates and the price that is paid over the course of the day and year.

Figure 2: LCOE v. Installed System Size



Source: Publicly available data from the DOE Loan Program Office, Xcel Energy, Greenfiretimes, Tristate Generation, Getsolar, California PUC, Business Wire, US Air Force Academy, Juwi Solar, Winston-Salem Journal, iStockAnalyst, EarthTechling, Environmental Leader, and PV-Magazine.

Categorized by technology, Figure 2 shows the LCOE of specific projects versus their system size. A 30% ITC and 5-year MACRS were included in this analysis, however state and local incentives were excluded. The figure illustrates LCOE for solar technologies of different sizes. It also indicates some surprising results.

Although one would expect economies of scale to result in a decrease in cost as system size increases, this is not reflected in the results. This may be because: (1) even though the larger projects have the advantage of offering a sizable amount of renewable energy from one source, they also have added transaction costs compared to smaller projects; (2) having a larger footprint can mean more siting, permitting and environmental costs, additional interconnection and transmission costs, and higher financing and development costs, resulting in the long lead-time. In addition, many of these larger projects have applied for loan guarantees and have not been built yet; therefore their estimated costs may prove higher than their actual costs.

Given that PV module prices have fallen dramatically since the time these estimates were made, one might expect the estimated costs to be too high. On the other hand, if these larger projects have already signed fixed-price contracts, some of these costs may already be set.

The LCOE analysis shows that, if project costs do not change, some larger projects are not as competitive from an LCOE perspective as many of the smaller-scale utility projects. If there is enough opportunity for smaller-scale utility projects to be built in the future, they may be the preferred choice for sizing a PV system. On the other hand, if the currently built projects were "low hanging fruit" with costs less than can be expected for future systems, the industry may construct larger-scale projects due to economies of scale.

Overall, LCOE is an imperfect tool for measurement, which does not take into account the complex nature of the electricity market. Projects with lower LCOE may not be economical because of time-of-use pricing. LCOE also does not take into account the advantage of having a stable, dispatchable energy source such as CSP with storage—that can also secure revenue from ancillary services and capacity markets. However, one thing is clear from the LCOE analysis—lowering costs is only one of several factors the solar industry should focus on to effectively compete in the energy market. Capacity factor, barriers affecting larger projects, and rate structures also must be considered.

LCOE Formula

$$LCOE = \frac{ICC - ITC + PV(RC) + PV(FOM) * (1-t) - t * PV(D_n)}{IEP * PV((1-d)^{n-1}) * (1-t)} - PTC + VOM$$

ICC=initial capital cost
ITC=investment tax credit
OP=operating profit
IEP=initial energy production
T=tax rate
D=fraction of depreciable base
d=loss of production capacity, per year
PV=present value
FOM=fixed operations & maintenance
VOM=variable operations & maintenance
n=analysis year
N=analysis period
i=nominal discount rate
r=real discount rate
PTC=production tax credit
RC=Replacement Cost