Title

New Berkeley Lab Report Tracks a Decade of PV Installed Cost Trends

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Installations of PV systems have been expanding at a rapid pace in recent years. In the United States, the market for PV is driven by national, state, and local government incentives, including up-front cash rebates, production-based incentives, requirements that electricity suppliers purchase a certain amount of solar energy, and Federal and state tax benefits. These programs are, in part, motivated by the popular appeal of solar energy and by the positive attributes of PV – e.g., modest environmental impacts, avoidance of fuel price risks, coincidence with peak electrical demand, and the location of PV at the point of use.

Given the relatively high cost of PV, however, a key goal of these policies is to encourage cost reductions over time. Therefore, as policy incentives have become more significant and as PV deployment has accelerated, so too has the desire to track the installed cost of PV systems over time, by system characteristics, by system location, and by component.

A new Lawrence Berkeley National Laboratory report, *Tracking the Sun: The Installed Cost of Photovoltaics in the U.S. from 1998-2007*, helps to fill this need by summarizing trends in the installed cost (i.e., the cost paid by the system owner) of grid-connected PV systems in the U.S. The report is based on an analysis of project-level cost data from nearly 37,000 residential and non-residential PV systems completed from 1998-2007 and installed on the utility-customer-side of the meter. These systems total 363 MW, equal to 76% of all grid-connected PV capacity installed in the U.S. through 2007, representing the most comprehensive data source available on the installed cost of PV in the United States.

The data were obtained from administrators of PV incentive programs around the country, who typically collect installed cost data for systems receiving incentives. A total of 16 programs, spanning 12 states, ultimately provided data for the study. Reflecting the broader geographical trends in the U.S. PV market, the vast majority of the systems in the data sample are located in California (83%, by capacity) and New Jersey (12%), The remaining systems are located in Arizona, Connecticut, Illinois, Massachusetts, Maryland, Minnesota, New York, Oregon, Pennsylvania, and Wisconsin. The PV systems in the dataset range in size from 100 W to 1.3 MW, almost 90% of which are smaller than 10 kW.

This article briefly summarizes some of the key findings from the Berkeley Lab study (the full report can be downloaded at http://eetd.lbl.gov/ea/emp/re-pubs.html). The article begins by summarizing trends related to the installed cost of PV systems prior to receipt of any financial incentives, and then discusses how changes in incentive levels over time and variation across states have impacted the net installed cost of PV to the customer, after receipt of incentives. Note that all cost and incentive data are presented in real 2007 dollars (2007$), and all capacity and dollars-per-watt ($/W) data are presented in terms of rated module power output under Standard Test Conditions (DC-STC).

Installed Costs Have Declined over Time, but Were Stable from 2005-2007

Average PV system installed costs (prior to receipt of financial incentives) declined from 1998 to 2007, as shown in Figure 1. Specifically, capacity-weighted average costs declined from $10.5/W in 1998 to $7.6/W in 2007, equivalent to an average annual reduction of $0.3/W, or 3.5%/yr in real dollars. The distribution of installed costs within a given system size range has narrowed significantly since 1998, with high-cost outliers becoming increasingly infrequent, indicative of a maturing market. The cost reductions and narrowing of the cost distribution, however, have not occurred steadily over time. Specifically, from 1998-2005, average costs declined at a relatively rapid pace, with average annual reductions of $0.4/W, or 4.8% per year in real dollars. From 2005 through 2007, however, installed costs remained essentially flat, and the distribution in installed costs remained relatively stable. During this latter period, U.S. and global PV markets expanded significantly, creating shortages in the supply of silicon for PV module production and putting upward pressure on PV module prices. As discussed below, however, silicon shortages are not the sole cause for the cessation of price declines during 2005-2007, as average non-module costs also remained relatively flat over this period.

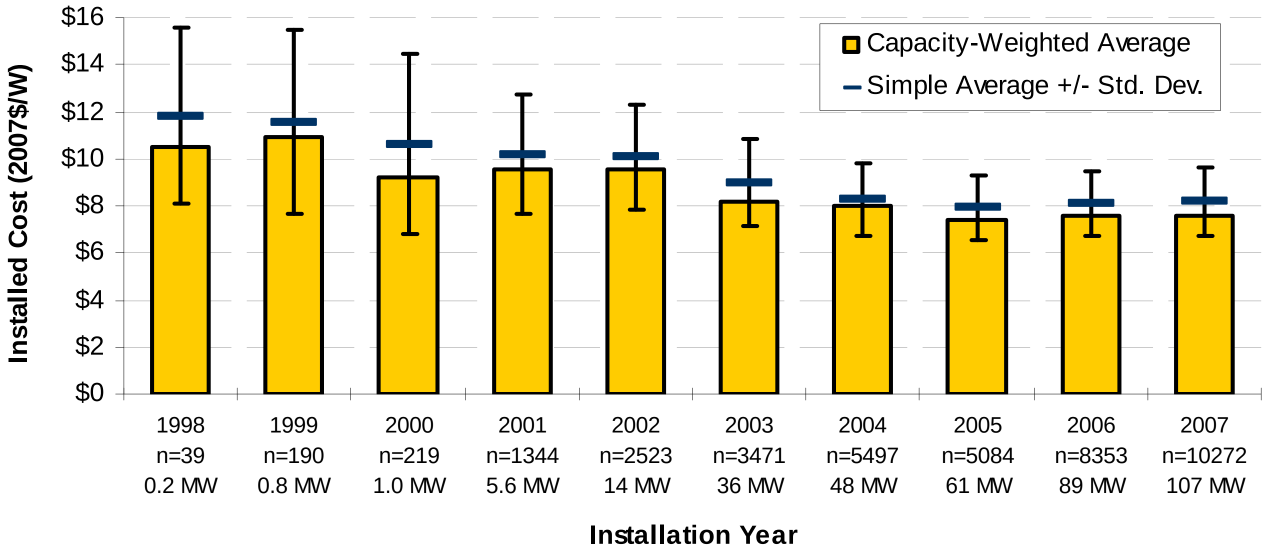


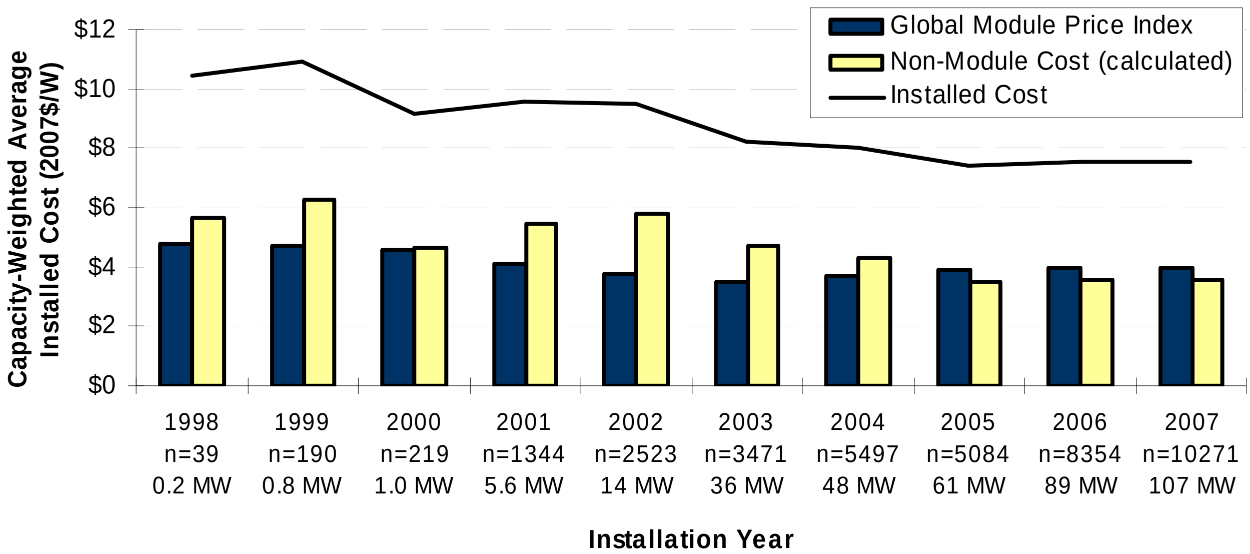
Figure 1. Installed Cost Trends over Time

Installed Cost Reductions Are Primarily Associated with Non-Module Costs

Figure 2 disaggregates average annual installed costs into average module and non-module costs. Few programs provided actual component-level cost data. In lieu of this information, Figure 2 presents Navigant Consulting's Global Power Module price index as a proxy for module costs. The non-module costs (which may include such items as inverters, mounting hardware, labor, permitting and fees, shipping, overhead, taxes, and profit) shown in Figure 2 are then calculated as the difference between the average total installed cost and the module price index in each year.

Using this method, the decline in total average PV installed costs since 1998 appears to be primarily attributable to a drop in *non-module* costs, which fell from approximately $5.7/W in 1998 to $3.6/W in 2007, a reduction of $2.1/W (or 73% of the $2.9/W drop in total installed costs of this period). In comparison, module index prices dropped by only $0.8/W from 1998-2007, and increased somewhat from 2003-2007. As with the trend in total installed costs, however, average non-module costs remained relatively stable from 2005-2007.

Trends in non-module costs may be particularly relevant in gauging the impact of state and utility PV programs. Unlike module prices, which are primarily established through national (and even global) markets, non-module costs consist of a variety of cost components that may be more readily affected by local programs – including both deployment programs aimed at increasing demand (and thereby increasing competition and efficiency among installers) as well as more-targeted efforts (e.g., training and education programs). Thus, the fact that non-module costs have fallen over time, at least until 2005, suggests (though, admittedly, does not prove) that state and local PV programs have had some success in driving down the installed cost of PV.



Note: Non-module costs are calculated as reported total installed costs minus the global module price index.

Figure 2. Module and Non-Module Cost Trends over Time

Installed Costs Exhibit Significant Economies of Scale

Large PV installations may benefit from economies of scale, through price reductions on volume purchases of materials and through the ability to spread fixed costs (including transaction costs) over a larger number of installed watts. This expectation has been borne out in experience, as indicated by Figure 3, which shows the average installed cost according to system size, for PV systems completed in 2006 and 2007. The smallest systems (<2 kW) exhibit the highest average installed costs ($9.0/W), while the largest systems (>750 kW) have the lowest average cost ($6.8/W, or about 25% below the average cost of the smallest systems). Interestingly, the economies of scale do not appear to be continuous with system size, but rather, most strongly accompany increases in system size up to 5 kW, and increases in system size in the 100-750 kW range. In contrast, the data do not show evidence of significant economies of scale within the 5-100 kW size range. To the extent that the economies of scale described above have persisted over time, they may partially explain the temporal decline in average installed costs, as the average size of PV systems has grown over time.

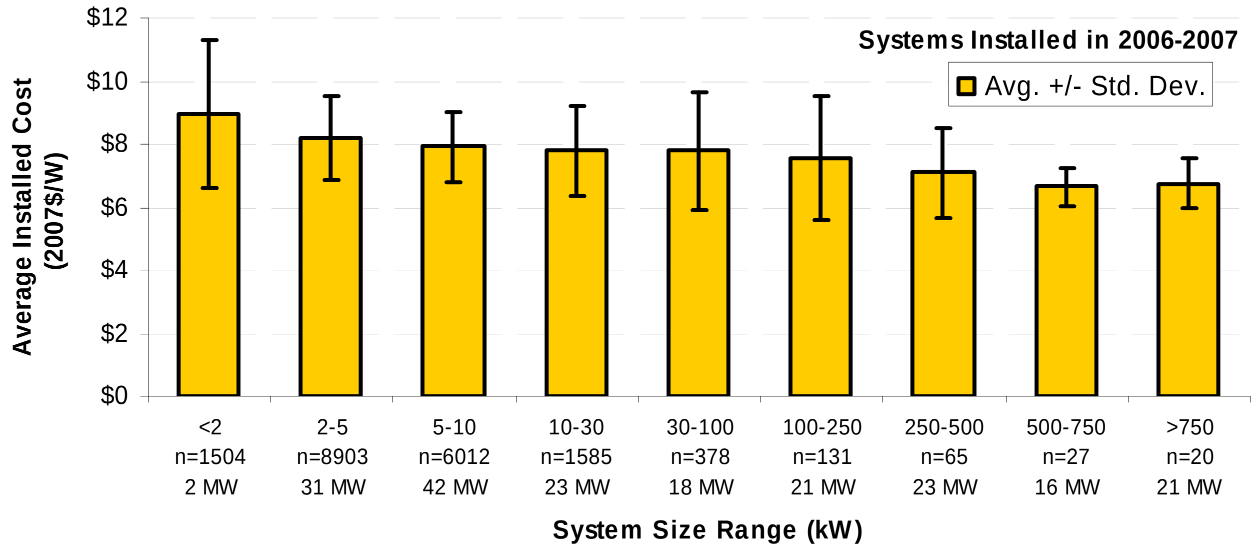


Figure 3. Variation in Installed Cost According to PV System Size

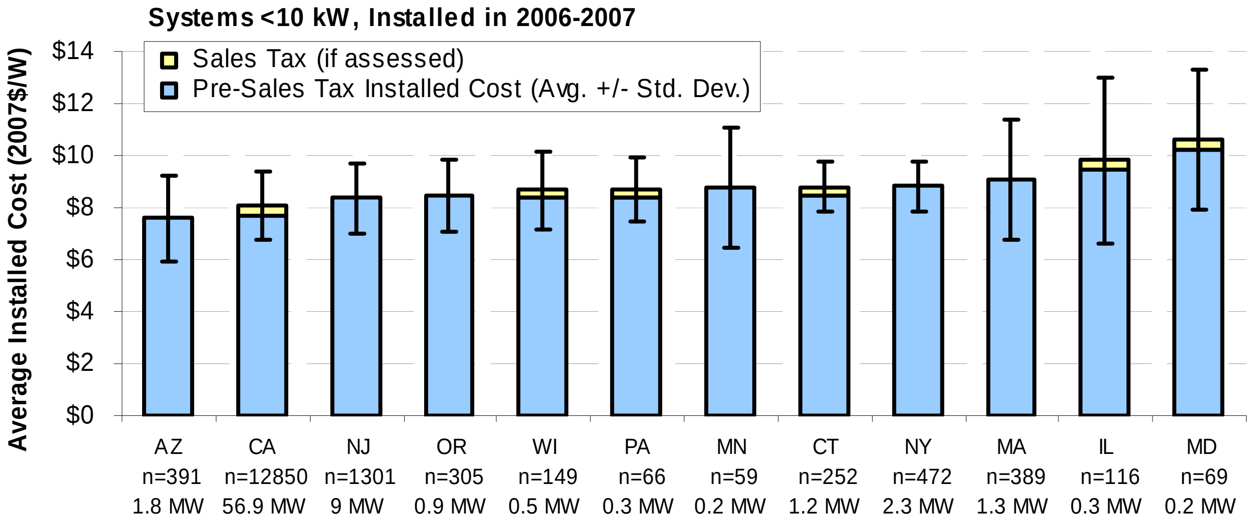
Average Installed Costs Are Still Lower in Germany and Japan than in the U.S., though Installed Costs Vary Widely Across U.S. States

Notwithstanding the significant cost reductions that have already occurred in the U.S., international experience suggests that greater near-term cost reductions may be possible. Among residential systems completed in 2007 in Japan, Germany, and the United States, average installed costs were substantially lower in Japan and Germany ($5.9/W and $6.6/W, respectively) than in the U.S. ($7.9/W). These differences may be partly attributable to the much greater cumulative grid-connected PV capacity in Japan and Germany (about 1,800 MW and 3,800 MW, respectively, at the end of 2007), compared to just 500 MW in the U.S. However, it is also evident that larger market size, alone, does not account for all of the variation – as indicated by the fact that installed costs are higher in Germany than in Japan, despite the substantially greater grid-connected PV capacity in the former.

Average costs also diverge within the U.S. As shown in Figure 4, which focuses on systems smaller than 10 kW and installed in 2006 or 2007, average costs ranged from a low of $7.6/W in Arizona to a high of $10.6/W in Maryland.

This variation in average installed costs across states is, in part, likely a consequence of the differing size and maturity of the PV markets, where larger markets stimulate greater competition and hence greater efficiency in the delivery chain, and may also allow for bulk purchases and better access to lower-cost products. Most notably, the two largest PV markets in the U.S. – California and New Jersey – have among the lowest average costs, lending some credence to the premise behind state policies and programs that seek to reduce the cost of PV by accelerating deployment.

Other factors however also drive differences in installed costs among individual states. Incentive application procedures and regulatory compliance costs, for example, vary substantially. Additionally, installed costs vary somewhat across states due to differing sales tax treatment. Five of the 12 states shown in Figure 6 (Arizona, Massachusetts, Minnesota, New Jersey, and New York) exempted PV hardware costs from state sales tax throughout 2006 and 2007, and Oregon has no state sales tax. Assuming that PV hardware costs represent approximately 60% of the total installed cost of residential PV systems, sales tax exemptions effectively reduce post-sales-tax installed costs by $0.2-0.4/W, depending on the state sales tax rate.



Note: Sales tax, if assessed on customer-sited PV installations in 2006-07, was assumed to be applied to only hardware costs, which were assumed to constitute 60% of the total pre-sales-tax installed cost.

Figure 4. Variation in Installed Costs among U.S. States

Cash Incentives Have Steadily Declined Over Time, although the Decline was Offset by the Increase in the Federal ITC for Commercial PV in 2006

Financial incentives provided through utility, state, and Federal programs have been a major driving force for the PV market in the U.S. These incentives potentially include some combination of cash incentives provided through state or utility PV incentive programs, Federal and/or state investment tax credits (ITCs), revenues from the sale of renewable energy certificates (RECs), and accelerated depreciation of capital investments in solar energy systems.

Focusing solely on the direct cash incentives provided through the 16 state/utility incentive programs in the study, plus state and Federal ITCs (i.e., ignoring REC sales and accelerated depreciation), average financial incentives in the U.S. fell steadily from 2002-2005, for both residential and non-residential systems. This trend largely reflects the reduction in cash incentives in California over time. However, the decline in average combined value of cash incentives plus ITCs abruptly reversed course in 2006 for commercial PV, when the Federal ITC for commercial PV increased from 10% to 30% of project costs. As a result, commercial PV systems received *greater* total financial incentives in 2006-2007, on average, than at any time since 1998, with the after-tax value of cash incentives plus ITCs averaging $4.0/W in 2007.

Residential PV also saw a slight boost in overall incentive levels when the Federal ITC was extended to these systems in 2006; however, the $2,000 cap on the residential credit severely muted the impact. Consequently, the combined after-tax incentive (cash incentives plus ITCs) for residential PV was, in 2007, at its lowest average level ($3.1/W) since 2001. Removal of the $2,000 ITC cap for residential systems installed on or after January 1, 2009 will, of course, provide an additional boost to residential incentives, though the effective impact will depend on the extent to which states and utilities reduce cash incentives accordingly.

The fact that combined after-tax incentives rose substantially from 2005-2007 for commercial PV, while remaining essentially flat for residential PV, may partially explain the shift towards the commercial sector within the U.S. PV market over this period. With the lifting of the cap on the Federal ITC for residential PV beginning in 2009, however, some movement back towards the residential sector may occur.

Net Installed Costs for Residential PV Remained Unchanged in 2007 from Their Level in 2001, but Were at a Near-All-Time Low for Commercial PV

Average installed costs across most PV system size categories declined significantly from 1998-2005, but remained relatively stable from 2005-2007. At the same time, average after-tax incentive levels for residential systems steadily declined from 2002-2007. The net effect of these two trends is that the net installed cost of residential has remained relatively flat since 2001, declining by $0.8/W from 2001-2004, and then increasing by $0.6/W from 2004-2007. Thus, in 2007, the average net installed cost of residential PV was $5.1/W, compared to an average of $5.3/W in 2001, a drop of just 1%.

The trend for commercial PV is markedly different, by virtue of the more-lucrative Federal ITC available beginning in 2006. Specifically, in 2007, the net installed cost of commercial PV was $3.8/W, compared to $5.6/W in 2001, a drop of 32%. Without Federal and state ITCs, though, the average net installed cost of commercial PV would be only 10% lower in 2007 than in 2001 ($6.3/W compared to $7.0/W), and would be essentially unchanged from the average net installed cost in 2003 ($6.2).

Incentives Have Diverged Widely Across States

The preceding time trends apply to the sample at large, which is itself dominated by the PV incentive programs in California and New Jersey. Of course, incentives and net installed costs vary significantly from state-to-state. Among residential systems installed in 2007, average after-tax incentives ranged from a high of $5.7/W in Pennsylvania to just $2.5/W in Maryland, as shown in Figure 5. These two states also represent the bookends in terms of net installed cost after incentives, averaging $3.2/W and $7.7/W, respectively. The largest PV markets, California and New Jersey, also fall at opposite ends of the spectrum. In California, after-tax incentives for residential PV averaged $2.8/W in 2007, yielding an average net installed cost of $5.4/W. In New Jersey, which offered a much more lucrative cash incentive in 2007, the combined after-tax incentive for residential PV averaged $5.1/W, yielding an average net installed cost of $3.3/W.

For commercial PV, average after-tax incentive levels and net installed costs also varied considerably across states in 2007. Comparing only those states for which the data sample contained five or more commercial systems completed in 2007 (which excludes Pennsylvania and Maryland, the two bookends from the residential comparison, as well as Illinois), average after-tax incentives for commercial PV in 2007 ranged from $6.2/W in Oregon to $3.7/W in California. The lowest average net installed cost belongs to Oregon, at $2.7/W (not accounting for SRECs, which, could reduce net installed costs in New Jersey by a substantial additional amount, potentially making it the state with the lowest net installed costs for commercial PV in 2007). In comparison, the net installed cost of commercial PV in 2007 was greatest in Minnesota, at $5.4/W.

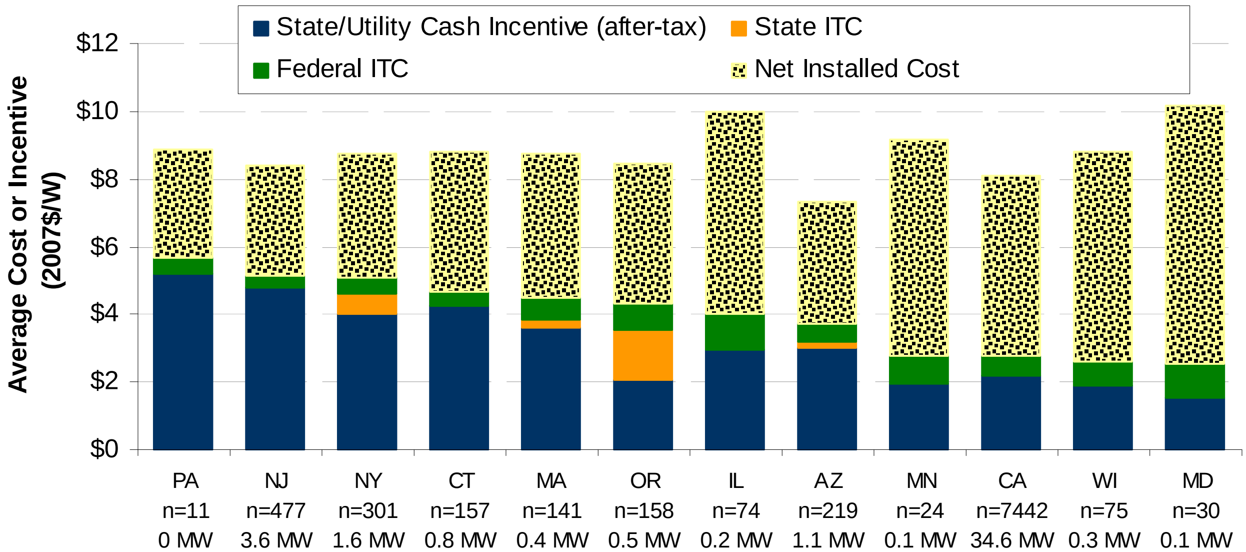


Figure 5. Comparison of Incentive Levels and Net Installed Cost across States for Residential PV Systems Installed in 2007 (Estimated)

Concluding Thoughts

The rate of PV system installations has been growing at a rapid pace in recent years, driven in large measure by government incentives. Given the relatively high cost of PV, a key goal of these policies has been to encourage cost reductions over time.

Available evidence confirms that PV installed costs in the U.S. have declined substantially over time, especially among smaller systems, and primarily as a result of reductions in non-module costs. Both module and non-module costs, however, remained largely unchanged from 2005-2007, reflecting constraints throughout the supply-chain and delivery infrastructure, as PV markets rapidly expanded. This trend, were it to continue indefinitely, would be cause for concern, given the desire of PV incentive programs to continue to ratchet down the level of financial support offered to PV installations.

Recent developments, however, portend a potentially dramatic shift over the next few years, with significant improvements in the customer-economics of PV. First, in contrast to the recent past, most industry experts anticipate an over-supply of PV modules in the near future, putting downward pressure on module prices in 2009 and, hence, on total installed costs (though projections of the magnitude of these price reductions vary considerably). Second, the lifting of the cap on the Federal ITC for residential PV, also beginning in 2009, will further reduce net installed costs for residential installations (to the extent that it is not offset by corresponding reductions in state and utility incentives). Thus, even if large commercial PV installations continue to be the dominant growth market (joined by utility-scale PV), the removal of the cap on the residential ITC may lead to some degree of renewed emphasis on the residential market in the years ahead.

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