Equivalent Breakeven Installed Cost: A Tradeoff-informed Measure for Technoeconomic Analysis of Candidate Heliostat Improvements

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1. Introduction

Technoeconomic analysis (TEA) is commonly used to determine the economic viability of power-generating technologies from pilot to industrial scales [1], including that of concentrating solar power (CSP) plants. A common metric used to compare the benefits of different candidate technologies and/or locations for a CSP plant is the levelized cost of electricity (LCOE), which accounts for time-weighted revenues and costs according to parameter-specific discount rates [2]. Plants designed to produce industrial process heat or fuels use the analogous measures of levelized cost of heat (LCOH) [3] or levelized cost of fuel [4], respectively. These measures are effective when assessing a technology's total lifecycle costs and productivity under various design or process options for the total system but assume certainty in both costs and production.

Parametric analysis that varies one or more inputs along a user-specified range, such as that available in TEA tools like System Advisor Model (SAM) [5], can provide perspective on the impact of changes in costs or production as compared to a baseline case. However, the use of LCOE or net present value (NPV) of a plant does not fully capture the projected return on investment for a candidate technology for which the costs and/or production impacts are either not fully known, or specific to a subsystem rather than the entire plant.

In this work, we propose a novel metric for TEA of a plant component technology that recasts relative changes in levelized systemwide costs due to changes in any plant component or input into a relative change in the capital cost of the target component, which we refer to as the *equivalent breakeven installed cost*. In this study, we recast changes in LCOH from parametric analysis of a heliostat field, tower, and receiver as equivalent breakeven installed heliostat cost ($\$/m^2$). We believe the metric can be useful for evaluating R&D decisions among many components and subcomponents relative to a common goal, in this case the installed heliostat cost, but generally for candidate improvements within a CSP system.

2. Methodology

To recast a technology improvement as a change in installation costs, we begin by determining the relationship between capital cost and a levelized cost metric for the case study's baseline inputs; for the results that follow, we use LCOH, as heliostat improvements may have an impact on receiver and tower characteristics (e.g., fewer, better heliostats may yield a smaller tower and receiver surface) but are unlikely to influence the size of the power cycle for an electricity-generating plant. We calculate LCOH using the LCOE estimate in SAM and adjusting for (i) the ratio of thermal energy delivered to the receiver and net energy production, as well as (ii) the fraction of installation costs allocated to the solar field, tower, and receiver. By running a parametric analysis in SAM, in which heliostat installation cost changes, we can use the resulting installation cost inputs and LCOH outputs to derive the affine relationship in equation (1):

$$L = a \cdot C + b, \quad (1)$$

in which L is the LCOH associated with the baseline plant design, C is the per-squared-meter installation cost of the heliostat, and a and b are constants derived via linear regression. We assume that (i) the fixed design's heat production does not change, and (ii) the variable (i.e., operations and maintenance) costs for the heliostats do not change in this analysis. We then determine the equivalent capital cost, C', via equation 2:

$$C' = \frac{(L'-L)}{a} + C, \quad (2)$$

in which C and L are the installation cost and LCOH associated with the baseline estimate, and L' is the LCOH for the new case, i.e., C' is the installed heliostat cost that achieves that same LCOH as the new case if the only measure to change is installation cost. Finally, to achieve the equivalent breakeven installed cost, C^*, we invert the change between C' and C as shown in equation (3) and use this as the *equivalent breakeven* installed heliostat cost. The resulting design is the new case, with equivalent capital cost C', combined with the equivalent breakeven installed heliostat cost of C^* to yield the same LCOH as the baseline case.

$$C^* = 2 \cdot C - C'. \quad (3)$$

3. Results

Figure 1 illustrates the *equivalent breakeven installed cost* by recasting the LCOH obtained by a parametric analysis of solar field optical error to the equivalent breakeven installed cost for a contrived case study of a 100-MW_e plant in Daggett, California. Using the baseline of an installed cost of $140/m^2 and approximately 4.3 mrad of total reflected image optical error, the results show that the budget for an improved heliostat that reduces the error to 3 mrad must not exceed $150/m^2 to improve the overall value of the system.

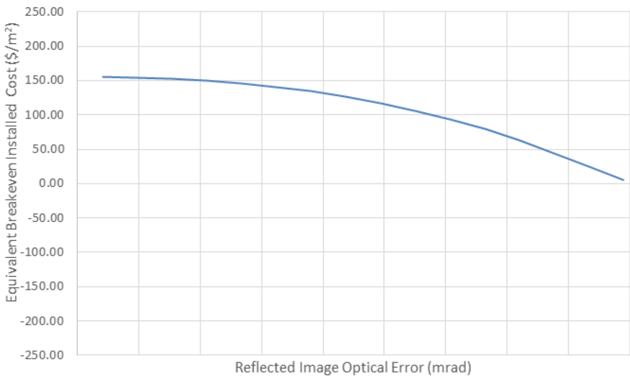

Figure 1. Equivalent breakeven installed cost as a function of heliostat reflected image optical error. The baseline case features a cost of $140/m2 with 4.3mrad of error

The new metric can be used to assess the relative value of candidate technology options but may offer a more directly comparable measure for component costs measure versus the systemwide LCOH measure. The full paper will cover additional scenarios that link to existing perceived gaps in heliostat technology.

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