Notes regarding submitting comments on this Draft Work Product:

Comments are Due April 20, 2018.

Comments shall be no longer than 5 pages.

Comments should be submitted to LDBPcomments@ebce.org

LCOE Analysis for Behind the Meter Resources

for

East Bay Community Energy

Prepared by
Optony Inc
2855 Kifer Road Suite 201
Santa Clara, CA 95051
www.optonyusa.com

March 2018

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BACKGROUND

The goal of this tool is to show currently trending market costs for behind the meter (BTM) distributed energy resources (DER) most readily available in Alameda County. These costs are expressed in levelized cost of energy or "LCOE" format, which represents the net present value of all energy procured from a resource over a fixed period of time. LCOE is a frequently used metric for cost comparisons between energy generation technologies.

The tool also shows potential capacities and energy output associated with these technologies. This allows the user to see an overall weighted cost of energy for EBCE's DER portfolio. The user-editable tool that accompanies this narrative report also allows the user to adjust the quantities of each technology to see how the overall weighted energy cost of the portfolio changes with varying resource mixes.

APPROACH

Step 1: Cost Inputs

Costs were primarily taken from empirical data, vendor quotes, and published industry reports. Costing data is broken out into 3 categories: initial capital cost, annual fixed cost, and annual variable costs. Initial capital costs normally account for the expense of installing and integrating the resource, annual fixed costs are primarily for regular maintenance programs, while variable costs are typically for fuel or other per kWh operating expenses. The cost estimates for most resources were not built from the ground up, so these 3 categories are the highest level of granularity which can be reliably provided.

Step 2: Estimate Energy Production

For solar, energy production is dependent on the system configuration and location. For this reason energy production estimates for solar were derived using modeling tools with inputs specific to the County. Separate line items are provided for inland (Livermore) vs coastal (Oakland) locations due to the difference in irradiance on each side of the County.

The other technologies in the tool are not constrained by resource availability as is the case for solar. For these technologies, energy yields are driven by utilization rates. For example, a demand response technology that can be called more frequently will provide much more energy for the same capital cost and thus have a much better LCOE. For these resources, the energy yields were chosen based on typical runtimes and use cases for these resources.

Note that for the storage technologies in particular, use cases and usage rates can vary greatly depending on the needs of the customer, EBCE, and the grid maintained by PG&E and the California Independent System Operator. An LCOE for typical usage rates has been provided (for example, one full discharge cycle per day for most of the battery options), though the "Calculator" tab allows the user to adjust the capacity factor and see the impacts on LCOE.

For both energy efficiency and demand response programs, the energy is being saved rather than produced. For LCOE purposes this distinction is irrelevant; that is, a unit of energy saved by an LED light bulb is treated the same as a unit of energy produced by a solar panel (note- this is often referred to as "negawatts," as opposed to megawatts).

Step 3: Calculate LCOE

Once cost and energy yield figures were established, LCOE is a simple summation. NREL's online LCOE calculator was used to run the numbers. A discount rate of 6% was chosen.

> Important Note: As energy procurement represents a large capital investment with a payback over multiple decades, LCOE is highly sensitive to both financing costs and the selected discount rate. This is particularly true for DG technologies such as batteries and solar in which the costs are front loaded.
>
> Important Note 2: The concept of LCOE is less clear for storage technologies, as you are not paying for the creation of energy but rather the shifting of energy to different times. For storage resources, only discharging cycles have been included in the energy side of the LCOE equation.

Special Note on Energy Efficiency

For these energy savings technologies, the utility is often an active participant by promoting energy efficiency measures through utility-administered programs. This involves costs for running the program, in addition to incentives or rebates that are often used to encourage customers to participate. Due to the high number of variables in program construction, and complexities in estimating total administration cost that also includes marketing, implementing, and evaluating the program, we are relying on empirical data for energy efficiency LCOE. These numbers relied heavily upon a Lawrence Berkeley National Labs (LBNL) study[1] published in 2015 that measured LCOE from a large sampling of utility-run EE programs. Programs in the low income sector typically have higher subsidies and administration costs, thus the separate line item for these programs.

The energy efficiency LCOE's shown represent the total cost contributed by both the program administrator (the utility) as well as the customer. The typical breakdown, from the LBNL report:

[1] Berkeley Lab report "The Total Cost of Saving Electricity through Utility Customer-Funded Energy Efficiency Programs." Page 2. Retrieved here: https://emp.lbl.gov/sites/all/files/total-cost-of-saved-energy.pdf

Table 1. Savings-weighted average total cost of saved electricity at the national level by market sector

Sector	Total Cost of Saved Electricity (2012$/kWh)*	Program Administrator Cost of Saved Electricity (2012$/kWh)	Participant Cost of Saved Electricity (2012$/kWh)
All Sectors	$0.046	$0.023	$0.022
Residential	$0.033	$0.019	$0.014
Commercial, Industrial, and Agricultural	$0.055	$0.025	$0.030
Low Income	$0.142	$0.134	$0.008

**Note: Totals may differ from sum of component values due to rounding.*

Administrator costs are a useful tool in budgeting for these programs. When planning for energy procurement, these costs can be a useful benchmark in comparing with the cost to obtain wholesale energy.

Special Note on Demand Response

As for energy efficiency, there are a high number of variables in how the utility can structure these programs. For this LCOE tool, we chose to mirror the demand response tariff programs currently offered by PG&E. This has been the approach for a couple of the early CCA programs in the Bay Area – to allow customers to participate in the existing PG&E demand response offerings. Though EBCE could choose to structure their demand response tariff riders differently, the existing programs provide a good benchmark for the cost to obtain demand response on the market.

FINDINGS

The accompanying Excel workbook catalogs the LCOE of each distributed generation technology.

Energy efficiency measures were found to have the lowest energy cost, with residential programs at $0.033/kWh and commercial/industrial programs at $0.055/kWh. The cost to EBCE would be even lower, as some of this cost is borne by the customer. Of course, there are limitations to this number. First, energy efficiency savings are not dispatchable in the same ways that energy storage or demand response are, nor are they typically as predictable. This limits the extent to which EBCE's energy procurement strategy can rely on efficiency savings to in reducing the amount of energy purchased. Additionally, while energy savings reduce the quantity of energy that EBCE must procure, it reduces retail energy sales and revenues collected by EBCE by a corresponding amount. Energy savings are most effective when they occur during high cost times, which is not necessarily the case with efficiency measures.

Demand response, on the other hand, is more highly dispatchable during high cost energy times, increasing its value to EBCE. However, demand response technologies are also found to have a much higher cost, the highest of any resource we considered. The utility must pay a premium in exchange for the ability to cut power to customers during high demand times on short notice, which provides a sort of hedge against under procurement and market price risks. The demand response program that is lowest cost, the Scheduled Load Reduction Program, has more customer-friendly participation terms (predictable call times and no penalties for non-reduction).

A clear winner in LCOE is ice-based thermal energy storage technology. The relatively simple technology and low cost to deploy make this a very affordable distributed resource, which yields valuable load shaping services for load-serving entities. Another advantage is that it is naturally deployed during peak energy times (when cooling loads are the highest).

The distributed generation technologies (solar and fuel cells) have LCOE's in the $0.10-$0.20/kWh range.

The full set LCOE results and assumptions can be found in the accompanying excel workbook.

LCOE "Calculator" Tab

The LCOE tool contains a "Calculator" tab in which the user can select a resource and adjust parameters to see the impact on LCOE.

Limitations

The LCOE tool addresses only the cost of distributed energy resources, not the value of the energy. The value of energy is both location and time dependent, and some of these resources have greater flexibility in that regard than others. As mentioned, a unit of energy saved through a demand response program is easier to push toward a specific time of day, while energy produced by a solar panel is dependent on ambient conditions.

Resource		Energy			Cost			LCOE
Resource Type	Capacity (MW)	Capacity Factor (%)	Conversion Losses (%)	Annual Production (MWh/yr)	Capital Cost ($/W)	Annual Fixed Cost ($/kW-yr)	Annual Variable Cost ($/kWh)	20 Year LCOE ($/kWh)
Generation								
Solar PV - 5 kW Roof - Oakland	25	16.4%	0%	35,900	$ 3.09	$ 15.00	$ -	$ 0.198
Solar PV - 5 kW Roof - Livermore	25	17.2%	0%	37,600	$ 3.09	$ 15.00	$ -	$ 0.189
Solar PV - 250 kW Roof - Oakland	25	16.4%	0%	35,825	$ 1.82	$ 15.00	$ -	$ 0.121
Solar PV - 250 kW Roof - Livermore	25	17.2%	0%	37,775	$ 1.82	$ 15.00	$ -	$ 0.115
Fuel Cell	2	95%	0%	16,644	$ 5.50	$ -	$ 0.065	$ 0.123
Storage								
Batteries - Lithium Ion - Residential	5	11.4%	7%	4,650	$ 4.00	$ 50.00	$ -	$ 0.429
Batteries - Lithium Ion - Commerical/Industrial	10	11.4%	7%	9,300	$ 3.00	$ 50.00	$ -	$ 0.335
Thermal - Ice-based technologies	2	12.3%	5%	2,052	$ 0.59	$ 23.00	$ -	$ 0.073
Demand Response								
Demand Response - Base Interruptible Program	1	2.1%	0%	180	$ -	$ 102.00	$ -	$ 0.567
Demand Response - Capacity Bidding Program	1	2.1%	0%	180	$ -	$ 59.39	$ 0.045	$ 0.375
Demand Response - Scheduled Load Reduction Program	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	$ 0.100
Energy Efficiency								
Energy Efficiency - Residential	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	$ 0.033
Energy Efficiency - Commercial/Industrial	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	$ 0.055
Energy Efficiency - Low Income	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	$ 0.142
TOTALS & WEIGHTED AVERAGES (Visible Rows Only)	**121**	**1,488**		**180,106**	**$ 2.54**	**$ 20.31**	**$ 0.00**	**$ 0.169**
GRAND TOTALS & WEIGHTED AVERAGES	**121**	**1,488**		**180,106**	**$ 2.54**	**$ 20.31**	**$ 0.00**	**$ 0.169**

Figure 1: Levelized cost of energy inputs and results for Alameda County distributed energy resources

ASSUMPTIONS

Solar

- The LCOE provided here is from the customer's perspective (e.g. what does it cost the customer to install solar), not the utility perspective.
- Energy yield modeled in PVWatts using TMY weather data from Oakland airport and Livermore, respectively. Inputs:
  - Residential systems are flush mount to 14 degree pitch roof, 225 azimuth, with losses 14%.
  - Commercial systems are 10 degree tilt-up, 180 azimuth, with losses 14%.
- Capital cost based on national average turnkey prices as documented in the U.S. Solar Market Insight Report 2016 Year in Review.
  - $0.20/watt added to national average system pricing to account for CA labor costs.
  - Federal ITC and depreciation benefits not considered in capital cost for this analysis since they will not be around long term.

Fuel Cell

- The LCOE provided here is from the customer's perspective (e.g. what does it cost the customer to install a fuel cell), not the utility perspective.
- Annual variable costs include $0.025/kWh fuel cost (natural gas) and $0.04/kWh O&M costs.
- Cost data from Lazard's LCOE Analysis version 10. Available here: https://www.lazard.com/perspective/levelized-cost-of-energy-analysis-100/
- The SGIP incentive for fuel cells is not considered since this will not be in place long term. Incentive levels for PG&E territory currently at $0.60/watt.
  - Current incentive levels are available here: https://www.selfgenca.com/home/program_metrics/
- The capacity shown, 2 MW, does not represent county-wide potential. It was chosen as the size for a potential pilot program for this LCOE analysis.

Lithium Batteries

- Residential battery installed cost assumed to be $1000/kWh. For this LCOE analysis we assume the battery energy is 4 hours at the rated power capacity. So capital cost is equivalent to $4000/kW or $4.00/watt.
- Commercial battery installed cost assumed to be $750/kWh. For this LCOE analysis we assume the battery energy is 4 hours at the rated power capacity. So capital cost is equivalent to $3000/kW or $3.00/watt.

- Annual cost of $50/kW-yr includes $9/kW-yr for regular O&M and $275/kW for major maintenance in years 5, 10, and 15 (annualized to $41/kW-yr).
- 5 MW (residential) and 10 MW (commercial) should not be considered the county-wide potential. These capacity targets were chosen as a target deployment size for a battery program for the purposes of this LCOE calculation.
- The capacity factor is highly variable and depends on the needs of the grid. For this LCOE calculation, 4 hours per day of discharge was chosen (representative of peak time shaving each day) on 250 days each year.
- Conversion losses for storage technologies are reduced from the quantity of deployed energy. Conversion losses have a similar effect as line losses. The round trip conversion efficiency is around 93% for a typical Li-ion battery.
- The cost to charge the batteries is not considered. The LCOE represents only the cost to shift the energy usage (without regard to how much was paid to charge the battery, or how much was saved when the battery was discharged).
- The SGIP incentive for energy storage is not considered since this will not be in place long term. Current incentive levels are $0.25-$0.40/Wh depending on category.
    - Current incentive levels are available here: https://www.selfgenca.com/home/program_metrics/
- Potential value streams for batteries outlined in Lazard's Levelized Cost of Storage version 2.0 (December 2016), pages 23-31.

Thermal Storage (ice-based technologies)

- Capital cost of $0.59/watt includes $0.25/watt for storage equipment, $0.19/watt for control systems and BOS, and $0.15/watt installation.
- Annual fixed cost of $23/kW-yr includes $6/kW-yr for regular O&M and $112/kW for major maintenance in years 5, 10, and 15 (annualized to $17/kW-yr).
- 2 MW should not be considered the county-wide potential. This is a typical project size for the popular Ice Bear system from IceEnergy.
- The capacity factor is highly variable and depends on cooling needs. For this LCOE calculation, the system was assumed to run for 6 hrs/day for 180 days per year (when the cooling load is highest).
- T&D loss factor is actually a placeholder for the conversion efficiency of ice based thermal storage, since losses in conversion have a similar effect as line losses. The round trip conversion efficiency is around 95% for typical Ice Bear system (according to product spec sheet).
- The cost to charge the batteries is not considered. The LCOE represents only the cost to shift the energy usage (without regard to how much was paid to charge the battery, or how much was saved when the battery was discharged).

Demand Response - Base Interruptible Program

- The "energy" portion of LCOE represents energy shed, not energy produced.
- These inputs based on PG&E's BIP program. See details here: https://www.pge.com/en_US/business/save-energy-money/energy-management-programs/demand-response-programs/base-interruptible/base-interruptible.page
- 1 MW is used as the capacity. This does not represent county-wide potential. It represents the sample numbers for a single customer participating in the program with 1 MW of curtailable load.
- Capacity factor assumes the program is deployed at its maximum allowable level (180 event hours per year)
- The annual cost is based on current incentive level of $8.50/kW/month offered by PG&E for participating in this program.
- No capital cost is assumed. An interval meter that can be read remotely is required to participate; it is presumed this is already present.
- The cost includes only the payments to customers for interrupting load - it does not include a cost to market or administer the program.

Demand Response - Capacity Bidding Program

- The "energy" portion of LCOE represents energy shed, not energy produced.
- These inputs based on PG&E's BIP program. See details here: https://www.pge.com/en_US/business/save-energy-money/energy-management-programs/third-party-programs/capacity-bidding.page
- 1 MW is used as the capacity. This does not represent county-wide potential. It represents the sample numbers for a single customer participating in the program with 1 MW of curtailable load.
- Capacity factor assumes the program is deployed at its maximum allowable level (30 event hours per month for the 6 summer months)
- The annual fixed cost is based on the "Capacity Payment" portion of the rate and assumes Day-Ahead payment rates (customers participating as Day-Of receive rates that are about 15% higher).
    - The current capacity price varies by month, from a low of $2.17/kW in October to $21.57/kW in August.
- The annual variable cost is based on the "Energy Payment" portion of the rate. The energy price is based on PG&E's wholesale gas rates for the day of the event.
    - For this tool, an average gas rate of $3.00/MBTU is assumed with a conversion rate of 15,000BTU/kWh.
- No capital cost is assumed. An interval meter that can be read remotely is required to participate; it is presumed this is already present.

- The cost includes only the payments to customers for interrupting load - it does not include a cost to market or administer the program.

Demand Response - Scheduled Load Reduction Program

- The "energy" portion of LCOE represents energy shed, not energy produced.
- These inputs based on PG&E's SLRP program. See details here: https://www.pge.com/en_US/business/save-energy-money/energy-management-programs/demand-response-programs/scheduled-load-reduction.page
- This program currently pays $0.10/kWh for all energy reduced. This is the LCOE.
- This program is available June through September. The amount of energy delivered is dependent on the customer. The customer selects participating times, and the utility measures energy reductions against a baseline.
- No capital cost is assumed. An interval meter that can be read remotely is required to participate; it is presumed this is already present.
- The cost includes only the payments to customers for interrupting load - it does not include a cost to market or administer the program.

Energy Efficiency

- Due to the challenges in deriving an LCOE using a ground-up approach for energy efficiency measures, these LCOE numbers are empirically derived.
- LCOE data from LBNL technical brief "The Total Cost of Saving Electricity through Utility Customer-Funded Energy Efficiency Programs", published April 2015.
    - Available here: https://emp.lbl.gov/projects/what-it-costs-save-energy
- The "energy" in LCOE represents energy savings, not energy production.
- The LCOE term is not specifically 20 years for EE technologies in this analysis. It is based on the lifetime savings from the EE technology, which for most programs analyzed was much less than 20 years.
- In the residential sector, consumer product rebate programs offer by far the lowest LCOE.
    - Lighting rebate programs are particularly effective, with an average cost of $0.018/kWh. Lighting rebate programs also accounted for the highest volume of EE savings.

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ABOUT OPTONY

Optony Inc. is a global research and consulting services firm focused on enabling government and commercial organizations to bridge the gap between clean energy goals and real-world results. Optony's core services offer a systematic approach to planning, implementing, and managing commercial and utility-grade renewable power systems, while simultaneously navigating the dramatic and rapid changes in the solar industry; from emerging technologies and system designs to government incentives and private/public financing options. Leveraging our independence, domain expertise and unique market position, our clients are empowered to make informed decisions that reduce risk, optimize operations, and deliver the greatest long-term return on their solar investments. Based in Silicon Valley, Optony has offices in Santa Clara, Chicago, and Beijing.

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