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MARKET TRANSFORMATION BENEFITS OF A PV INCENTIVE PROGRAM

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ABSTRACT

Policy makers require a firm understanding of the value of investments in photovoltaics (PV) in order to design the most effective energy policy. They need to know how investments produce economies of scale, encourage technological improvements, and drive costs toward convergence with conventional generation technologies. This paper decomposes total program value into three components: price reduction benefits, additional value of energy generated by PV, and the premium or discount for PV energy. The paper examines component level PV price data from the New York State Energy Research and Development Authority's (NYSERDA's) PV incentive program from 2003 to 2008 to quantify labor price reduction benefits experienced in the New York energy market. While total price levels have fluctuated due to global economic factors, local labor prices have steadily declined and can be modeled using a learning curve approach. Results suggest that the benefit of labor price savings ranges from about \$0.01 to \$0.05 per kWh.

1. INTRODUCTION

Government agencies are under a growing pressure to justify the expense of programs providing incentives for PV installations. As a result, it is important to model the value that a program has created explicitly. Previous work (e.g., Hoff et al., 2006) examined the value that was directly created using PV as an additional energy source. It quantified savings in areas such as power generation, capacity deferrals, environmental savings, price hedges, loss savings, etc. An incentive program, however, can also influence the rate of technology adoption further adding to the direct benefits that accrue related to the installed capacity.

Satisfying long-term renewable energy goals will require PV prices to decline in order for consumer incentives to make adoption viable. The value associated with changing price trends in the market has not been well defined in the literature.

Before assessing how incentives influence the rate of adoption, it is important to understand how change in a market generally occurs.

One way to forecast price change is to look at cumulative installed capacity. Wright (1936) first observed this in his work with manufacturing airplanes. He recognized that the required labor decreased at a fixed percentage as cumulative production increased. This fundamental observation, modeled using learning curves, has been used in a number of different formulations throughout the literature (Yelle, 1979) with the basic model specified as:

$$Cost_t = Cost_0 \left(\frac{Q_t}{Q_0}\right)^{Learning\ Coeff.}$$

The learning coefficient can be used from this model to calculate the commonly used progress ratio, or the rate at which costs decrease when cumulative production doubles, by evaluating the equation:

$$Progress\ Ratio = \left(\frac{1}{2}\right)^{Learning\ Coeff.}$$

The progress ratio for a technology is frequently estimated using historical data. Estimates are used in a variety of ways to predict the continued evolution of costs driving to different policy implications. Sark (2007) noted differences in estimates across papers and presented a model for including an error term in the estimation of progress ratios and specifically illustrated its effect on PV learning curves. This term allows for the error of the estimate to be directly modeled and estimated. While some variation in the estimates of the progress ratio in the literature are due to different time periods or source data, the model Stark uses creates a range into which reasonable estimates fall allowing for accurate consideration of best and worst case developments.

Several authors have evaluated the specific expectation for the continued decline of PV cost. Van der Zwaan and Rabl (2004) quantified the rapid decline of PV prices from 1976-

1999 and were able to estimate the progress ratio over this period and sub-periods. They showed that worldwide progress ratios changed over time and could be approximated by a ratio of about 80 percent. They went on to estimate that the progress ratio would need to be 80 percent or less in order for costs to become such that PV became economically viable compared to traditional sources.

If policy can create an environment where the progress ratio is likely to be less than 80 percent, it creates a case for how incentive programs help PV become a realistic alternative in the future. When thinking about what impact policy can have on the progress ratio it is helpful to think about the underlying factors that contribute to the reduction of cost. Nemet (2005) explored factors that influence the cost of PV and found that expected future demand, risk, R&D and knowledge spillover had the greatest impact on the observed downward price trend. Learning from experience was only one of several factors that contributed to the change in PV cost. Ferioli (2009) further went on to analyze PV price trends and recognized that time in business was another important factor in predicting the rate of cost decline.

These drivers of change are important to consider when developing policy geared to reducing the time until PV is independently viable. However, once a program is designed to accelerate change, the value created by this change must be understood to determine if the effort was worthwhile. This paper presents a model to specify and calculate a portion of the market transformation benefit that NYSERDA's program has created.

2. SPECIFICATION OF PROGRAM VALUIE

PV incentive programs have the potential to transform markets by increasing the number of PV installations and thus accelerating PV price reductions. This benefit within the context of grid-connected PV, when taken from an overall societal perspective, can be quantified as the difference between the net present value (NPV) of all energy expenditures with and without the incentive program. The NPV of the incentive program equals the difference between the NPV of electricity expenditures with the incentive program minus the NPV of electricity expenditures without the incentive program from both traditional and PV sources.

$$B = \underbrace{\sum_{t=1}^{T} \frac{[\hat{V}_t^{PV} - \hat{P}_t^{PV}](\hat{Q}_t^{PV}) + [\hat{V}_t^{U} - \hat{P}_t^{U}](\hat{Q}_t^{U})}{(1+r)^t}}_{NPV\ with\ Program} - \underbrace{\sum_{t=1}^{T} \frac{[V_t^{PV} - P_t^{PV}](Q_t^{PV}) + [V_t^{U} - P_t^{U}](Q_t^{U})}{(1+r)^t}}_{NPV\ without\ Program}$$

V, P, and *Q* represent value, price, and quantity. The superscripts, *PV* and *U*, correspond to PV generated electricity and utility generated electricity. The variables with the ^ correspond to the situation with the incentive program.

The mathematical specification of the problem can be decomposed into three components: (1) additional value of electricity generated by PV as compared to electricity generated by conventional fuel sources – including items such as fuel price risk mitigation value and environmental benefits; (2) premium or discount for PV-generated electricity; and (3) benefits of accelerated PV price reductions.

$$B = \underbrace{\sum_{t=1}^{T} \frac{(V_t^{PV} - V_t^{U})(\hat{Q}_t^{PV} - Q_t^{PV})}{(1+r)^t}}_{Additional\ Value\ for\ PV} + \underbrace{\sum_{t=1}^{T} \frac{(P_t^{U} - P_t^{PV})(\hat{Q}_t^{PV} - Q_t^{PV})}{(1+r)^t}}_{Premium\ and\ Discount\ for\ PV} + \underbrace{\sum_{t=1}^{T} \frac{(P_t^{PV} - \hat{P}_t^{PV})\hat{Q}_t^{PV}}{(1+r)^t}}_{Benefit\ of\ Price\ Reduction}$$

This paper focuses on the benefits of price reduction.

3. EMPIRICAL ANALYSIS OF MARKET TRANSFORMATION VALUE IN NEW YORK

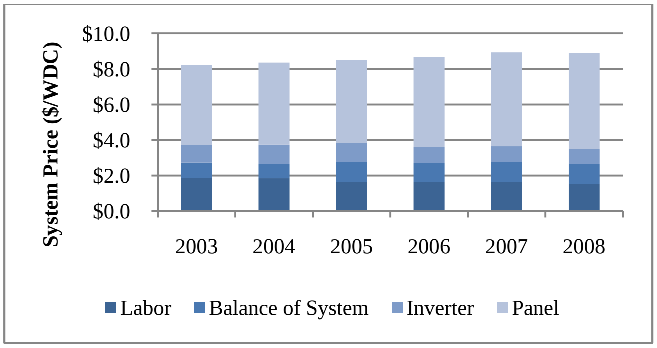
As an initial attempt to explore the value that market transformation creates, this paper examines historical data from 2003 to 2008 of NYSERDA's incentive program. Recalling from the findings above, the benefit related to the market transformation is described by the change in the price levels as a result of the incentive program. Some claim that a single program cannot affect PV system prices because there are much larger factors affecting system price. A good response to this argument is that the price of a PV system should be divided into several components, including PV module, inverter, balance of system, and installation labor prices. While PV module, inverter and perhaps the balance of system costs are predominantly driven by world market conditions, the installation labor prices are likely to be driven by the actions within the local market.

To the extent that solar contractors require a specialized skill set and are non-transient, labor costs will be driven by the local rather than global demand for PV. Because of this, labor costs provide a good measure to evaluate the effectiveness of the incentive program at transforming prices within the local market. The remaining sections of this paper aim to address whether NYSERDA's program reduced PV installation labor prices in a predictable manner. Once establishing that prices have declined predictability, it aims to assess how the long-term PV labor price has changed and to quantify the economic value of such a change.

3.1 Labor cost trends

Figure 1 presents the PV system price break down by component. At initial glance, this figure suggests that the total system price actually increased over the period from 2003 to 2008. Upon closer inspection, it appears that the costs the incentive program has the highest chance of affecting, the labor costs, steadily declined over that period.

Fig. 1: PV system price broken down by component.



The trend in PV labor costs was analyzed further over the course of the program period. Figure 2 presents the PV Labor Price component to highlight this trend and Table 1 presents the cost levels using constant 2003 dollars to separate to impact of inflation. This is particularly interesting because wage levels rose in New York by around 18 percent over the same period. That such a difference is observed between PV labor costs and average wage levels provides some support for the notion that an incentive program can transform the local market.

Fig. 2. PV system labor price.

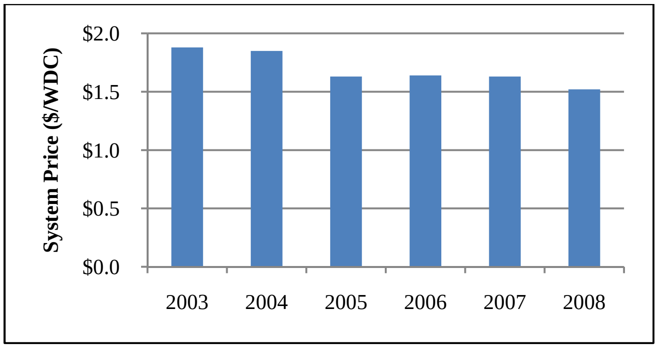


Table 1. PV system labor prices adjusted for inflation.

Year	Nominal Price	Yearly Inflation	Multi-yr. Inflation	Inflation Factor	Real Price (2003$)
	($/WDC)	(%/yr)	(%/yr)	(% ‘03)	($/WDC)
2003	$1.88			1.000	$1.88
2004	$1.85	2.7%	2.7%	1.027	$1.80
2005	$1.63	3.4%	3.0%	1.062	$1.54
2006	$1.64	3.2%	3.1%	1.096	$1.50
2007	$1.63	2.9%	3.0%	1.127	$1.45
2008	$1.51	3.9%	3.2%	1.171	$1.29

3.2 Prediction of labor cost

The labor cost trend must be modeled in order to estimate the benefit of the incentive program. The most widely used learning curve models assume that prices decline by a fixed amount every time capacity doubles. A more generic version of this model results in the following estimation of the nominal price at time t.

$$P_t = P_0\ (1+i)^{(Year_t - Year_0)} \left(\frac{Capacity_t}{Capacity_0}\right)^{\left[\frac{ln(Progress\ Ratio)}{ln(2)}\right]}$$

where *i* is the annual rate of inflation and the *Progress Ratio* is calculated using observed data as follows:

$$Progress\ Ratio = 2^{\left[ln\left(\frac{Real\ Price_t}{Price_0}\right)/ln\left(\frac{Capacity_t}{Capacity_0}\right)\right]}$$

Note that while the price estimation is presented in nominal dollars, the *Progress Ratio* is calculated using real rather than nominal prices. This is done to separate the effect of inflation from the *Progress Ratio*.

An important implementation benefit associated with the more general model presented above is that the *Progress Ratio* can be determined by observing the prices and capacities at any two points in time (0 and *t*) and inputting the results into the equation. For example, the *Progress Ratio* using and only 2003 and 2004 data equals $2^{\left[ln\left(\frac{\$1.80/W}{\$1.88/W}\right)/ln\left(\frac{1.18\ MW}{0.73\ MW}\right)\right]}$, or 94 percent. The *Progress Ratios* calculated using increasing windows of data are presented Table 2.

Table 2. Progress ratios.

Year	Progress Ratio
2003 – 2004	94%
2003 – 2005	85%
2003 – 2006	89%
2003 – 2007	91%
2003 – 2008	90%

The *Progress Ratio* based on the five-year period of 2003 to 2008 is 90 percent. The nominal price can be then be estimated using a 90 percent *Progress Ratio* and 3 percent inflation. Substituting these values into the calculation results in:

$$P_t = P_0\,(1.03)^{(Year_t - Year_0)}\left(\frac{Capacity_t}{Capacity_0}\right)^{-0.152}$$

Using this equation and comparing the predicted values with the recorded values this paper develops a model of price progression. The results are presented Figure and Table 3 below.

Fig. 3. Nominal PV installation prices ($/Watt$_{DC}$).

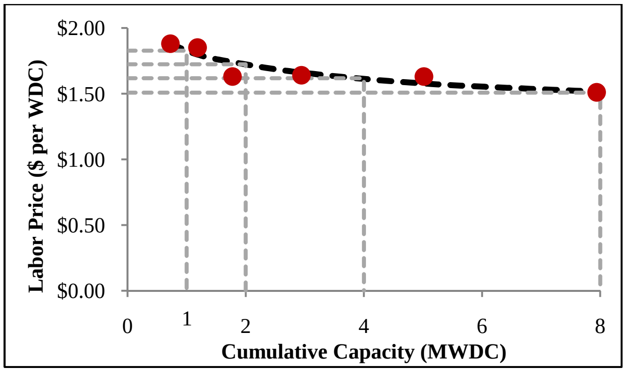


Table 3. Nominal and real prices recorded and predicted.

	Nominal Price ($/$W_{DC}$)		Real Price ($2003/$W_{DC}$)	
Year	Recorded	Predicted	Recorded	Predicted
2003	$1.88	$1.88	$1.88	$1.88
2004	$1.85	$1.80	$1.80	$1.74
2005	$1.63	$1.74	$1.54	$1.63
2006	$1.64	$1.66	$1.50	$1.51
2007	$1.63	$1.58	$1.45	$1.39
2008	$1.51	$1.51	$1.29	$1.29

3.3 Estimation of market transformation benefit

Several assumptions about the impact an incentive program has on adoption are made in order to calculate the benefit of accelerated PV price reduction on the market. It is assumed that customers will adopt as system prices reach a certain point of economic attractiveness. Practically this means the case without an incentive program can be modeled as a delay in the adoption of PV or a shift of the curves to the right in time. Figure 4 presents the installed capacity that would result with and without an incentive program. Figure 5 forecasts how this impacts the labor price in the market based on the model developed in the previous section.

Fig. 4. Installed capacity (Watt$_{DC}$).

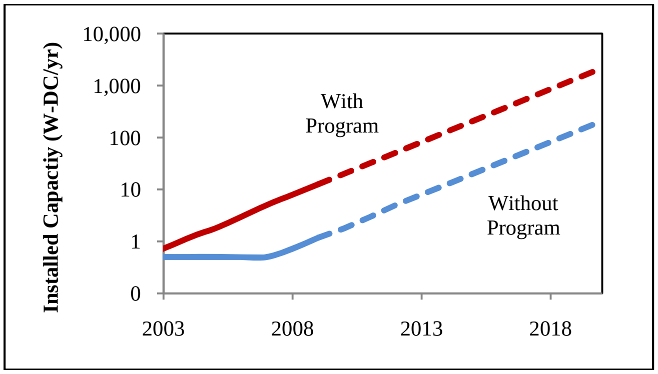
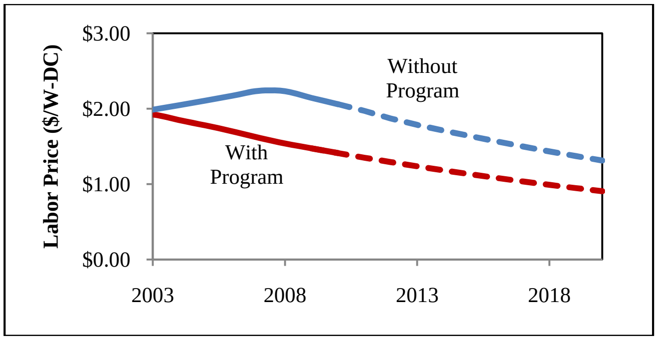
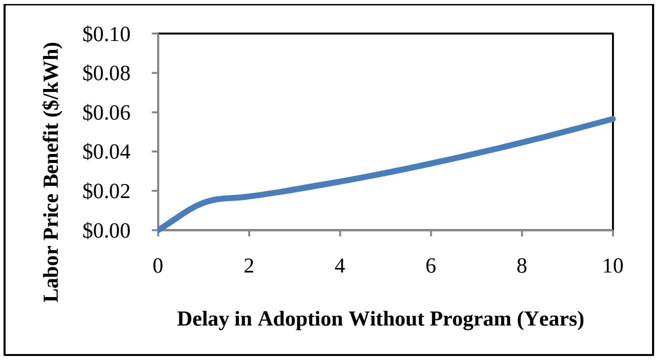


Fig. 5. Labor price ($/Watt$_{DC}$).



Without an incentive program, labor rates would initially rise with inflation before the cumulative number of PV installations begins to drive prices down. An incentive program encourages earlier PV adoption and prices decline steadily from the program's inception. To estimate the market transformation value that is created because of NYSERDA's program, the price reduction benefit is evaluated with input from estimated cost trends. Figure 6 presents the results with different assumptions about the number of years adoption of PV would be delayed without the stimulus of the incentive program.

Fig. 6. Labor price benefit ($/kWh).



Taking a conservative assumption of a 50 percent annual growth rate in the PV installation, results suggest that the benefit of labor price savings ranges from about $0.01 to $0.05 per kWh. If it is assumed that market growth is closer to 100 percent annually, as needed to meet New York state MW goals, the benefit can reach as high as $0.10 per kWh.

4. CONCLUSION

The paper suggests that NYSERDA's PV incentive program has been effective at reducing PV labor prices and provides a justification on an economic basis for such a program existence. Looking at just one portion of the value the program creates, this paper finds clear positive value is created in the market. This portion of the value, which ignores any of the benefits to society of the actual energy production, accounts for a meaningful percentage of a typical incentive payment.

Additional work to expand the simplified assumptions of delayed market growth presented in this paper would further refine estimates of program value. Furthermore, additional work is needed to quantify the value differential between traditional sources and PV sources in order to calculate the total benefit of an incentive program. Once this difference is clearly quantified, it will be possible to estimate the aggregate value that an incentive program creates and to set incentive levels to match this benefit.

5. REFERENCES

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