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Moving Towards a More Comprehensive Framework to Evaluate Distributed Photovoltaics

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Abstract

There is a growing interest in customer-owned generation with a particular interest in photovoltaic (PV) systems. This has resulted in a growing number of analytical studies aimed at determining their value. Two difficulties that these studies have encountered are how to select the proper evaluation perspective and which benefits and costs to include in the analysis.

This paper presents a framework to perform a more comprehensive analysis. It frames the established Standard Practice Tests used for demand side management cost-effectiveness evaluation within a benefit-cost matrix and then expands this matrix to include additional perspectives and benefits/costs. It also suggests which benefits/costs apply from the various perspectives for customer-owned distributed PV systems.

This paper is not a final word on the subject. Rather, it is intended to facilitate a discussion that will lead to a more formalized set of tests to evaluate distributed PV systems. It is also hoped that it will stimulate the development of analytical methods for benefits that have been identified but for which evaluation methodologies do not exist.

Introduction

There is a growing interest in the U.S. and many other parts of the world in customer-owned generation with a particular interest in grid-connected photovoltaic (PV) systems. Along with this interest, there have been (and continue to be) many analyses aimed at determining the benefits of customer-owned generation. There have been studies that evaluate distributed resources in general [1], [2], [3] as well as those that focus on distributed PV systems in particular [4], [5], [6]. An examination of these studies suggests that performing such an analysis has proven difficult. The source of this difficulty can be traced to two primary issues. First, it is difficult to select the evaluation perspective. Second, it is difficult to decide which benefits and costs to include in the analysis.

Since the 1970s, conservation and load management programs have been promoted by the California Public Utilities Commission (CPUC) and the California Energy Commission (CEC) as alternatives to power plant construction and gas supply options. These programs have been implemented by the major California utilities through the use of ratepayer money and by the CEC pursuant to the legislative mandate to establish energy efficiency standards for new buildings and appliances. During the 1970s and early 1980s, there were no official guidelines for utility-sponsored programs. In order to provide a consistent methodology to evaluate cost-effectiveness, the *Standard Practice for Cost-Benefit Analysis of Conservation and Load Management Programs* was published in 1983.

Some distributed PV studies that have attempted to explicitly account for perspective by using the same methods as have been applied to demand-side management (DSM) programs [7], [8]. In addition, a recent study focused on the framework issue [3]. Even with these studies, however, both perspective and which benefits to include need to be more explicitly identified in order to provide a more consistent basis to evaluate PV.

Objective

The objective of this paper is to present a framework to evaluated distributed PV resources. It qualitatively describes how the established Standard Practice Tests used for demand side management can be framed within a benefit-cost matrix. It then expands this matrix in terms of perspective and which benefits to included. The resulting framework: (a) includes neglected perspectives and (b) accounts for potentially important benefits/costs.

Standard Practice Tests

As mentioned above, a set of standard tests were developed to evaluate the cost-effectiveness of efficiency and load management programs. The California Standard Practice Manual: Economic Analysis of Demand-Side Programs and Projects [9] identifies the cost and benefit components and cost-effectiveness calculation procedures from four major perspectives.[1] Those perpectives include:

1. Participant
2. Ratepayer Impact Measure (RIM)
3. Total Resource Cost (TRC)
4. Program Administrator Cost (PAC)

Participant Test

The Participant Test is the measure of the quantifiable benefits and costs to the customer due to participation in the program. The benefits include: reduction in utility bills, incentives, federal, state, or local tax credits, and increased productivity and/or service. The primary costs include: equipment cost, installation cost, sales tax, ongoing O&M (operation and maintenance) cost, and removal cost.[2]

Program Administrator Cost (PAC) Test

The Program Administrator Cost Test measures the net costs of a demand-side management program as a resource option based on the costs incurred by the program administrator including incentive costs and excluding any net costs incurred by the participant. The benefits are the savings from the avoided supply costs and include:

[1] Reference [9], p. 4.
[2] Reference [9], p. 8.

generation cost savings (energy and capacity), transmission cost savings, and distribution cost savings. The only costs that are included are the administration program costs and incentives paid to the participants.[3]

Rate Impact Measure (RIM) Test

The Rate Impact Measure Test measures what happens to customer bills or rates due to changes in utility revenues and operating costs caused by the program. The benefits are the savings from the avoided supply costs and include: generation cost savings (energy and capacity), transmission cost savings, and distribution cost savings. The costs include: administration program costs, incentives paid to the participants, and decreased revenues.[4]

Total Resource Cost (TRC) Test

The Total Resource Cost Test measures the net costs of a demand-side management program as a resource option based on the total costs of the program, including both the participants' and the utility's costs. Since the revenue (bill) change and the incentive terms cancel, the benefits include: federal, state, or local tax credits, increased productivity and/or service, generation (energy) cost savings, capacity cost savings, transmission cost savings, and distribution cost savings. The costs include: administrative costs for incentive program, equipment cost, installation cost, sales tax, ongoing O&M (operation and maintenance) cost, and removal cost.[5]

Benefit-Cost Matrix

It is helpful to view these tests within a matrix of benefits and costs arranged by perspective to obtain additional insights into the relationship of the various tests to each other. Figure 1 presents such a matrix. The rows correspond to a benefit or cost component and the columns correspond to a perspective. The first column is the participant, the second column is all rate payers, and the third column is the utility. These columns can be combined to form the various Standard Practice Tests. The first column is the Participant Test, the third column is the Program Administrator Cost Test, the second column plus the third column is the Rate Impact Measure Test and the combination of all columns is the Total Resource Cost Test.

While the results for each perspective can be expressed in a variety of ways, net present value is a common measure that can be used across all tests. Each entry in the matrix can be viewed as the present value benefit or cost over the life of the measure. Present value is a useful measure in that it explicitly accounts for time and technology life[6] and it also allows different perspectives to use discount rates that reflect their different time value of money.

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[3] Reference [9], p. 23.
[4] Reference [9], p. 13.
[5] Reference [9], p. 18.
[6] One measure that is easily understood is $/kWh. This measure, however, lacks a time element as to technology life.

Assume that the investment is energy efficiency or customer-owned distributed renewable energy technologies (as opposed to a fuel switching). In this case, each cell in the matrix can indicate whether there is a benefit (+), cost (-), or neither a benefit nor a cost (no entry).

Figure 1. Summary of Standard Practice Tests

Total Resource Cost (TRC)		
Participant		***(PAC)***
	Rate Impact Measure (RIM)	

	Particpant	***All Ratepayers***	***Utility***
Investment			
Equipment	-		
Installation	-		
Sales Tax	-		
O&M Cost	-		
Electric Utility Bill	+	-	
Incentives			
Incentive Payments	+		-
Program Administration			-
Tax Effects			
Tax Credits	+		
Utility Cost Savings			
Energy			+
Capacity			+
T&D System			+
Losses			+

A More Comprehensive Benefit-Cost Matrix

There are a several limitations of the matrix presented in Figure 1. First, for the given perspectives that are defined, there are benefits and costs that are not included in the analysis. Second, there are additional perspectives that are not included in the analysis.

Other Benefits and Costs

The benefits and costs that are not in the standard tests can be grouped into the categories of:

- Tax effects (in addition to tax credits)
- Environmental (this may be included in a Societal test)
- Job Creation
- Reliability
- Risk factors

Other Perspectives

Additional perspectives that could be included are:

- Other industry (e.g., manufacturers, installers)
- Government (at the local, state, and federal levels)

Expanded Matrix

The matrix needs to be expanded to include missing benefits and perspectives in order to perform a more comprehensive analysis. Figure 2 illustrates how this expanded matrix could be implemented for customer-owned distributed PV generation under the current U.S. incentive structure.

The blue section titles are the various tests, the headers at the top are the perspectives, and the labels down the side of the matrix are the benefit/cost components. Within the body of the matrix, the boxes have three possible colors: white, yellow, or gray. White indicates that the benefit is currently included in existing Standard Practice tests, yellow indicates that it is not typically included (although some studies may include these components), and gray indicates that the component does not apply from that perspective. A + corresponds to a benefit and a – corresponds to a cost for that particular component and perspective.[7] Note that while a Societal Test is included in the tests described in the Standard Practice Manual, it is treated informally.[8]

There are several general observations that can be made based on a comparison of Figure 1 to Figure 2. First, the expanded matrix contains many more perspectives and benefits/cost components than Figure 1. Second, the industry and government perspectives have many new entries. Third, many of the components have a yellow background and thus are not included in a typical financial analysis even for the existing tests (RIM, TRC, PAC, Participant). Finally, there are generally more pluses than minuses with the new entries. Including these benefits and costs could increase the overall cost-effectiveness of distributed PV systems.

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[7] The categorization of components in Figure 2 is intended to be generally correct based on the existing structure in the U.S. for customer-owned distributed PV systems. There may be some components, however, that could also be included in other categories.

[8] While there are four primary perspectives (and corresponding tests) are listed in the Standard Practice Manual, a fifth perspective, Societal perspective is mentioned. The Societal Test is treated as a variation on the Total Resource Cost Test. The Societal Test differs from the TRC Test in that it includes the effects of externalities (e.g., environmental, national security), excludes tax credit benefits, and uses a different discount rate. This test is not treated as a separate test. Thus, it is beneficial to be explicitly define what the Societal Test includes.

Figure 2. A more comprehensive benefit-cost matrix .

	SOCIETAL					
	Total Resource Cost (TRC)			*Industry*	*Government*	
	Participant		*(PAC)*			
		Rate Impact Measure (RIM)				
	Particpant	***All Ratepayers***	***Utility***	***Industry***	***State/Local Gov.***	***Federal Gov.***
Investment						
Equipment	-			+		
Installation	-			+		
Sales Tax	-				+	
O&M Cost	-			+		
Financing	-			+		
Electric Utility Bill	+	-				
Incentives						
Incentive Payments	+		-			
Program Administration			-		+	+
Tax Effects						
Tax Credits	+				-	-
Depreciation	+				-	-
Loan Interest Write-Off	+				-	-
O&M Costs	+				-	-
Utility Bill Savings	-				+	+
Tax on Tax Credits	-					+
Utility Cost Savings						
Energy			+			
Capacity			+			
T&D System			+			
Losses			+			
Technology Synergies			+	+		
Environmental						
Emissions		+				
Water		+				
Health		+				
RECs/Green Tags	+		+			
Job Creation			-	+	+	+
Reliability						
Blackout Prevention		+	+		+	+
Emergency Utility Dispatch	+		+			
Catastrophe Recovery		+			+	+
Backup Power	+				+	+
Risk Factors						
Manage Load Uncertainty			+			
Wholesale Price Hedge			+		+	+
Retail Price Hedge	+				+	+
Retail Price Cap		+	-		+	+
National Energy Security		+			+	+

Discussion

This section provides a brief discussion on the various benefit and cost categories for the various perspectives.

Investment

The investment category includes the initial costs of equipment, installation, and sales tax and the ongoing costs of operation and maintenance (O&M) and financing. These represent costs to the Participant and revenue (and thus benefits) to other industry participants: manufacturers increase revenue due to equipment sales; installers and dealers increase revenue due to installation and the ongoing O&M. The state increases sales tax revenue, and finance companies increase revenue through system finance.

Electric Utility Bill

The electric utility bills savings is typically the most important benefit to the Participant. While the amount of money saved by the Participant in reduced utility bills represents a decrease in revenue to the utility, this is not money that is paid out of the utility's budgets. And in many cases, in order to retain neutral effect on overall revenue requirements, the Standard Practice tests treat a portion of the reduction in revenue as being passed on to other ratepayers.

Incentives

The incentives category includes the incentive payments and the cost of incentive program administration. The incentive represents a benefit to the Participant and a cost to the utility because it is a cash expenditure that the utility pays to the Participant. In order to administer the incentive, the utility incurs an incentive adminstration cost. Since the administrative cost is a labor cost, there is an increase in income tax revenue for the government agencies.

Tax Effects

The tax credit is a benefit for the Participant and a cost to the local, state, or federal government. While the tax credit is typically included in an analysis, there are other tax effects that need to be accounted for. Some are benefits to the Participant (in the form of income and other taxes decrease) and costs to the government while others are costs to the Participant (in the form of income and other taxes increases) and benefits to the government. The magnitude of the other tax effects depends on the particular participant (including annual income and tax filing status). For example, depreciation benefits and the O&M cost deductions are only available to for-profit commercial customers while the the loan interest write-off can be available to all commercial customers and to residential customers who finance their system with a home equity or other tax deductible loan. One tax effect that is often excluded from the analysis is the increase in state and federal taxes due to a reduction in utility bills for for-profit commercial customers (i.e., if a commercial customer has a reduction in utility bills, they have fewer expenses to deduct and thus have an increase in their tax bill). Another tax effect that can often be missed for residential customers is the tax effect that occurs for residential customers with state tax credits (state tax credits are taxable at the federal level and thus represent a transfer payment from the state governments to the federal governments).

Utility Cost Savings

The utility cost savings include the more traditional benefits that the utility gains from a reduction in consumption (or increase in on-site generation), such as the energy savings, generation capacity deferrals, O&M costs savings, transmission and distribution (T&D) system deferals, and loss savings (both energy and capacity). In addition, a benefit that is often neglected is the potential for technology synergies. For example, for utilities with late summer peaking loads, an increase in distributed PV generation can reduce the utility's daytime load (either on the overall generation system or on a particular T&D system) but still leave a peak load that occurs during a small percentage of time late in the afternoon. A utility with a robust load management program could realize a cost savings from this by having to dispatch their load management program for fewer hours during the year and thus pay less to customers who participate in the load management program. This may also be a benefit to industry in increased business.

Environmental

The environmental category includes emissions reductions, improvement in people's health as a result of an improvement in the environment, water savings, and the direct financial benefit that can be obtained by selling Green Tags or by not having to purchase Renewable Energy Credits (RECs) from another source in order to be in compliance with RPS mandates. All rate payers benefit from the environmental and health improvements; the REC benefit depends upon who owns the environmental attributes of the system.

Reliability

The reliability category includes blackout prevention, emergency utility dispatch, catastrophe recovery, and backup power. Both the utility and all of its customers benefit from preventing a blackout. Emergency utility dispatch is beneficial to the utility and to the Participant (if the utility pays the owner for the right to dispatch the system in an event of emergency). All ratepayers benefit from catastrophe recovery protection. The PV system owner benefits from outage protection. For almost all of the reliability benefits, there are benefits to the government in the form of increased tax revenues or greater tax revenues stability.

Job Creation

Distributed PV systems create new jobs. The industry employing the new people and the government agencies realizing additional tax revenue associated with increased income are the ones who will benefit from the increase is jobs.

Risk Factors

The risk factors category includes the ability to manage load uncertainty through short-lead times and modularity, wholesale price hedge, retail price hedge, and retail price cap due to the lack of fossil-fuel based requirements, and the benefit of national energy security. These benefits are often neglected and have the potential to be very significant. The utility benefits from the ability to manage load uncertainty and the wholesale price hedge. The PV system owner benefits in the short term from the rate retail rate protection. In the long term, all consumers will benefit from the availability of a technology that provides an economically viable alternative to traditional utility service: even if they never purchase a PV system, this will provide an effective price cap on the retail price of electricity. All rate payers benefit from improved national energy security. And with almost all of the risk protection benefits, there will be an increase in revenue or more protected tax revenue for the governmental agencies.

Conclusions

There is a growing interest in customer-owned PV systems. This has resulted in a growing number of analytical studies aimed at determining their value. As one examines these studies, it becomes clear that they grapple with the issues of how to select the proper evaluation perspective and what benefits and costs to include in the analysis.

This paper offers a framework that can be used to perform a more comprehensive (and thus a more accurate) analysis. It frames the established Standard Practice Tests used for demand side management cost-effectiveness evaluation within a benefit-cost matrix and then expands this matrix to include additional perspectives and benefits/costs. It also suggests which benefits/costs apply from the various perspectives as well as whether they are a benefit or a cost.

Future Work

This paper is not a final word on the subject. Rather, it is intended to accomplish several goals. First, it will facilitate discussion that will lead to a consensus on how to evaluate distributed PV systems. This can happen through the experience gained by performing various case studies as well as through the discussion process. Second, it will stimulate the development of analytical methods for benefits that have been identified but for which evaluation methodologies do not exist.

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