Estimating Market Potential for Reducing Customer Peak Loads Through Photovoltaics

Joseph Bryan **Richard Perez**

Atmospheric Sciences Research Center
University of New York at Albany

Abstract

The ability of photovoltaics (PV) to provide electricity at competitive rates in the near term depends in part on the resource's capability to offset customer peak demands. Using PV to reduce peak customer demand for electricity maximizes the economic potential of the resource by reducing customer demand as well as energy charges. Studies have quantified PV's peak load matching capability on a utility-wide scale. The goal of this paper is to estimate the number of utility customers whose peak loads are well matched with solar availability. We develop a simple tool for estimating the market size of high load matching PV customers and provide illustrative examples of customer owned PV economics. We show that (1) the market size of high load matching PV applications on the customer scale is significant even within utility systems whose load requirements are not particularly well matched with PV; and (2) the cost of PV as a peak shaving resource for utility customers is approaching competitive levels.

Introduction

The near term economic viability of photovoltaics (PV) depends in part on the resource's ability to act as a peak-shaving device for utility customers. Time of day energy rates and seasonal demand rates often reflect this reality. Using PV to offset peak loads maximizes the economic potential of PV by reducing customer demand as well as energy charges. The effectiveness of PV in this respect depends on how well the solar resource matches customer peak demand periods.

Studies have quantified the match between PV output and utility peak loads. This paper focuses on the customer scale. A simple tool based on the utility scale load-PV match is developed to estimate the market size of customer scale PV applications with high load-PV matches. Site specific examples of customer side economic analysis are provided to illustrate the near term economic potential of PV as a peak shaving resource.

I. Capacity Value of Photovoltaics

Because it is not a dispatchable resource, photovoltaics has traditionally been assigned low or no capacity credit. Quantifying the load matching capability of PV is important because this parameter is relevant to the value of the PV resource.

Analysis of actual utility loads and coincident PV output have shown that there is often a substantial degree of correlation between utility peak loads and the availability of the solar resource (Perez et al., 1993). This relationship was found to be largely independent of the overall magnitude of the solar resource; instead the relationship was found to strongly relate to a utility's summer to winter peak load ratio (Perez 1993).

Utilities with large summer commercial air conditioning loads and low levels of electric heating in winter have shown the strongest relationship between peak loads and solar availability. Thus, many high value PV applications have been found to lie outside the traditional solar energy regions of Florida and the Southwest. Using the effective load carrying capability (ELCC) as an indicator of PV's ability to meeting utility peak demands, it has been possible to estimate the value of the resource on the utility scale. The need to identify high value PV applications *within* a utility system remains.

II. Use of the Effective Load Carrying Capability (ELCC)

Effective Load Carrying Capability (ELCC) of a generating unit was originally defined by Garver as the additional load that a utility system can deliver as the result of the additional generating unit, taking into account the system's loss of load probability, installed reserves, and the new unit's forced outage rate (Garver, 1966). The use of ELCC was generalized (Perez et al., 1993) to characterize only the load-resource relationship. This allowed the ELCC measure to be extended to any type of load. The determination of a resource's ELCC helps to determine the capacity value of the resource within the overall utility system.

III. Methodology

ELCC was estimated for over 500 utilities based on the strong relationship between sample load shape parameters and ELCC (Perez, 1995). The ELCC data are representative of the load carrying capability of PV at a modest penetration level on the utility grid for a one axis tracking PV array.

A probability distribution of utility PV ELCC in the United States was constructed. A beta distribution was fitted to the data (figure 1).[1]

---

[1] The correlation coeficient between the transformed utility data and the beta distribution is .999.

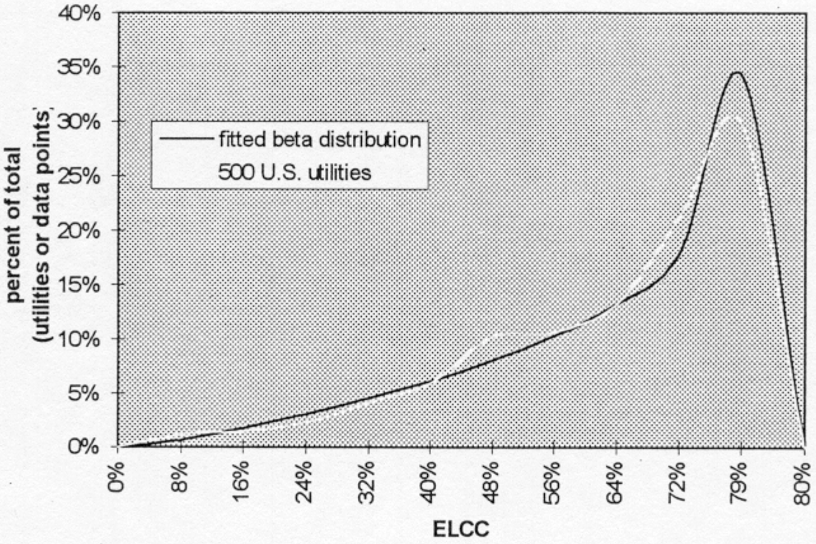

figure 1: Probability Distribution of Transformed Utility ELCC Data and Beta Distribution with Equivalent Mean

The beta function is commonly used to study the variation in the percentage of a variable across samples, such as utility ELCCs (McFarlane, 1950) The function is represented by the density:

$$f(x) = \frac{(a+B+1)!}{a!B!} * x(1-x) = 0$$

The mean ELCC for the 500 utilities is about 60%. A series of similar beta distributions were derived to represent ELCC distribution for other mean values. Assuming self similarity between the ensemble of U.S. utilities and the ensemble of substations and large customers within a utility, these distributions are used to model the distribution of customer ELCC within a particular utility, given the utility-wide ELCC. This relies on two assumptions.

1) The distributions of utility-level ELCCs and utility customer ELCCs are self similar. That is, the distributions will remain similar despite the differences in the scale of the variables (e.g. see Mandelbrot).
2) The expected value of the beta distribution is the ELCC of a particular utility.

The customer distributions were derived from beta functions with standard deviations equal to that shown in figure 1 and expected values ranging from 10% to 70%. The resulting beta distributions (figure 2) estimate the percentage of a particular utility's customers that can be expected to have high ELCCs for PV. Using ELCC as an input to measure of the value of a resource to a utility, the distributions also estimate the market size of high value PV applications within a utility system (figure 3).

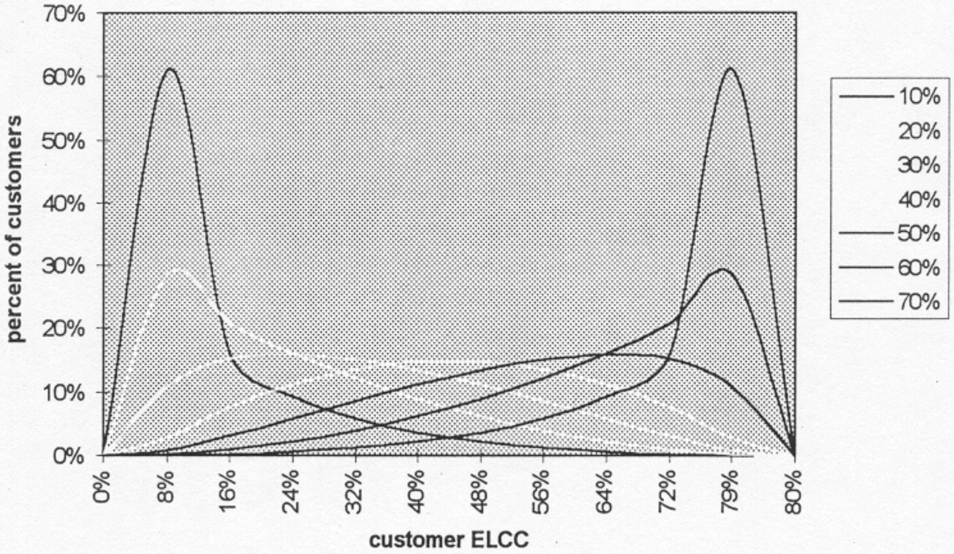

figure 2: Beta Probability Distribution of Utility Customer ELCC (knowing utility-wide ELCC)

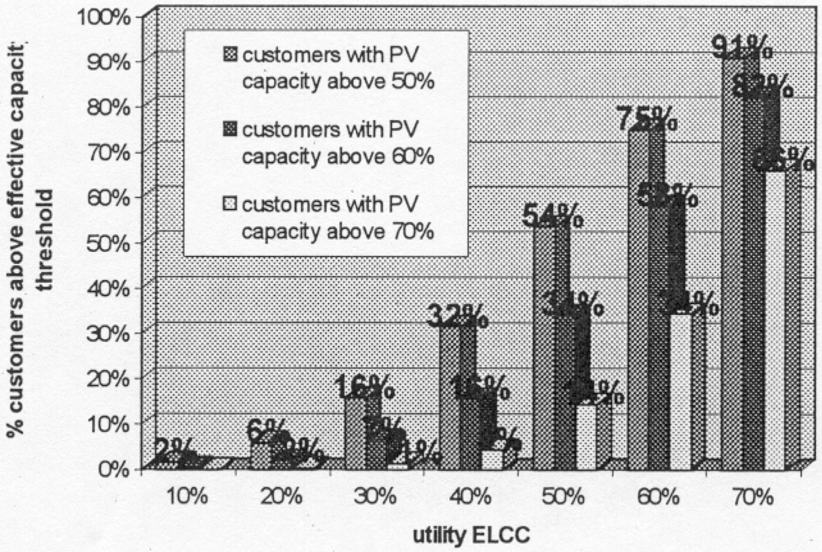

figure 3: Market Share of High PV Capacity Customers as a Function of Utility-Wide PV ELCC

Application of findings

Having estimated the market size of high ELCC PV customers, a customer side economic analysis of an investment in PV was completed.

A life cycle model was developed to estimate the costs and benefits for a customer investing in PV. The rate structures of several utilities along with tax incentives of individual states were modeled to determine the economic viability of PV as a demand-side resource at current and projected PV and electricity costs. A list of assumptions for the economic analysis is contained in appendix A. Chart 1 shows the benefit-cost ratio of a customer investment in a PV-DSM system with a 70% customer effective capacity. Based on our findings, over 70% of Con Edison customers, 34% of Duke Power customers, 36% of Salt River Project customers and 4% of Portland General Electric customers would be in this categary. Chart 2 shows the benefit cost ratio of a PV-DSM system with an ELCC of zero.

Chart 1 reinforces to point that PV's potential is not limited to traditional solar energy regions. The benefit/cost ratios of Con Edison in New York and Salt River Project in Arizona are comparable at $7.50/watt for PV. However, benefit/cost ratio of a Con Edison customer reaches 1.00 at $5.00/watt while the cost of a PV-DSM system must be $4.25/watt for the benefit/cost ratio a Salt River Project customer to arrive at the same level. The power provided by the PV-DSM system is peak power, allowing the customer to capture both demand and energy savings. Because Con Edison has relatively high demand charges the power provided by the PV-DSM system replaces more expensive power for a Con Edison customer than it does for a customer of the Salt River Project.

Chart 1: PV captures capacity credit

ConEdison			**Duke Power**		
$/w	b/c ratio		$/w	b/c ratio*	
$7.50/w	0.88		$7.50/w	0.93	
$5.00/w	1		$5.00/w	1.08	
$2.50/w	1.37		$2.50/w	1.37	
break-even system cost $5.00/w			break-even system cost $6.00/w		
Portland GE			**Salt River Project**		
$/w	b/c ratio		$/w	b/c ratio	
$7.50/w	0.69		$7.50/w	0.83	
$5.00/w	0.73		$5.00/w	0.94	
$2.50/w	0.85		$2.50/w	1.23	
break-even system cost $1.50/w			break-even system cost $4.25/w		

Chart 2: PV is given no capacity credit

ConEdison			**Duke Power**		
$/w	b/c ratio		$/w	b/c ratio*	
$7.50/w	0.72		$7.50/w	0.86	
$5.00/w	0.77		$5.00/w	0.98	
$2.50/w	0.92		$2.50/w	1.19	
break-even system cost $2.00/w			break-even system cost $4.75/w		
Portland GE			**Salt River Project**		
$/w	b/c ratio		$/w	b/c ratio	
$7.50/w	0.67		$7.50/w	0.8	
$5.00/w	0.71		$5.00/w	0.89	
$2.50/w	0.8		$2.50/w	1.14	
break-even system cost $1.15/w			break-even system cost $3.50/w		

* Figure includes North Carolina's 35% tax credit for commercial investments in photovoltaics (General Assembly of North Carolina, 1993).

III. Conclusions

It has been assumed that most high value PV-DSM sites lie within utility systems with high ELCCs. Using the derived beta distributions of utility customers reveals that the market size of high value PV customers (or alternatively, the number of high load-PV match substations) may remain significant even within utility systems of marginal to low utility level ELCCs. This finding is encouraging because it shows that the overall market size for PV as a peak shaving resource may be larger than previous estimates. For example, Figure 2 shows that more than 14% of the customers of a utility with an ELCC of 50% have effective load carrying capabilities of 70% or greater.

The ability of PV to offset electricity demands during peak periods allows customers to capture both energy and demand savings. A customer's ELCC is an effective measure of this ability. The near term economic potential for PV as a peak shaving investment appears promising for customers with high ELCCs. Many of these high value PV applications lie outside traditional solar energy regions of Florida and the Southwest. In fact, strong market potential exists for PV as a peak shaving resource in the Northeast. Many customers in this region of the country have peak loads driven by the need for air conditioning and have high utility demand and energy costs. For example, at current system cost, the economic benefits cover nearly 90% of the costs of a PV-DSM system for a Con Edison customer with an ELCC of 70%.