Designing Performance Based Incentives: Preliminary Results

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Executive Summary

This paper is part of a project to develop a utility-sponsored performance based incentive (PBI) program for commercial customers who purchase photovoltaic (PV) systems. This paper develops the theoretical basis for a proposed PBI design methodology and structure, covering the rate per kWh of production, the variation of this rate over time, and the duration over which the payments are made. Subsequent phases of the work will incorporate tax implications and other factors and recommend how to implement a specific PBI program.

The paper demonstrates that a PBI structure incorporating both customer and utility perspectives can be designed by ensuring (1) the customer receives no economic benefit by delaying investment to take advantage of declining PV prices versus investing immediately and (2) that a cost-effectiveness test is satisfied. Utilities want to ensure that systems are installed and maintained in a way consistent with the use of ratepayer dollars. The utility would pay its minimum amount of money in any given year and yet still have customers who want to invest. In addition, the utility would be able to attract new customers at any point during the duration of the PBI program, should a customer leave the program due to system failure, equipment removal, or some other reason.

The pricing constraint that ensures customer investment is satisfied by a fixed declining PBI structure where the year-to-year PBI rate changes are known in advance to prospective customer-owners. The PBI rate declines over time as a function of anticipated PV price reductions, annual utility bill savings, expected utility bill escalation, and PV energy production. The duration of the PBI payments is established by the same set of variables plus a cost-effectiveness test. The PBI structure would remain available for future customer-investors who join the program provided market conditions remain consistent; however, customers who delay investment would forfeit the benefit of prior year PBI payments.

While only the first step of the analysis, the methodology outlined in this paper has the potential to be applicable for PBI program design at any utility. The variables upon which the structure is based are location specific, especially the utility bill savings, savings escalation, and PV energy production. Consequently, each location could use the same methodology but would have a different PBI structure. Several important steps remain before the methodology should be used to implement a program.

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The views in the paper only reflect that of the author and not that of SMUD or PIER or any of the reviewers.

Introduction

While investments in grid-connected photovoltaics (PV) are growing at a steady pace, high capital costs remain the principal barrier to widespread adoption. Many public agencies and utilities offer incentive programs to lower this barrier, often providing capacity-based incentives upon installation, effectively lowering the capital cost to the customer.

A criticism directed at capacity-based incentives is that they do not recognize power production or motivate good project management or maintenance once the project is installed. Performance-based incentives (PBI), on the other hand, recognize good project performance by paying the project owner on the basis of the energy produced [1].

A range of PBI structures have been implemented in the U.S. Figure 1 presents a sample of the structures. For example, the California Energy Commission's pilot program pays a constant rate of 50¢ per kWh over the duration of 3 years, WE Energies (Wisconsin) pays a constant rate of 22.5¢ per kWh for a duration of 10 years, and the New Jersey Clean Energy Program (as well as other programs) offers a capacity-based incentive plus the payment of market-based Renewable Energy Credits that do not have a fixed duration or rate. See Appendix A for additional programs and details and [2], [3], [4], and [5] for results from other studies.

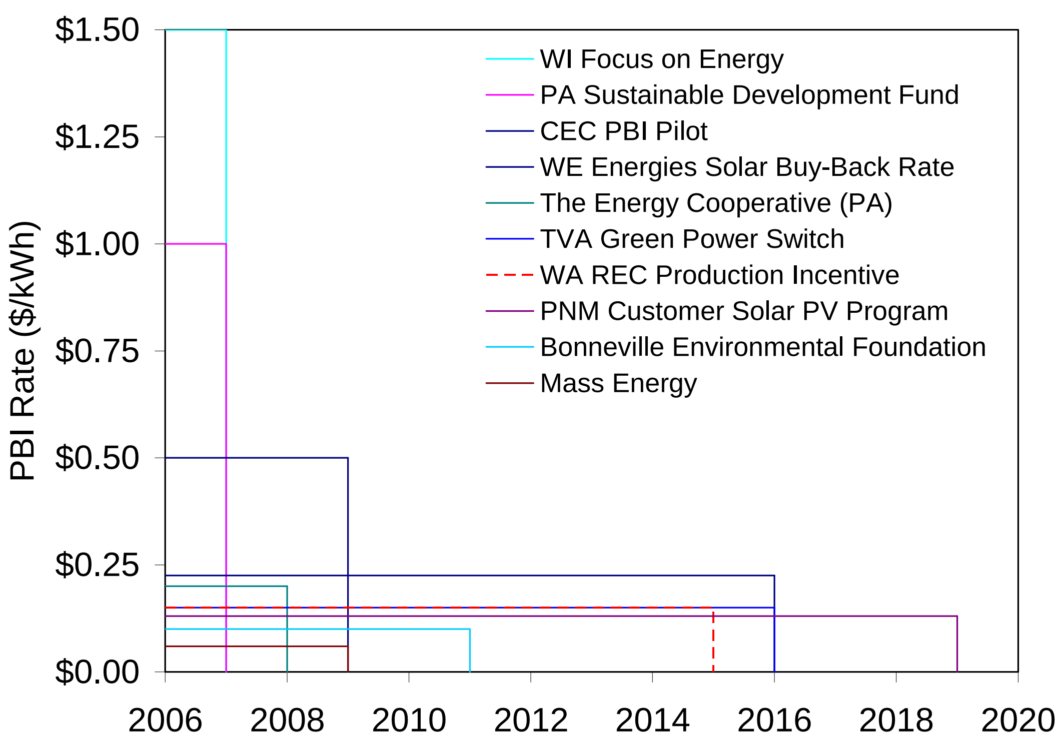

Figure 1. There is a wide variety among the various PBI structures in the U.S.

The lack of consistency across these programs and studies suggest that there is little industry consensus in addressing questions such as:

- What should the PBI rate be to provide customers with an adequate return?
- Should the PBI be paid out over 1 year? 3 years? 5 years? 10 years? 20 years?
- Should the PBI be constant or vary over time?
- How should the PBI structure change for new customers in subsequent years?
- Should the PBI structure vary by geographical location?

Objective

This paper is part of a larger, multiphase project to develop a PBIprogram for commercial customers. The first phase, presented here, is to develop the theoretical basis for the PBI structure. The second phase will be to incorporate other factors into the structure that reflect additional “real world” conditions. The third phase will be to recommend how to implement the resulting PBI, and the fourth phase will be to implement the resulting pilot PBI Program at SMUD.

The objective of this paper is to develop the theoretical basis for a PBI structure that satisfies the requirements of the combined perspectives of both the utility and the customer.

PBI Design

Introduction

PBIs are premised on the notion that customers would make more judicious equipment selections and would take measures to ensure proper maintenance if the incentive were tied to system performance. As shown in Figure 2, the utility[1] uses a PBI to influence customer behavior: (i) the utility establishes the PBI structure (rate and duration), (ii) the customer determines whether or not to purchase, what sort of system to purchase, and how to install and maintain the PV system, and (iii) the utility obtains the benefits from the energy produced by the PV system.

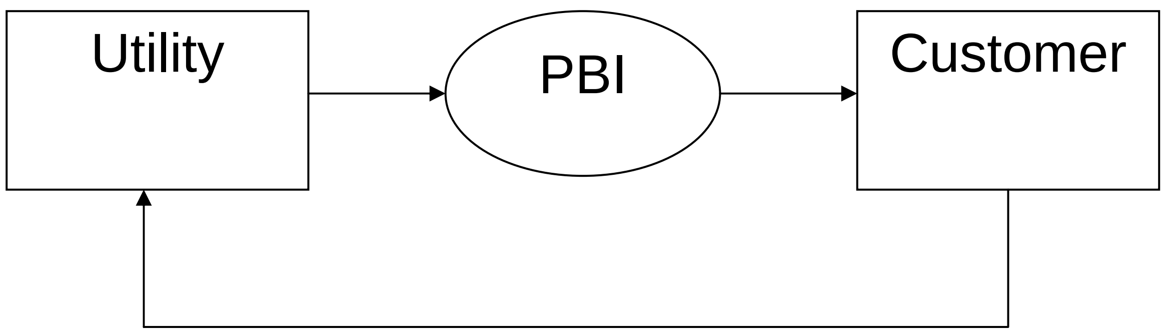

Figure 2. The PBI establishes the interaction between utility and the customer.

In order to answer the questions posed earlier, it is important to begin the analysis with an examination of the perspectives of two key parties who are affected by the PBI structure: the party that is paying for the PBI (and receiving the benefits of the PV system energy production) and the party that is receiving the PBI payment. In most cases, the "paying" party is the utility[1] and the "receiving" party is the customer that purchases the PV system.

There are two fundamental decisions that these parties face with regard to performance-based incentives. First, the utility needs to establish the PBI structure. Second, the customer must decide when (and whether) to invest.

[1] Throughout this paper, the word utility will be used to denote either the utility or some other agency that represents the value of the benefits that a utility would receive from PV system output.

Utility Perspective

The value provided to the utility is a function of the PV system performance and the corresponding avoided utility costs. The cost to the utility equals the incentive cost plus administrative costs to run the program.

The utility needs to establish a PBI structure that ensures that systems are installed and maintained in a way consistent with the use of ratepayer dollars. The utility wants to maximize the benefits that result from its investment while keeping its program spending within budget. In addition, the utility wants to be protected against systems that have poor performance (or no performance due to system failure, equipment removal, or some other reason) over the PBI program duration.

While the PBI structure is established within the context of multiple uncertainties, PV system performance is the critical uncertainty that motivates the utility to offer a PBI rather than a capacity-based incentive. As shown by the uncertainties (represented by circles) in Figure 3, the PV could have good or poor performance for each year during the PBI program. If the system performs poorly, the PBI structure will need to stimulate future investments by new customers in order to provide the desired amount of energy production (or to meet some budget constraint).

Customer Perspective

The value to the customer depends upon the PBI structure, the utility rate structure, tax impacts, and system performance. The cost to the customer includes the PV capital cost and operation and maintenance costs.

The customer needs to decide whether or not to invest based on the PBI structure established by the utility. From the customer's perspective, two basic criteria must be satisfied. First, the investment must be cost-effective. The combined benefits the customer receives should at least offset the initial capital costs of PV. Second, as shown by the decisions represented by squares in Figure 4, the customer faces the decision of whether to invest immediately or to wait. In order to invest immediately,the customer should receive no economic benefit by delaying investment to take advantage of declining PV prices versus investing immediately to capture additional incentive and utility bill savings benefits.

Combined Perspectives

The PBI structure flows out of the combined perspectives as shown in Figure 5. The utility wants to create a PBI structure that provides customers with a sufficient incentive to invest while protecting itself against poorly performed systems. It accomplishes this by combining the customer's investment decision (shown in blue) with PV system performance uncertainty (shown in red). If the customer invests and the PV works well, the utility pays the incentive. If, however, the system fails to perform, the structure needs to provide future customers with the incentive to invest in more PV. Since both existing customers and potential new customers face the same investment decisions in future years, the PBI structure should be fixed at the beginning of the program.

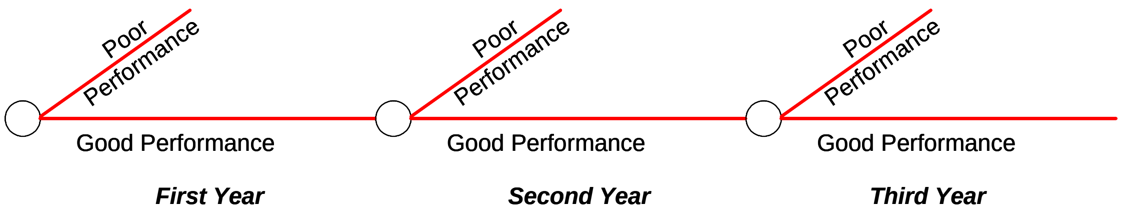

Figure 3. PV system performance is a critical uncertainty for utility.

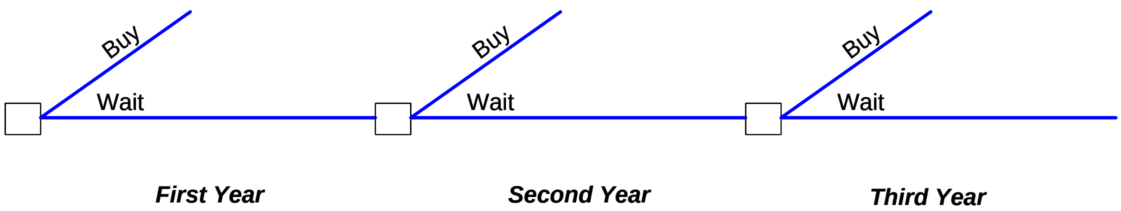

Figure 4. Each customer must make the investment decision to buy now or to wait.

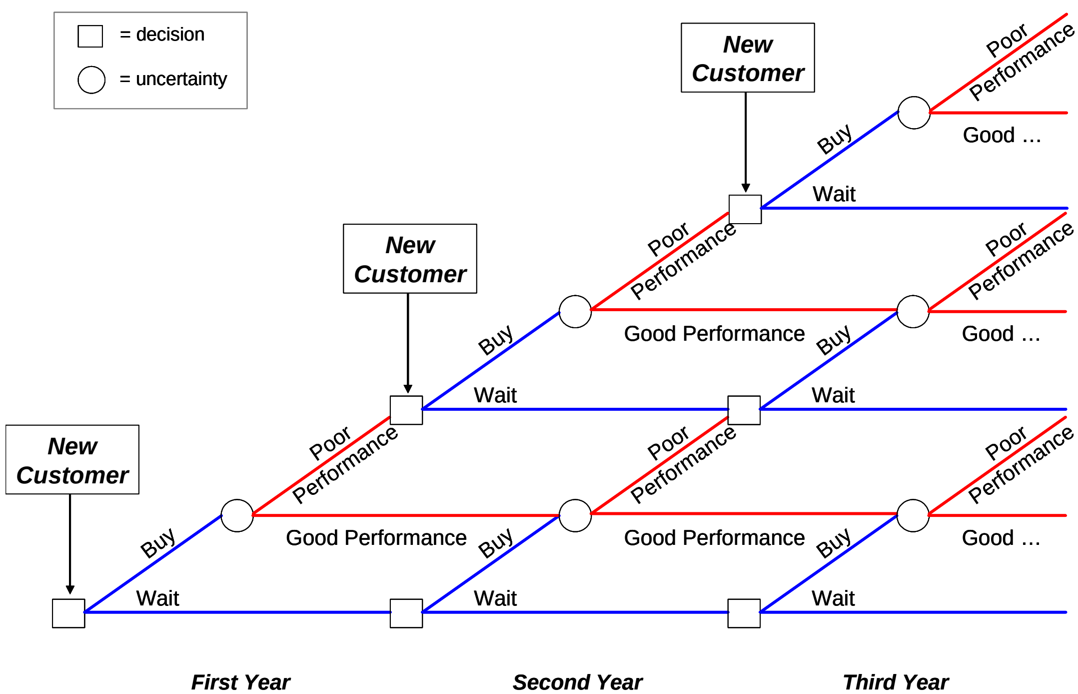

Figure 5. Combined customer decisions and system performance uncertainty leads to PBI structure.

PBI Structure: Declining Rates and Decreasing Duration Known in Advance

The proposed PBI payment structure developed in this paper is fixed in advance both in terms of rate for each year and duration.[2] That is, customers investing in subsequent years will be eligible for the same structure as customers who invested in prior years; they will simply receive fewer PBI payments.

For example, suppose that a PBI design analysis results in the hypothetical structure presented in Figure 6. The figure indicates the rate should be 50¢ per kWh for any electricity produced in 2007, 45¢ per kWh in 2008, and so on down to 5¢ per kWh in 2016 as shown in. Customers who invest on January 1, 2007 receive the full set of incentives: 50¢ per kWh in 2007, 45¢ per kWh in 2008, and so on, until they obtain 10 years worth of PBI payments. Customers who wait one year to invest receive nothing in 2007, 45¢ per kWh in 2008, and so on down to 5¢ per kWh in 2016 until they obtain 9 years of PBI payments.

To compare this proposed PBI structure to existing PBI programs, Figure 9 converts the proposed structure into an economically equivalent structure that has a constant rate once the customer starts receiving payments and a constant duration (assumes fixed 10-year payment stream using a 10 percent discount rate). See Appendix B for the discussion of an alternative structure.

[2] Note that this does not prevent future adjustments to the structure as new participants are added. Rather, the planned structure for all outlying years is published as a fixed schedule in advance. This avoids influencing immediate customer behavior.

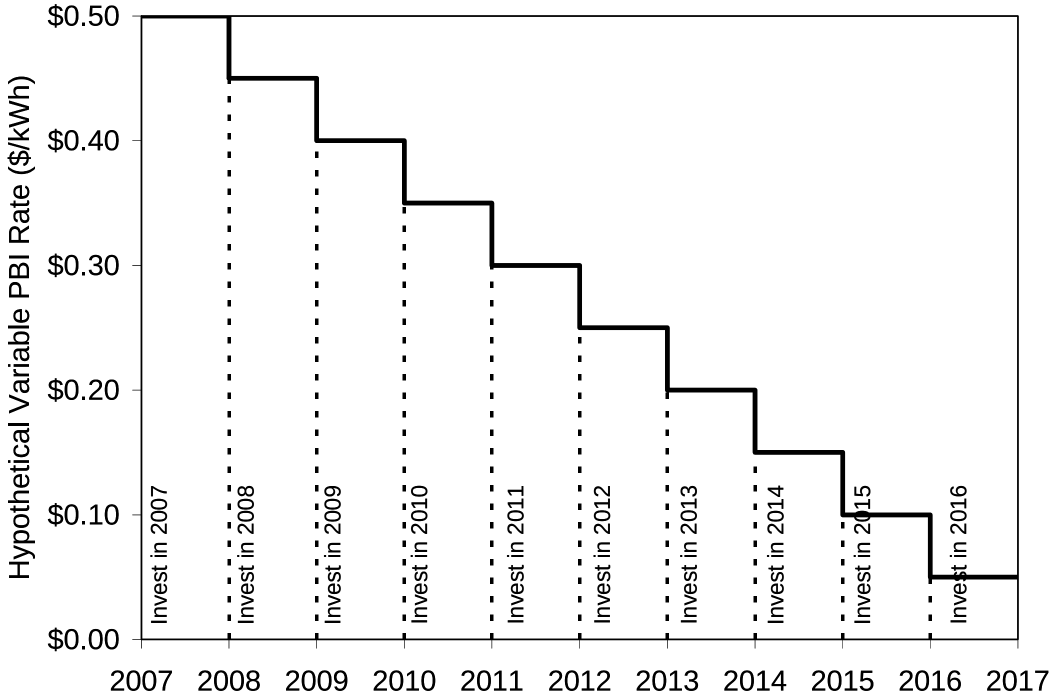

Figure 6. Proposed (hypothetical) PBI structure: declining rate, decreasing duration.

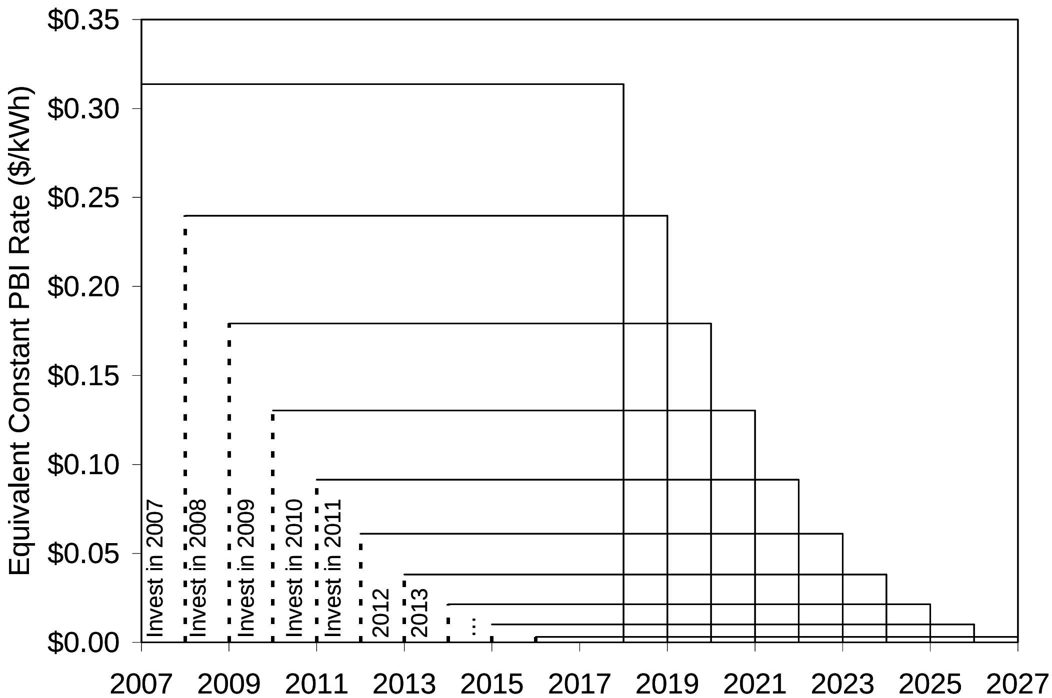

Figure 7. Equivalent typical PBI structure: constant rate (based on investment date) and constant duration.

There are several reasons for proposing a structure where the annual rate declines and the duration decreases with the investment delay. Some of the benefits are that the proposed structure:

- Is simple for any customer to evaluate: a customer forfeits PBI payments for as long as investment is delayed.
- Eliminates the expected benefit a customer might gain by waiting to invest and take advantage of a different PBI structure.
- Protects program administrators against a barrage of "last minute" filings triggered by incentive changes because it eliminates the discontinuous value effect of PBI rate changes.[3]
- Provides a natural transition to a competitive market since the structure is designed based on the anticipation that the discontinuation of PBI payments will coincide with the time when unsubsidized systems are cost-effective.[4]
- Will be beneficial over a constant rate with a similar duration structure because it can be shown that the program will cost less when the utility has a lower discount rate than the customer.
- Reduces administrative costs because the PBIs are paid out for half as many years as under the typical constant duration structure.

Optimization Problem

The combined perspectives can be satisfied by formulating a constrained optimization problem. The utility wants to maximize value minus cost subject to the constraints that:

- Incentive program cost does not exceed program budget at any point in time
- The PBI structure is sufficient for customers to invest immediately
- The PBI structure does not encourage customers to wait to invest
- The PBI structure makes the utility indifferent between whether or not systems perform as predicted (or are even removed entirely)

Rather than formulating the full optimization problem, this paper focuses on the PBI structure constraints since it is these constraints that will be critical in designing the PBI structure.

[3] For example, in the hypothetical example above, suppose that a customer is considering investing either on December 31, 2007 or on January 1, 2008 and that their 1 kW system is expected to produce 2 kWh per day in December. Investing on December 31, 2007 gets 50¢ per kWh for 1 day (for a value of $1) and then the structure moves to 45¢ per kWh for all energy produced in 2008.

[4] Incentives are only intended to be temporary bridges to cost-competitiveness. One of the strengths of the PBI programs that are being implemented in the U.S. is that they are combined with utility bill savings, ths providing for a point at which systems will be cost-effective without any incentive.

Example

Consider an example PBI design problem. Suppose that the utility desires 165,000 kWh of PV-generated electricity per year and that a customer is considering investing in a PV system. Assume:

- The current year is 2007
- A 100 kW system will produce 165,000 kWh per year
- A 100 kW system costs $600,000 in 2007 and will cost $550,000 in 2008
- The only other benefit a customer gains from investing in PV is the utility bill savings; that is, all tax effects are excluded
- A 100 kW system reduces the current annual utility bill by $20,000 and these savings escalate at a rate of 3 percent per year
- PV system life is 30 years
- The PBI payments will last some currently unknown period (but less than 30 years)
- The discount rate is 10 percent

The utility wants to determine what the PBI rate should be for 2007.

Table 1 presents the cash flows associated with the two investment alternatives that are available to the customer under a given PBI set of rules. The top part of the table is the “Buy Now” alternative and the bottom part of the table is the “Wait 1 Year” alternative. If the customer purchases immediately, the utility bill savings will be by $20K in 2007, $20.6K in 2008, etc., the customer will receive the PBI for some number of years, and the customer will incur an immediate cost of $600K. If the customer delays investment for one year, the utility bill will be reduced by $20.6K in 2008, $21.2K in 2009, etc., the customer will receive the (now slightly lower) PBI, and for one less year, and the customer will incur a cost of $550K in 2008.

Notice that there is very little difference between the cash flows for the two alternatives. In fact, the only difference is that a customer with the “Buy Now” alternative (i) saves on the utility bill immediately, (ii) receives a PBI payment in 2007, and (iii) incurs the higher system cost in 2007 while a customer with the “Wait 1 Year” alternative (i) adds a year of utility bill savings after 30 years (ii) forfeits the 2007 PBI payment, and (iii) incurs a lower system cost one year later in 2008.

In order to provide the customer with the proper investment incentive in 2007, the utility would need to determine what amount would make it so that there would be no economic benefit for customers between buying now and waiting. This would occur when the two cash flow streams are equal in net present value terms.

The difference between the cash flows for the two alternatives is shown in the top of Table 2 and the discounted difference is shown in the bottom part of the table. An examination of the bottom part of the table indicates that the only way to make the sum of the net discounted cash flows equal to $0 is to set the 2007 incentive at $82.8K, so that it satisfies the equation $0 = I_{2007}$ -\$580k + \$500k - \$2.8k. As a 100 kW system produces 165,000 kWh, per year, this corresponds to a PBI payment of 50¢ per kWh in 2007.

The next section will demonstrate how to establish the full PBI structure.

Table 1. Cash flows associated with two investment alternatives.

	2007	2008	2009	…	2036	2037
Buy Now						
Bill Savings	\$20K	\$20.6K	\$21.2K	…	\$47.1K	
Incentive	I_{2007}	I_{2008}	I_{2009}	…		
System Cost	-\$600K					
Wait 1 Year						
Bill Savings		\$20.6K	\$21.2K	…	\$47.1K	\$48.5K
Incentive		I_{2008}	I_{2009}	…		
System Cost		-\$550K				

Table 2. Difference between “Buy Now” versus “Wait 1 Year” cash flows.

	2007	2008	2009	…	2036	2037
Difference: Buy Now Minus Wait 1 Year						
Net	**I_{2007} - \$580K**	**\$550K**	0	...	0	**-\$48.5K**
Net (Discounted)	**I_{2007} - \$580K**	**\$500K**	0	...	0	**-\$2.8K**

PBI Structure Specification

The simple example above produced the result of what the incentive needs to be in 2007 in order to provide customers with the proper investment incentive. Several questions still remain. First, what should the PBI be after 2007? Second, what is the correct duration of the PBI payments?

The PBI structure needs to be designed to satisfy two criteria. First, a customer should receive no economic benefit by delaying investment versus investing immediately over the duration of the PBI program.[5] Second, the PBI payments should continue until some cost-effectiveness test has been satisfied.

Customer Investment Constraint: No Benefit in Waiting

Consider the value of a PV investment that occurs either now or at some time in the future. The value (expressed in $/kW) of waiting W years to invest (neglecting tax effects and O&M costs) equals the present value of the utility bill savings over the life of the PV system plus the present value of the PBI payments minus the system price. That is,

$$\begin{matrix} \text{Value of} \\ \text{Investing in} \\ \text{Year } W \end{matrix} = \overbrace{\sum_{t=W}^{L-1+W} \frac{U_t E_t}{(1+r)^t}}^{\text{Utility Bill Savings}} + \overbrace{\sum_{t=W}^{D-1} \frac{I_t E_t}{(1+r)^t}}^{\text{Performance Based Incentives}} - \overbrace{\frac{P_W}{(1+r)^W}}^{\text{Price}} \qquad (1)$$

where:

- t is the year
- U_t is the effective utility bill savings ($ per kWh) including the impacts of demand charge savings, net metering, and net production
- I_t is the performance based incentive ($ per kWh)
- P_W is the price of the PV system in year W ($ per kW)
- E_t is the energy produced by the PV system (kWh per kW per year)
- L is the life of the PV system (years)
- D is the PBI program duration (years)
- W is the number of years that the customer waits before investing (years)
- r is the customer's discount rate (percent)

This analysis also assumes that, with the declining cost of PV installations and the increasing utility costs, PV will become cost effective without further subsidies within the service life of PV systems installed today. That is, the PBI program duration (D) is shorter than PV system life (L).

[5] This can be more formally stated as the criterion that the customer needs to be economically indifferent to the year in which the investment occurs over the duration of the PBI program.

PBI Rate

The first criterion is that a customer should receive no economic benefit by delaying investment versus investing immediately over the duration of the PBI program. This criterion is satisfied exactly when the value to the customer is the same whether the customer invests now or the customer waits to invest. The second criterion is that the PBI payments should continue until some cost-effectiveness test has been met.

When these two criteria are satisfied, the result is that the PBI rate for any particular year equals the cost premium of not waiting for the following year's price reduction less the added upfront utility savings benefits. The payments continue until the year that the cost-effectiveness test is satisfied in an unsubsidized market. Appendix B provides a detailed derivation of the PBI payment that the utility would make for any given year of the program. The results is as follows:

$$I_t = \begin{cases} \overbrace{\left[\left(P_t - \frac{P_{t+1}}{1+r}\right)\left(\frac{1}{E}\right)\right]}^{Cost\ Premium} - \overbrace{\left[U_t - \frac{U_{L+t}}{(1+r)^L}\right]}^{Added\ Benefit} & for\ t < D \\ 0 & for\ t >= D \end{cases} \tag{2}$$

In this relationship, the "Cost Premium" is the premium the customer would have to pay to invest in year t rather than wait for a lower (discounted) price the following year t+1. The "Added Benefit" is the utility bill savings gained from investing in year t versus waiting for the following year. As desired, the optimum PBI payment I_t provides only the incremental additional incentive the customer would require to in order to invest in the given year.

Suppose, for example, that the current price is $6,000 per kW, the price next year is expected to be $5,500 per kW, the system produces 1,650 kWh per kW per year, the utility bill savings rate is 12¢ per kWh and will be 30¢ per kWh in 30 years, and the discount rate is 10 percent. Equation (2) suggests that the "Cost Premium" is 60¢ per kWh, the "Added Benefit" is 10¢ per kWh, and the PBI rate is the difference between the two and equals 50¢ per kWh.

Appendix D uses this result to prove that the value of an investment in any year in a subsidized market (with the PBI payments) exactly satisfies the cost-effectiveness test of a delayed investment in an unsubsidized market (with no PBI payments). That is, the value of investing at any time over the duration of the PBI program equals the value of the investment in the year after the PBI payments cease (year D), discounted to the current year.

Variable Specification

The PBI rate structure can be completely specified using Equation (2). There are, however, several variables that are unknown in the current year. These variables include future utility bill savings and PV system prices.

Future Utility Bill Savings

It will be assumed that utility bills savings will escalate at a consistent rate (*e*) over time so that the utility bill savings at time t is a function of the utility bill savings at time 0.

$$U_t = U_0 (1+e)^t \tag{3}$$

PV System Price

While PV system prices could be assumed to decline from time 0 at a fixed percentage, a more accurate approach would be to use a learning curve price model. A good review of learning curve price models can be found in [6]. Margolis provides a brief review of the literature that examines learning by doing, learning by using, and experience curves. The general form of the experience curve as applied to price estimates is:

$$P_t = P_0 \left[\frac{Q_t}{Q_0} \right]^{\frac{\ln(PR)}{\ln(2)}} \tag{4}$$

where Q_t is the cumulative quantity of installed PV capacity at time t and PR is the progress ratio. The Progress Ratio for crystalline PV modules is currently estimated to be 0.82. A 0.82 progress ratio indicates that the price is reduced by 18 percent for a doubling of cumulative PV capacity.

Using this formula, future PV capital costs are estimated based upon today's cost and an estimate of future production.[6]

[6] While the progress ratio presents the price in real terms, it will be used for the nominal price projection due to uncertainty in what is the correct progress ratio for a complete PV system rather than PV modules alone (see [6] for a presentation of the range of progress ratios for PV prices).

Sample PBI Results

The PBI structure can be calculated based on the assumptions presented in Table 3 using Equations (2), (3), and (4).[7] While other cost-effectiveness tests could be used, it is assumed that the PV investment is cost-effective (and thus the point at which a PBI is no longer paid) when the PV Price is less than or equal to 10 times the corresponding year's utility bill savings (i.e., the investment has a 10 year simple payback).

The results are summarized in Table 4 and Figure 8. For this particular set of assumptions, the result is an optimized 13-year PBI that starts at 47¢, and declines to 10¢ in the final year.

Table 3. Assumptions

Utility Savings		
Average Utility Savings (U_0)	$0.12	per kWh
Savings Escalation (e)	3%	per year
PV Is Cost Effective When	10	yrs savings > cost
PV System		
Effective Price (P_0)	$6,000	per kW
Energy Production (E)	1,650	per kW per year
System Life (L)	30	years
PV Market Estimate		
Installed PV Capacity (Q_0)	5.00	GW
Annual PV Sales	1.50	GW per year
Growth in Sales	20%	per year
Progress Ratio (PR)	82%	
General		
Discount Rate (r)	10%	

[7] The price is assumed to be the price a commercial customer would pay after a 30 percent federal tax credit.

Table 4. PBI calculations.

	Cumulative PV Capacity (GW)	Annual PV Sales (GW)	Effective PV System Price	Utility Savings	PBI Rate
2007	5.0	1.5	$6,000	$0.12	$0.47
2008	6.5	1.8	$5,566	$0.12	$0.41
2009	8.3	2.2	$5,190	$0.13	$0.36
2010	10.5	2.6	$4,857	$0.13	$0.32
2011	13.1	3.1	$4,559	$0.14	$0.28
2012	16.2	3.7	$4,288	$0.14	$0.25
2013	19.9	4.5	$4,040	$0.14	$0.22
2014	24.4	5.4	$3,812	$0.15	$0.20
2015	29.7	6.4	$3,601	$0.15	$0.18
2016	36.2	7.7	$3,404	$0.16	$0.15
2017	43.9	9.3	$3,220	$0.16	$0.13
2018	53.2	11.1	$3,048	$0.17	$0.11
2019	64.4	13.4	$2,887	$0.17	$0.10
2020	77.7	16.0	$2,735	$0.18	$0.00
2021	93.8	19.3	$2,592	$0.18	$0.00
2022	113.1	23.1	$2,457	$0.19	$0.00
2023	136.2	27.7	$2,330	$0.19	$0.00
2024	163.9	33.3	$2,209	$0.20	$0.00
2025	197.2	39.9	$2,095	$0.20	$0.00
2026	237.1	47.9	$1,988	$0.21	$0.00

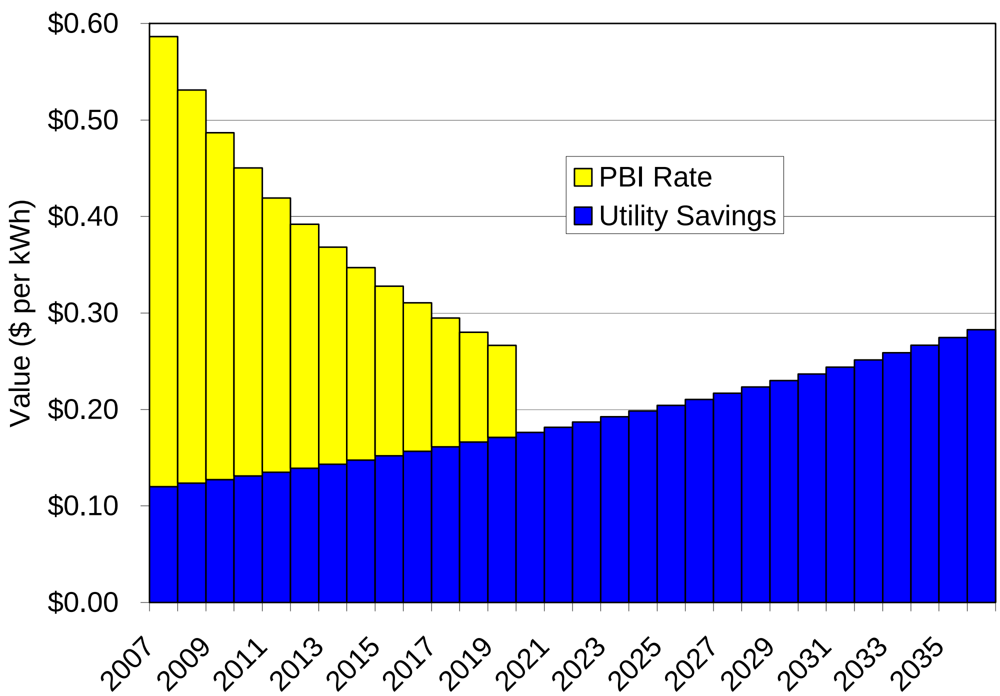

Figure 8. Total value versus year.

The results of this analysis can be verified by demonstrating that the customer is economically indifferent between investing and waiting during each year using the PBI structure specified in Table 4. In order to do this, the utility bill savings are added to the PBI rate and then multiplied by the PV system output to give the annual benefits. The results are shown in Table 5.

For example, the benefits equal $968 in 2007 when the sum of the utility savings (12¢ per kWh) plus the PBI rate (47¢ per kWh) is multiplied by the annual output (1,650 kWh per installed kW). This is repeated for each year as shown in the first column. The second column presents the 30-year present value savings. The net present value to the customer in any particular year is the difference between the 30-year present value savings (second column) and the price (third column) and is presented in the fourth column. The final step is to discount future years to 2007 (fifth column).

The table shows that the net present value of the investment from the perspective of 2007 is constant during all years that the PBI is offered. This confirms that the customer is economically indifferent between investing immediately and investing at any time during the next 12 years when the PBI is offered.

Notice also that the discounted savings minus cost is constant until after year 13, the point at which the cost-effectiveness test is satisfied.

Table 5. Verification of customer timing indifference.

	Annual Benefit	***30-yr NPV Savings***	***Effective PV System Price***	***Savings - Cost***	***Discounted Savings - Cost***
2007	$968	$6,347	$6,000	$347	**$347**
2008	$876	$5,948	$5,566	$382	**$347**
2009	$803	$5,610	$5,190	$420	**$347**
2010	$743	$5,319	$4,857	$462	**$347**
2011	$691	$5,067	$4,559	$508	**$347**
2012	$647	$4,847	$4,288	$559	**$347**
2013	$608	$4,656	$4,040	$615	**$347**
2014	$573	$4,489	$3,812	$677	**$347**
2015	$541	$4,345	$3,601	$744	**$347**
2016	$512	$4,223	$3,404	$819	**$347**
2017	$486	$4,121	$3,220	$901	**$347**
2018	$462	$4,039	$3,048	$991	**$347**
2019	$440	$3,977	$2,887	$1,090	**$347**
2020	$291	$3,934	$2,735	$1,199	**$347**
2021	$299	$4,052	$2,592	$1,460	**$384**
2022	$308	$4,173	$2,457	$1,716	**$411**
2023	$318	$4,298	$2,330	$1,969	**$428**
2024	$327	$4,427	$2,209	$2,218	**$439**
2025	$337	$4,560	$2,095	$2,465	**$443**
2026	$347	$4,697	$1,988	$2,709	**$443**

Conclusions

The objective of this paper was to present the theoretical basis for a PBI structure that satisfies the requirements of the combined perspectives of both customer and utility. Results indicate that the year-to-year PBI rate is determined by (1) calculating the point where the customer receives no economic benefit by delaying investment versus investing immediately and (2) paying the incentive until a cost-effectiveness test is expected to be satisfied.

Using this structure, it is clear that the questions posed at the beginning of the paper can be answered:

- There is a single PBI payment structure (it is a declining structure that depends primarily the anticipated PV price declines, current utility bill savings, utility bill savings escalation, and PV system output)
- There is a set number of years for which the payment should be made (it depends on the same variables plus a cost-effectiveness test)
- The incentive structure should reflect a declining PBI payment each year, known in advance to all prospective PV investors.
- The PBI structure should not change over time but customers who invest in future years will forfeit the PBI payments from the early years[2]

Furthermore, the results of this paper demonstrate that the PBI structure (both the rate paid each year and the duration for which the PBI is paid) will differ by location because the fundamental inputs into establishing the PBI (e.g., utility bill savings and energy production) are location-specific. That is, locations throughout the U.S (and other countries as well) who use the analytical structure presented in this paper will have PBI structures that are tailored to their specific situation.

Next Steps

The objective of this paper was to present a theoretical basis for establishing a PBI structure. This paper represents a first step at designing a PBI structure. Prior to implementing a PBI for an actual program and location, several items need to be addressed. They include the following.

1. Evaluate how the PBI structure should recognize state and federal tax benefits. Simplifying assumptions were made in order to perform this analysis. A key assumption was that there are no tax effects when a customer purchases a PV system. In reality, commercial customers have tax credits, depreciation, and tax loss due to utility bill savings, to name a few. The next step of the analysis will be to utilize a more detailed analytical tool[8] to assess the economics from the customer's perspective.

2. Improve the accuracy of the learning curve-based price model

    a. Modify the price model to calculate PV system price as the sum of the PV module price and the remainder of system (inverter, BOS, labor, etc.). The PV module price will continue to be based on the world PV module market price and the remainder of system price will be based on the local PV market.[9] The prices will be based on separate learning curves.

    b. Develop a progress ratio (PR) for the remainder of system price. It may be useful to draw upon the Japanese experience for this information.

    c. Demonstrate how to estimate cumulative local PV capacity over time (and thus the remainder of system price over time) by integrating planned local incentive programs into the model.

    d. The price model implied a smooth change over time. Determined whether or not (and how) to capture market disruptions such as module shortages where prices increase rather than decrease, and the effect of events such as the expiration of the 30 percent U.S. federal tax credit at the end of 2007.

    e. Present projected prices in nominal rather than real dollars.

3. Consider the benefit of having a PBI structure that discriminates by PV system size (smaller systems tend to have a higher price than larger systems) and/or market sector (i.e., residential, commercial, public, etc.).

[8] QuickQuotes will be used for the analysis (available at http://www.clean-power.com).
[9] It may be that the correct location is regionally rather than locally.

4. Select and calibrate the cost-effectiveness test that is sufficient to provide customers with the proper investment incentive. This could address questions such as how long the payback period should be in order to provide an adequate incentive level.

5. Assess how the PBI structure should change over time in response to market conditions.

    a. One option is to shorten the duration of the PBI payments so that the PBI structure remains the same and the modification occurs by reducing the number of years for which the incentive is paid. This option is desirable if the cost-effectiveness criterion used to establish the structure does not match the customer behavior. This option might be implemented through an auction, bidding system, or some sort of trigger based on the incentive funding levels.

    b. Another option is to modify the PBI rate. This option is desirable if customers use a different discount rate or if the future PV price and/or utility bill savings do not follow the anticipated path.

6. Determine what sort of administrative activities are needed to implement and monitor the PBI program. Questions such as the following need to be addressed:

    a. How should the program deal with meter reading?

    b. What happens when the building ownership changes?

    c. How should the funds be administered and reserved? Trust fund? Other?

    d. What type of software tools could assist with administration?

7. Incorporate the results of a utility value analysis (a separate study) into the PBI structure.

    a. This would enable the incentive payment to better reflect to the value to the utility. For example, this might take the form of an adjustment that provides added value ($/kWh) for a southwest orientation (providing extra capacity benefits to the utility but reducing the energy production) and reduced value for an east orientation as compared to a south orientation.

    b. This would assist the utility in addressing the issue of what is the optimal program size and how it relates to budget.

8. Expand the analysis to include the other perspectives such as non-participating ratepayers, local, state, and federal government, industry, etc. [7]

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Appendix A: Performance-Based Elements in PV Incentive and REC Programs

Introduction

Table 6 and the following discussion illustrate the range of performance-based payments and duration among state incentive programs, green power programs, and REC purchase programs developed for compliance with renewable portfolio standards.

Table 6. Performance-Based Elements in PV Incentive and REC Programs.

State	Program Name	Amount	Payment Period
State PV Incentive Programs			
California	CEC Emerging Renewables Program PBI Pilot	$0.50/kWh	3 years
Pennsylvania	Sustainable Development Fund Solar PV Grant Program	$4/W capacity-based incentive plus $1/kWh produced in first year	1 year
Washington	Renewable Energy Production Incentives	$0.15/kWh, multiplied by a factor dependent on technology type and where equipment was manufactured	Through mid-2014
Wisconsin	Focus on Energy Incentives/Grants	$1.00 - $2.00/kWh depending on installer and building type; $1.50/kWh for systems > 20 kW	1 year
REC Programs for RPS Compliance			
Nevada	Renewable Energy Credit Program	Market based	undefined
New Jersey	Solar Renewable Energy Certificate Program	Market based; ~ $200 per MWh ($0.20 per kWh)	undefined
New Mexico	PNM Customer Solar PV Program	$0.13/kWh	Through 2018
Green Power Programs			
Massachusetts	Mass Energy REC Incentive Program	$0.06/kWh	3 years
North Carolina	NC GreenPower Production Incentive	$0.18/kWh	undefined
Pennsylvania	The Energy Cooperative Solar Energy Buy-Back Program	$0.20/kWh	2 years
Tennessee Kentucky Georgia Mississippi North Carolina	TVA Green Power Switch Generation Partners Program	$500 (residential only) plus $0.15/kWh (residential/small-commercial) or $0.20/kWh (commercial)	10 years
Washington Oregon	Bonneville Environmental Foundation Solar Starters	$0.10/kWh	5 years
Washington	Chelan County PUD SNAP Program	Up to $1.50/kWh; currently $0.47/kWh	undefined
Wisconsin	We Energies – Solar Buy-Back Rate	$0.225/kWh	10 years

State PV Incentive Programs

States are showing increased interest in implementing a performance-based approach to PV incentive programs to ensure quality installations. Performance-based approaches currently include either direct metering or production estimates using production estimation software, shading analysis and other site-specific details.

- The Pennsylvania Sustainable Development Fund mixes a $4/W rebate with a one-year production-based incentive of $1/kWh in its PV program. Unique among incentive programs, SDF also offers installers a PBI of $0.10/kWh for the first year's production.
- The Emerging Renewables Rebate Program in California offers an option for consumers to participate in a performance-based incentive pilot program, paying out 50¢/kWh for three years in lieu of the traditional $/kW buy-down -- currently at $2.80/kW for PV.
- Wisconsin provides a performance-based incentive, but it is calculated based on a PV-Watts production estimate that incorporates shading and other site-specific conditions. The incentive is paid after installation similar to capacity-based rebates.
- In 2005, Washington State enacted a long-term, production-based incentive of 15¢/kWh (capped at $2,000 per year) through June 30, 2014 for individuals, businesses, or local governments that generate electricity from PV and other renewables. Using a set of multipliers, an even greater incentive is paid if the modules, inverter, or other components are manufactured in Washington State. The state's utilities, whose participation is voluntary, will pay the incentives and earn a tax credit equal to the cost of those payments.

Nearly all state PV programs, whether capacity-based or performance-based, allow the project owner to retain ownership of the renewable energy credits (RECs or Green Tags) and may be sold separately. For example, participants in the Pennsylvania SDF program can also take advantage of the Energy Cooperative's Solar Energy Buy-Back Program if they also purchase the Co-op's 100% renewable energy product. The program pays $0.20/kWh for two years for RECs bundled with electricity. Similarly, PV owners in Washington State can combine the state incentive with the REC purchase program ($0.10/kWh for 5 years) offered by Bonneville Environmental Foundation. In New Jersey, participants in the state rebate program can sell their RECs via an online trading system to energy providers who must comply with the solar set-aside in the state's renewables portfolio standard (RPS). The REC price is market based but is around $0.20/kWh.

Utility Compliance with RPS Solar Set-asides

A growing number of state RPS programs contain a provision which requires energy suppliers to provide a certain percentage of retail sales using solar electric resources.

Programs are still under development in some states, but the following performance-based utility and state-wide programs have emerged.

- The New Jersey RPS calls for at least 0.16% of retail sales (about 90 MW) to be met with solar electric generation by 2008. (Currently proposed RPS changes would boost the solar electric requirement to 1,500 MW by 2020.) To demonstrate compliance with the solar set-aside, electric suppliers must use an on-line solar REC tracking system established by the NJ Board of Public Utilities. PV system owners register with the program and use the online market to sell S-RECs (in 1 megawatt-hour denominations). The S-REC program is anticipated to compensate system owners an average rate of around $200 per MWh ($0.20 per kWh). An engineering estimate is used to calculate the monthly S-REC generation for systems under 10 kilowatts. The program web site allows owners of systems 10 kW and larger to upload monthly meter readings and/or production information.

- Nevada also has a solar set-aside as part of its RPS. The two investor-owned utilities offer a capacity-based rebate for PV systems up to 30 kW and retain ownership of the RECs for RPS compliance. However, larger PV and other renewable energy installations register through the Nevada Public Utilities Commission and can sell RECs on a performance-basis. The REC price is market based. A multiplier of 2.55 RECs per kWh of electricity generated from customer-maintained PV systems is used for compliance purposes.

- PNM, an investor-owned utility in New Mexico, is planning a March 2006 implementation of a performance-based customer PV program as part of its plan to comply with the state’s RPS. PNM will purchase RECs from customers who install solar PV systems (up to 10 kW) at a rate of $0.13/kWh through 2018. The electricity output of the PV system may be used on-site, and customers retain their net-metering benefit for excess generation. REC payments are based on the system’s *total* output.

Green Power Programs

Several utilities and green tag marketers, determined to include solar in their green power product mix, offer production-based incentives for PV power and their associated RECs. The payments range from $0.06/kWh to $0.47/kWh with contract periods ranging from two years to 10 years. Some programs have an undefined payment duration.

- The Tennessee Valley Authority and participating distributors in Georgia, Kentucky, Alabama, Tennessee, North Carolina, Mississippi, and Virginia offer a $0.15/kWh incentive for a minimum of 10 years for PV or wind power (plus a one-time $500 incentive to residents). Large commercial customers receive $0.20/kWh for 10 years. The output from these systems will serve as a renewable resource for TVA's *Green Power Switch* Program.

- We Energies offers to purchase electricity and associated RECs generated by PV systems owned by its Wisconsin customers to supply a portion of the energy sold under the "Energy for Tomorrow" green power program. The payment is $0.225/kWh for a 10-year period. Customers will receive a monthly credit for the energy and will receive a check whenever any net accumulated amount exceeds $100.
- Chelan PUD (WA) offers up to $1.50/kWh plus avoided cost for the bundled RECs and electricity produced by PV and other renewables as part of the Sustainable Natural Alternative Power (SNAP) Program, the utility's green power program. The greater the amount contributed to the SNAP Program, the greater the amount that will be distributed among participating SNAP producers. The current rate is $0.47/kWh, and the time period is undefined. Under the SNAP program, the energy producer sells 100 percent of the produced power is directed onto the grid. Payments are made to SNAP Producers annually. Several utilities in Minnesota and one in Alaska offer similar programs.
- NC GreenPower, a statewide green-power program in North Carolina, offers production payments for grid-tied PV and other renewables. PV systems less than 10 kW generally receive $0.18/kWh plus avoided cost for the bundled electricity and RECs. The time period is undefined.
- The Bonneville Environmental Foundation, a non-profit Green Tag marketer based in Portland, Oregon, has teamed with the Northwest Solar Cooperative to market RECs from small solar installations throughout Oregon and Washington. The cooperative pays PV system owners $0.10/kWh for a 5-year contract period for their unbundled RECs. BEF offers the Green Tags for resale to its wholesale and retail customers.
- Non-profit programs in Massachusetts (Mass Energy Consumers Alliance) and Rhode Island (People's Power & Light) purchase RECs from PV systems at $0.06/kWh for three years. The RECs are packaged together with wind, small hydro and biomass renewable energy certificates and sold as New England *GreenStartSM*, a green power product offered by National Grid.
- The Energy Cooperative Association of Pennsylvania, a non-profit, Philadelphia-based competitive energy supplier, pays PV system owners $0.20/kWh for a 2-year contract period for RECs bundled with electricity to incorporate solar into the resource mix of its green power product offering.

Appendix B: Constant Rate, Variable Duration Structure

The constant rate, constant duration structure is currently the most popular PBI structure. This paper proposed that the PBI structure should be a declining rate and variable duration that is known in advance. A structure that is similar to the proposed structure () is one that has a constant rate that changes from year to year with a variable duration. Such a structure applied to the simple example from Figure 6 is presented in Figure 9. While this structure is pretty good, it does risk increasing the administrative burden due to discontinuous value changes (there could be a flood of last minute filings). In addition, it may not be the least cost alternative if the utility has a lower discount rate that the customer.

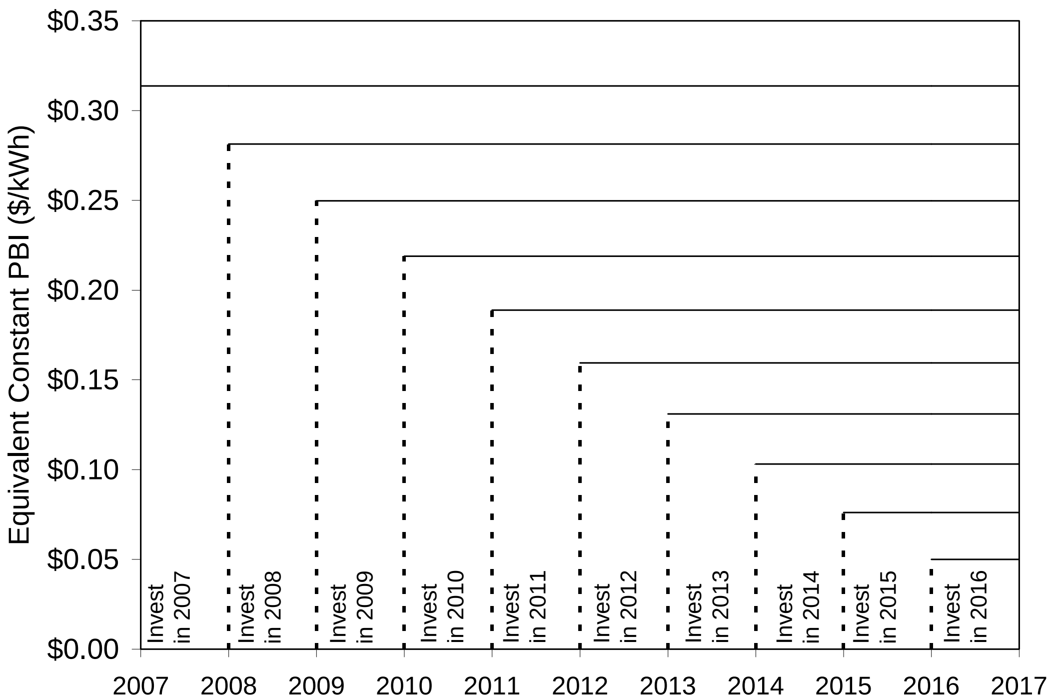

Figure 9. Equivalent PBI structure constant with rate and variable duration.

Appendix C: PBI Structure Derivation

This appendix presents the PBI structure derivation. The PBI structure is derived so that it satisfies two criteria.

No Benefit in Waiting

The first criterion is that a customer needs to be economically indifferent to the year in which the investment is made over the duration of the PBI. This criteria is satisfied when the value to the customer given by Equation (1) is the same whether the customer invests now (W=0) or the customer invests later (W>0). If it is assumed that the energy production E is constant over time, the customer is indifferent when:

$$\overbrace{\underbrace{\sum_{t=0}^{L-1}\frac{U_t E}{(1+r)^t}}_{\text{Utility Bill Savings}} + \underbrace{\sum_{t=0}^{D-1}\frac{I_t E}{(1+r)^t}}_{\text{Performance Based Incentives}} - \underbrace{P_0}_{\text{Price}}}^{\text{Value of Invest Now}} = \overbrace{\underbrace{\sum_{t=W}^{L-1+W}\frac{U_t E}{(1+r)^t}}_{\text{Utility Bill Savings}} + \underbrace{\sum_{t=W}^{D-1}\frac{I_t E}{(1+r)^t}}_{\text{Performance Based Incentives}} - \underbrace{\frac{P_W}{(1+r)^W}}_{\text{Price}}}^{\text{Value of Invest in W Years}} \qquad (5)$$

Many of the terms are the same on both sides of Equation (5) and the terms cancel. The result is that

$$\sum_{t=0}^{W-1}\frac{I_t E}{(1+r)^t} = P_0 - \frac{P_w}{(1+r)^W} - \left\{\sum_{t=0}^{W-1}\frac{U_t E}{(1+r)^t} - \sum_{t=L}^{L+W-1}\frac{U_t E}{(1+r)^t}\right\} \qquad (6)$$

This can be rewritten by expanding the price terms to create a summation and by modifying the second utility bill savings summation in order to have all of the summation terms begin at 0 and end at W-1 years.

$$\sum_{t=0}^{W-1}\frac{I_t E}{(1+r)^t} = \sum_{t=0}^{W-1}\left[\frac{P_t}{(1+r)^t} - \frac{P_{t+1}}{(1+r)^{t+1}}\right] - \left\{\sum_{t=0}^{W-1}\frac{U_t E}{(1+r)^t} - \sum_{t=0}^{W-1}\frac{U_{L+t} E}{(1+r)^{L+t}}\right\} \qquad (7)$$

The incentive for each year is calculated by varying W from 1 to the PBI duration D and then substituting back into Equation (7) for each previously defined I_t. The result is that the PBI for any particular year is the cost premium of not waiting for the following year's price reduction less the added upfront utility savings benefits, or:

$$I_t = \overbrace{\left[\left(P_t - \frac{P_{t+1}}{1+r}\right)\left(\frac{1}{E}\right)\right]}^{\text{Cost Premium}} - \overbrace{\left[U_t - \frac{U_{L+t}}{(1+r)^L}\right]}^{\text{Added Benefit}} \qquad (8)$$

Cost-Effectiveness Criteria

The second criterion is that the PBI payments should continue until some cost-effectiveness test has been met based upon forecasted prices and market conditions. This test could be based on the net present value, simple payback, rate of return, or some other test, in an unsubsidized market. The result is that the incentive rate is calculated using Equation (8) until the year in which the investment is expected to be cost-effective and then it is equals 0 after that point. The result is stated here and in the body of the paper.

$$I_t = \begin{cases} \overbrace{\left[\left(P_t - \frac{P_{t+1}}{1+r}\right)\left(\frac{1}{E}\right)\right]}^{Cost\ Premium} - \overbrace{\left[U_t - \frac{U_{L+t}}{(1+r)^L}\right]}^{Added\ Benefit} & for\ t < D \\ 0 & for\ t >= D \end{cases} \quad (2)$$

Appendix D: Indifference Validation

The PBI payments are intended to provide a customer the incentive to purchase PV, an otherwise uneconomic investment, until such time as the price of PV drops to a cost-competitive level and subsidies are no longer required. To minimize the cost to the utility (and its ratepayers), the value of these payments should equal, but should not exceed, the economic shortfall. This appendix demonstrates that the PBI structure as derived in this paper provides the correct value to achieve this balance.

Under such a balanced PBI structure, the customer would be considered to "break even" provided that the "Wait to Invest" alternative (in which the investment is made in a year W) resulted in the same value as a future, cost-competitive, unsubsidized PV system. By definition, this would first occur in year D, the year following the conclusion of the PBI program. Thus, it needs to be demonstrated that the customer investing in year W is made whole, deriving the same value as the customer investing in year D.

The value of the "Wait to Invest" alternative is given by Equation (1) for any year W less than or equal to D with the assumption that the energy production E for any year is the same. The PBI structure from Equation (2) is substituted into Equation (1) (where $t<D$).

As shown below, the result is that the value of the "Wait to Invest" alternative is equal to the value of an investment in year D, discounted to the current year. The conclusion is that PBI structure provides the correct level of subsidy to ensure that the early investment for any year between 0 and D is economically equivalent to the future, unsubsidized investment.

$$\begin{matrix}\textit{Value of}\\ \textit{Investing in}\\ \textit{Year } W\end{matrix} = \sum_{t=W}^{L-1+W}\frac{U_t E}{(1+r)^t} + \sum_{t=W}^{D-1}\frac{I_t E}{(1+r)^t} - \frac{P_W}{(1+r)^W}$$

$$= \sum_{t=W}^{L-1+W}\frac{U_t E}{(1+r)^t} + \sum_{t=W}^{D-1}\frac{\left\{\left[\left(P_t - \frac{P_{t+1}}{1+r}\right)\left(\frac{1}{E}\right)\right] - \left[U_t - \frac{U_{L+t}}{(1+r)^L}\right]\right\}E}{(1+r)^t} - \frac{P_W}{(1+r)^W}$$

$$= \sum_{t=W}^{L-1+W}\frac{U_t E}{(1+r)^t} + \sum_{t=W}^{D-1}\left[\frac{P_t}{(1+r)^t} - \frac{P_{t+1}}{(1+r)^{t+1}}\right] - \sum_{t=W}^{D-1}\left[\frac{U_t E}{(1+r)^t} - \frac{U_{L+t}E}{(1+r)^{L+t}}\right] - \frac{P_W}{(1+r)^W}$$

$$= \sum_{t=D}^{L-1+W}\frac{U_t E}{(1+r)^t} + \sum_{t=L+W}^{L+D-1}\frac{U_t E}{(1+r)^t} - \frac{P_D}{(1+r)^D}$$

$$= \sum_{t=D}^{L+D-1}\frac{U_t E}{(1+r)^t} - \frac{P_D}{(1+r)^D}$$

$$= \overbrace{\left[\sum_{t=0}^{L-1}\frac{U_{t+D}E}{(1+r)^t} - P_D\right]}^{\substack{\textit{Present Value of}\\ \textit{Investment in Year } D}} \quad \overbrace{\left[\frac{1}{(1+r)^D}\right]}^{\substack{\textit{Discount to}\\ \textit{Current Year}}}$$

