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Publication Date
2013-04-25

LBNL-XXX

ERNEST ORLANDO LAWRENCE

BERKELEY NATIONAL LABORATORY

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Environmental Energy

Technologies Division

April 2013

Conference paper published for the ASES Solar 2013 Conference, Baltimore, MD, April 16-20, 2013

This work was supported by the Office of Energy Efficiency and Renewable Energy (Solar Energy Technologies Program) and the Office of Electricity Delivery and Energy Reliability (National Electricity Delivery Division) of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

AN ANALYSIS OF RESIDENTIAL PV SYSTEM PRICE DIFFERENCES BETWEEN THE UNITED STATES AND GERMANY

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ABSTRACT

Customer-owned residential photovoltaic (PV) systems are significantly more expensive in the United States than in Germany ($6.21/W vs. $3.42/W in 2011). These price discrepancies stem from differences in "soft costs" between the two countries. A survey of German PV installers was deployed to collect granular data on PV soft costs in Germany, and the results are compared to those of a similar survey of US PV installers. Analyzed non-module hardware costs and soft costs are found to be lower in Germany, especially for customer acquisition, installation labor and profit/overhead costs, but also for expenses related to permitting, interconnection, and inspection procedures.

In order to reduce these costs the United States could introduce policies that enable a robust market while minimizing market fragmentation. Incentive structures offering a simple and certain value proposition combined with simple interconnection, permitting, and inspection requirements should be complemented by regular incentive declines that drive and follow cost reductions.

1. INTRODUCTION TO US AND GERMAN PV MARKET

Although the United States was a leader in early PV technology in the 1980s, the German PV market has been significantly larger than the US market for the past twelve years. Annual capacity additions (including residential, commercial and utility-scale projects) accelerated in Germany since the 2004 reform of the German Renewable Energy Sources Act; Germany exceeded installations in the United States over the following years by a factor ranging between three and nine. In the years 2010-2012, more than 7.4 GW/yr were added in Germany. The German PV market is much larger than that of the United States with a cumulative installed capacity across all customer segments five times greater in Q3 2012 (31 GW c.f. 6.4 GW). Annual installations in 2011 in the residential sector in Germany were however only 2.5 times greater than US installations (761 MW c.f. 297 MW) while the German cumulative residential capacity was about 3.5 times the size of the US residential capacity in 2011 (3420 MW vs. 934 MW). Especially when normalized for the respective populations (3W of cumulative residential PV capacity per capita in the United States c.f. 42W in Germany), it is evident that residential PV systems are much more ubiquitous in German neighborhoods than in the United States and that the German residential PV market is more mature (1), (2).

2. HISTORICAL RESIDENTIAL SYSTEM PRICING

2.1 Data Sources and Methodology

The "Tracking the Sun" database series by the Lawrence Berkeley National Laboratory (LBNL), reflecting 70% of the PV capacity installed between 1998 and 2012, was used to analyze system prices (3). Systems larger than $10kW_{DC}$ were excluded, as were non-residential and third-party owned systems, in order to maintain comparability to reported pricing for customer-owned residential systems in Germany. Information on German system prices for the years 2005 to 2009 was aggregated from the national survey reports to the International Energy Agency (IEA), and the market research companies Photon and EuPD (4)-(6). In 2010 and 2011, a collection of 5,666 German price quotes was analyzed for systems smaller than or equal to $10kW_{DC}$ (6). For the year 2012, price averages for systems smaller than or equal to $10kW_{DC}$ reported by the German Solar Industry Association (BSW) were used (7).

Throughout the analysis all prices are reported in US$2011, German historical data were adjusted with German inflation data to €2011 and then translated to US$2011 by using the average $-€ exchange rate for the year 2011 ($1.39/€).

It is important to acknowledge that focusing only on the installed price (with the metric $/W) has inherent limitations, as a range of quality characteristics are glanced over, such as longevity and degradation rates of the hardware components, module capabilities (e.g. efficiency under diffuse light in cloudy Germany), inverter power quality management capabilities or the ability to perform remote data analysis of the generated and self-consumed electricity. In addition, the levelized generation costs of solar electricity (ultimately mattering most to the final consumer) are not only determined by the installed price but also by factors such as system uptime and, more importantly, annual insolation. Thus, despite significant installed price differences between the United States and Germany, electricity generation costs from residential PV may be very similar due to the more favorable solar resource endowment in most regions of the United States. Germany has average insolation rates ranging between those of Alaska and the state of Washington, the least sunny areas of the United States. Capacity pricing in $/W was considered to be nevertheless the most appropriate metric of choice, as it enabled a direct comparison of residential PV systems between the two countries.

2.2 Results

In the year 2005, residential PV systems were at similar prices at $8.6/W in both the United States and Germany. In the following years, however, prices increasingly diverged: during a time of nearly constant module pricing from 2005 to 2008, US prices moved down only slightly to $8.1/W in the year 2009, while installers in Germany were able to significantly reduce their non-module costs, leading to median residential prices of $5.2/W in 2009. As shown in Figure 2, prices decreased largely in parallel since 2010, maintaining a price gap of about $2.8/W between systems installed in Germany and the United States.

Figure 1 depicts an analysis of the price distribution within the year 2011 that showed a much wider US price spread in comparison to the German price spread (standard deviation of $1.95/W vs. $.50/W). This discrepancy can partly be explained by significant system price differences between individual states. For example, Arizona (one of the lower-priced markets) had a median residential price of $5.11/W in Q4 2011, while Californian systems registered in the California Solar Initiative (CSI) featured a median price of $6.23/W (California is one of the higher-priced markets and also the largest solar market in the United States).

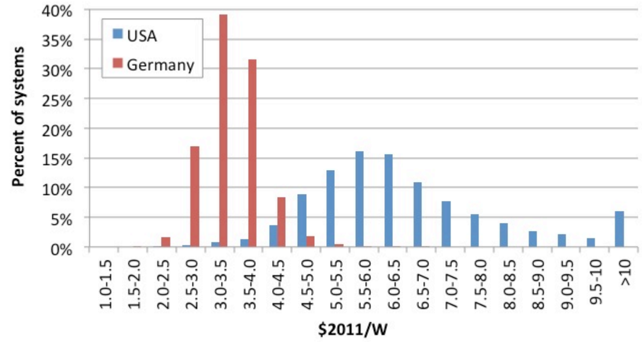

Fig. 1: Price Distribution of Customer-Owned PV Systems ≤10 kW installed in 2011.

One consequence of the larger US spread is that – despite substantial differences in the national median price between the United States and Germany – the cheapest 15% of all US systems were installed at prices found among the more expensive systems in Germany. At the same time the greater variation in system prices in the United States provides evidence for greater market fragmentation across jurisdictions.

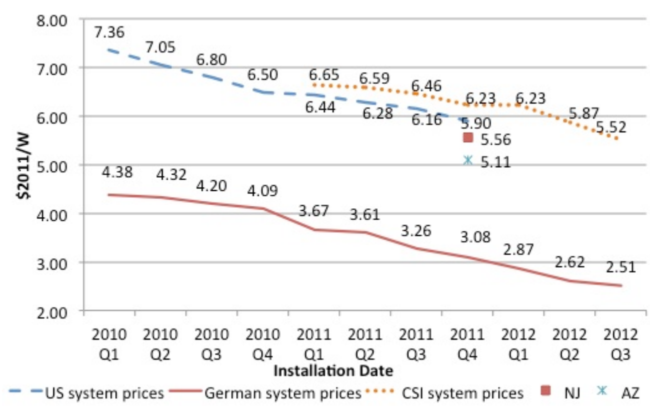

Fig. 2: Median Installed Price of Customer-Owned PV Systems ≤10 kW.

To a small degree, the difference between system pricing in Germany and the United States is an artifact of the longer development lead-time in the United States. Analyzing the time span data between the date of incentive application and the date of project completion (3) reveals that the average project development time is nearly four times greater for residential systems in the United States than in Germany (126 days for U.S. systems (11) c.f. 35 days for German systems, according to our German survey described below). Assuming that US residential installers price their systems based on hardware costs around the date of contract closure, the longer project development times inflate the price gap slightly. If US installers completed their projects in a similar timeframe as their German counterparts, the US pricing curve could be effectively shifted backward by one quarter. The apparent extra costs depend on the speed of the quarterly price declines; in Q3 2011, this effect constituted $.26/W ($6.16/W minus $5.90/W) of the total $2.9/W gap between PV pricing in the United States and Germany. In effect, German installers are able to pass along declines in module and other component costs more quickly to consumers than their American counterparts.

3. NON-MODULE COSTS AS DRIVER OF PRICE DIFFERENCES

3.1 Learning Curve Methodology and Results

With the significant growth and increasing internationalization of the module manufacturing market, PV modules have become an increasingly globalized good, which can be purchased at very similar prices in the large and mature PV markets around the world. Previous analyses have shown very little pricing discrepancy for PV modules between Germany and the United States (5), (8). This leaves non-module costs as the primary driver of system price differences.

These price differences can be partly explained by experience-based cost reduction (i.e., learning-by-doing), given the differing market sizes between the two countries. As indicated in the following equations, a learning rate (LR) describes the average relative cost decline (C_0 to C_t) for each doubling of global cumulative module production (q_0 to q_t). The learning coefficient -b is the slope of the line of best fit through a log-log plotting of cost and cumulative module production:

$$C_t = C_o \left(\frac{q_t}{q_0}\right)^{-b}, \qquad (1)$$

$$LR = 1 - 2^{-b} \qquad (2)$$

Traditional PV learning curve analyses have often focused on PV modules and relate global module production to module prices (9). This concept of learning by experience, however, can also be applied to the learning by local installer communities that become more skilled at reducing non-hardware balance of system (BoS) costs – also called "business process costs" or "soft costs" – with an increasing volume of residential PV installations.

We present here a learning curve analysis based on average annual non-module costs of residential systems between 2001 and 2011, plotted against the log of the national installed cumulative PV capacity across all customer types. Data on non-module costs are not directly available; instead, these values were derived by subtracting average global factory-gate module prices from total median national residential system prices in each year. This method is premised on the assumption that installer profit margins are constant over time, and close to zero. (10). Our later analysis suggests that at least the latter condition may not be met and that the resulting learning curve should thus be viewed with caution. The conceptual development of learning rates for soft costs is nevertheless helpful to analyze and evaluate progress in soft-cost reductions.

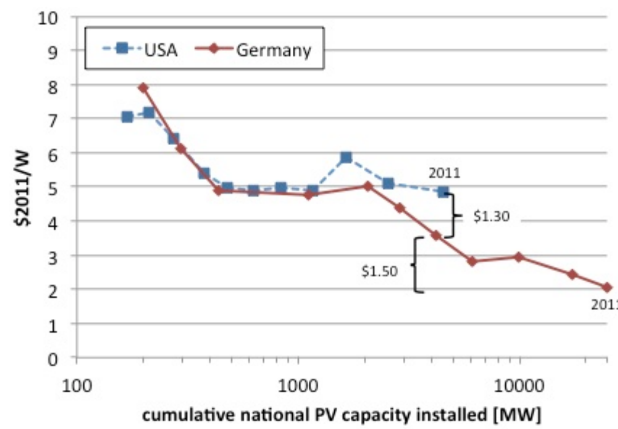

Fig. 3: Learning Curve of Residential Non-Module Costs

As shown in Figure 3, the derived non-module costs fell initially in both the United States and Germany in a similar manner, falling sharply during the first 500MW of deployed PV capacity and remaining rather flat over the next 1500MW. Starting at a national PV capacity of 2000MW (in the year 2005), Germany was able to significantly reduce non-module costs while US costs stayed largely constant. At a capacity similar to that of the United States in 2011 (4500MW), Germany's non-module costs were about $1.30/W lower ($3.56/W in Germany c.f. $4.86/W in the United States in 2011). As Germany's PV market has grown further since the 4500MW mark, non-module costs have fallen by an additional $1.50/W. One might thus infer (somewhat crudely) that, of the total $2.79/W difference in non-module costs in Germany and the United States in 2011, roughly $1.50/W (or 53% of the total non-module cost gap) is due simply to the larger base of German experience.

A simple regression analysis indicates that the development of non-module costs is less correlated with market growth in the US than in Germany (R^2=.48 in the United States, implying that 52% of the variation in non-module costs across years is explained by other factors, compared to R^2=.91 in Germany). In addition, the learning rate is lower in the United States, where for each doubling of the national PV market, non-module costs fell only by 7% over the years 2001 to 2011, while costs decreased by 15% in Germany with each doubling of installed capacity.

3.2. Introduction to Soft-Cost Survey and Methodology

More detailed information was needed on the composition of soft costs in order to identify the sources of the price gap. Building on a bottom-up benchmarking analysis for the US residential PV market for the year 2010 (11), a survey developed by the National Renewable Energy Laboratory (NREL) was adapted to collect data on soft costs for residential PV systems in Germany and to allow for direct comparisons between the two countries. The survey instrument inquired about German residential systems installed in the year 2011 and was distributed in early 2012 to over 300 German residential PV installers both in excel format and as an online survey on the platform www.photovoltaikstudie.de. The survey asked either about total annual expenditures for a given business process, translated into $/W based on each installer's annual installation volume, or it asked for labor-hour requirements per installation for individual business process tasks, which were multiplied by a survey-derived task-specific fully-burdened wage rate.

The German survey respondent sample consisted of 24 installers that completed 2056 residential systems in 2011 yielding a residential capacity of 17.9MW, which is roughly half the sample size of the corresponding US survey.

Due to surprisingly low installation labor hours in the German survey (likely because of a misunderstanding of the term "man-hours"), a follow-up survey was fielded in October 2012 focusing solely on installation labor requirements during the preceding twelve months. Forty-one German installers participated in that second survey, collectively representing 1842 residential systems installed over the previous year, with a capacity of 11.9MW.

The median reported residential system sizes was 8kW, which is close to the median system size of all grid-connected PV systems smaller or equal to 10kW in Germany 2011 (6.8kW) (1). In both German surveys, most respondents were relatively small-volume installers completing fewer than 50 residential systems a year (median: 25 in 2011, 26 in 2012). Responses were weighted by the installed residential capacity of each installer.

3.3. Survey Findings

The median reported German residential system price for the year 2011 was $3.00/W: slightly lower than the previously listed EuPD results of $3.44 (6), but very much in line with Photon estimates of $3.05/W (5). Total non-hardware costs (including margin) were much lower in Germany and accounted for only $.62/W (21% of system price) in comparison to $3.34/W (54%) in the United States.

Of the three specific soft cost categories examined, the largest difference between the United States and Germany was associated with **customer acquisition costs** as shown in Figure 4 (a difference of $.62/W). Here and elsewhere within this section, the default US data are based on survey response reported in (11). In Figure 4, *"Non-project specific Marketing & advertising"* includes non-project specific expenses such as online and magazine ad campaigns while "Other *project-specific Customer Acquisition"* includes categories such as sales calls, site visits, travel time, bid preparation and contract negotiation. Previous analyses confirmed a similar degree of expense differences between the two countries for the year 2010 (12) and similar levels of US customer acquisition costs in 2012 (13). Customer acquisition costs may be lower in Germany because of partnerships between installers and both equipment manufacturers and lead-aggregation websites, where potential customers are quickly linked to 3 to 5 installers in their zip code areas. In addition, the large German market has transformed residential PV systems from an early-adopter product into a more mainstream product, where a critical mass is recruiting new customers primarily by word of mouth.

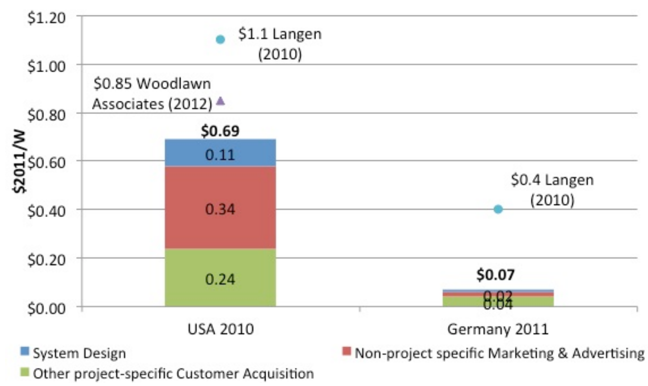

Fig. 4: Average Customer Acquisition Costs.

The next largest business process cost difference stems from the **physical installation process** (a difference of $.36/W), as shown in Figure 5. According to the follow-up survey, German companies installed residential PV systems in 39 man-hours, on average, while US installers required about twice as many labor hours (75 man-hours per residential system). One possible contributor to the difference in installation labor hour requirements is the prevalence of roof penetrations. Most surveyed German installers either never or only rarely install residential systems requiring rooftop penetration; this share is likely higher in the United States due to differences in roofing materials and climatic requirements. Hypotheses about faster German installations due to less usage of an extra conduit for wiring or much faster grounding practices could not be confirmed. Other studies have reported even shorter installation times for Germany (14), (15).

In Germany, the bulk of installation labor consisted of cheaper non-electrician labor (77% of total man-hours), whereas non-electrician labor represents only 65% of total installation labor hours for US residential systems. Fully burdened wages are also slightly lower in Germany than in the United States. As a result of this combination of factors (fewer total installation labor hours, greater reliance on non-electrician labor, and lower overall wage rates), installation labor costs averaged $.23/W in Germany compared to $.59/W in the United States, as depicted in Figure 5.

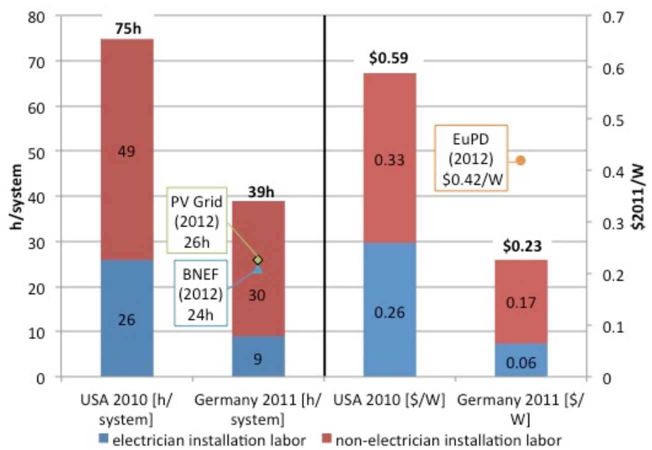

Fig. 5: Installation Labor Costs.

Costs associated with **permitting, interconnection, inspection** (PII), and incentive application processes have been widely discussed in the United States. Based on our survey results, PII costs are $.21/W lower in Germany than in the United States (see Figure 6). This difference is mostly due to lower PII labor hour requirements in Germany (5.2h vs. 22.6h). In Germany, local permits (structural, electrical, aesthetical) and inspection by county officials are not required for the construction of residential PV systems, and incentive applications are done quickly online on one unified national platform. In addition, no permit fee is required in Germany, while residential permitting fees in the United States average $.09/W. These survey results are very similar to other estimates of both permit time requirements and total PII costs (15)-(17).

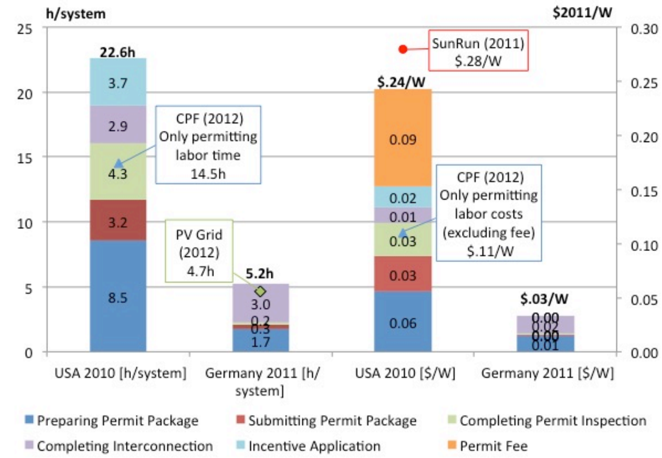

Fig. 6: Permitting, Interconnection, Inspection and Incentive Application Costs.

In addition to the soft cost categories explored through the survey, another reason for the divergence between PV system pricing in the United States and Germany is the impact of sales taxes. German PV systems are effectively exempt from sales and value-added taxes (usually 19%) either due to the "Kleinunternehmer" or "Vorsteuererstattungs" clause. In the United States, 23 states assess sales taxes on residential PV systems, usually ranging between 4% and 8% of the hardware costs. In addition, local sales taxes are often levied. Given the spatial distribution of PV systems in the United States, and accounting for sales tax exemptions in some states, state and local sales taxes added $.21/W to the median price of US residential PV in 2011.

A bottom-up cost model was devised for US systems using hardware cost estimates for the year 2011 (2), (8) and US business process costs benchmarks of 2010 (11). To the authors' knowledge, no detailed national data are available on additional overhead costs (e.g. property-related expenses, inventory-related costs, insurances and fees or general administrative costs) and net profit margins of US residential installers. The additional category "overhead, profit and other residual costs" subsumes the difference between system prices (3) and bottom-up cost estimates. German installers reported $.29/W for overhead costs and profits while the US residual was at $1.61/W. Figure 7 summarizes the identified sources for the price difference of $3.19/W between US and German residential systems installed in 2011. The largest difference in business process costs stems from customer acquisition costs, followed by installation labor costs and permitting, inspection and interconnection costs. Figure 7 also suggests a need to develop a better understanding of the residual term among US systems, in particular what residual and overhead cost components are so dramatically different between Germany and the United States.

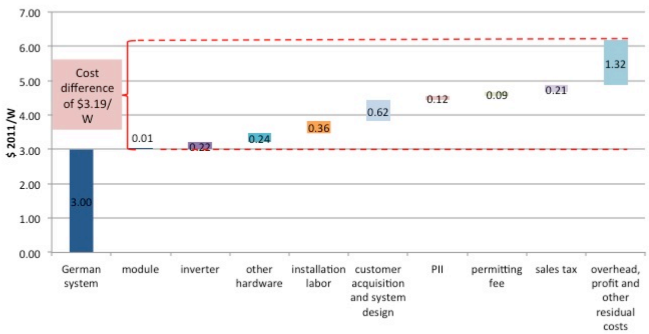

Fig. 7: Build-up of cost differences between German and US residential PV systems.

3.4. Secondary Findings

3.4.1 US residential systems are smaller than German systems

Analyzing the LBNL database (3) and interconnection data from the German Federal Grid Agency (BNetzA) (1) revealed that German residential systems are slightly larger than US systems. Clearly identifying residential systems among the German PV installations is challenging as no information about the customer type is registered and hence no clear boundaries between larger residential and smaller commercial systems exist. As a proxy for residential systems, the distribution of systems under 10kW$_{DC}$ is compared in Figure 8.

The frequency distribution of German systems shows two local maximums at 5-6kW$_{DC}$ and 7-8kW$_{DC}$, a broad right-hand tail flattening out at 16kW$_{DC}$, and a third strong spike occurring at 30kW$_{DC}$ (the upper boundary for the highest-price Feed-in Tariff (FiT) class until April 2012). A similar frequency distribution for the United States demonstrates a clear concentration for systems sizes between 3kW$_{DC}$ and 6kW$_{DC}$ followed by a strong decline with nearly no systems falling in the range between 11kW$_{DC}$ and 30kW$_{DC}$. This divergence can partly be explained by differences in the policy framework, where every generated kWh is rewarded under the German FiT policy, while most US residential customers are effectively limited to annual PV generation less than or equal to their annual electricity consumption. The strong decline of the FiT (being below residential electricity rates by nearly 0.10€/kWh in early 2013) will likely change customer choices in Germany, who now primarily strive to offset their own instantaneous electricity consumption and thus are likely to decrease their PV system sizes.

Focusing on installations ≤10kW$_{DC}$ confirms the size differences with a medium US system size of 4.95kW$_{DC}$ compared to a German medium size of 6.8kW$_{DC}$. This size difference is relevant because of a general trend of economies of scale, where fixed costs (e.g. wiring, inverter costs or most business process costs) can be spread out over a larger capacity, yielding a lower $/W$_{DC}$ price. Figure 8 is particularly telling as the strongest declining price effect occurs among small systems (2-5kW$_{DC}$), a range in which most US systems are installed. If the US installations had the same system size distribution as German systems, the median system price would be expected to be $.15/W lower than the actual observed median price in 2011.

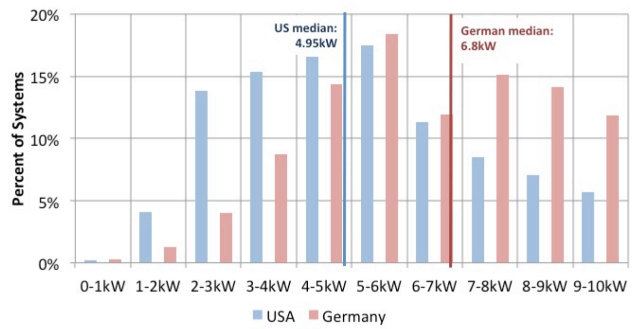

Fig. 8: Size Distribution of PV Systems ≤10kW$_{DC}$ installed in 2011.

3.4.2 German systems do not have more Chinese modules

The hypothesis that German residential PV systems are cheaper than US systems because of cheaper Chinese modules could not be confirmed (installer purchase prices were 0.25€-0.50€/W less for Chinese modules than for non-Chinese modules in 2011). An analysis of 20,761 US customer-owned residential systems (3) and 3,041 German residential systems (6) showed no significant difference in the share of modules originating from China or Taiwan (25% in the United States and 27% in Germany). The German residential market was, at least in 2011, still clearly dominated by German modules (53%) with only moderate contributions from Japanese, US or other module manufacturers (5%-9%). In the United States, the market was more balanced, with nearly even market shares of Chinese, US, Japanese and German modules (20%-25%). A distinction between US costumer-owned residential systems and third-party-owned systems is important, as the latter are likely to have even a higher share of Chinese modules than German residential systems (14).

4. DISCUSSION OF FINDINGS

Our systematic and detailed empirical analysis has shown that the primary source of price differences between the United States and Germany stems from non-module costs such as business process costs and "overhead costs and profit." The learning curve analysis indicated that about half of these costs may be attributable to the smaller size of the residential PV market in the United States in comparison to Germany: with greater market-wide deployment, installers become more experienced, allowing them, for example, to streamline workflows during the physical installation process.

The transferability of the German experience to the Unites States may be somewhat limited due to a number of structural differences between both markets that are unlikely to change: Germany has a higher population density, leading to lower transportation costs and travel times, and climatic differences such as higher wind loads or roofs not designed to withstand larger snow masses may require a higher degree of scrutiny during the structural design process of the PV system.

Some of the market fragmentation in the United States (between states, utility service territories or "authorities having jurisdiction" in the permitting process) is politically-induced and originates in the substantial role that states assume in the design of renewable energy policy in comparison to the federal level. In contrast, Germany's renewable energy policy is primarily governed by the national Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz; EEG) and the German Energy Act (Energiewirtschaftsgesetz - EnWG), which provide the country with a national incentive structure and one unified PV market. The relative simplicity of the German regulatory framework, a large potential customer base that holds strong environmental values, and a very competitive market of PV installers have enabled a strong demand for PV systems. This demand allowed for a quick project flow and low customer acquisition costs, while the regular incentive declines kept installer profits in the single to low double digits.

The German market growth and the rapidly falling prices may have been additionally facilitated by the regularly adjusted FiT, which has historically provided for a simpler, more certain, and more lasting value proposition compared to US policies consisting of a combination of tax credits, local incentives and net metering policies. Until an EEG-amendment in April 2012, it had been relatively easy to calculate the value of the revenue stream of the FiT-payments in Germany, which was determined primarily by the local insolation resources. Figure 9 shows the decline of FiT-payments for new systems (blue line in $/kWh, right axis) and the corresponding net-present-value (NPV) in $/W for systems in the sunny regions in the German south (generating per year roughly 860kWh/kW, red dotted line, left axis) and for systems in the less sunny north (generating per year roughly 730kWh/kW, violet dotted line, left axis). This policy mechanism of automatic incentive reductions has forced residential installers to regularly lower system prices (even in times of stable module prices before 2008) in order to offer their customers attractive rates of returns.

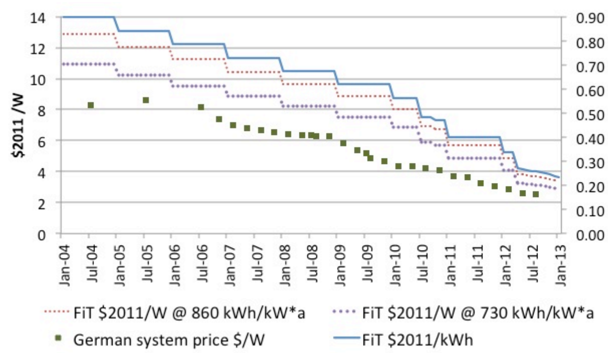

Fig. 9: German residential systems prices and the value of FiT payments in high- and low-solar regions in Germany.

Similar pressures to reduce system prices may not exist to the same degree in the United States, where the largest incentive (the federal 30% Investment Tax Credit) is stable, at least until 2016. In addition, the NPV associated with electricity cost savings from net-metering-agreements also does not fall regularly but may even increase with rising electricity prices over time and significant variation in bill savings occur due to rather complicated rate structures. Only a very competitive market and the incentive to capture a higher market share may motivate installers to price their systems very aggressively.

One subject still insufficiently understood is the composition of overhead costs and margins among US residential PV installers. Studies analyzing pricing decisions (the degree of value-based-pricing) and competition between installers could fill an important gap in the current literature. Similarly field studies detailing differences in installation practices between both countries could highlight remaining optimization opportunities for installers in the United States.

5. CONCLUSION

US residential PV systems were nearly twice as expensive in comparison to German systems in the year 2011, and price differences of about $3/W seemed to continue through 2012. Most of these differences originate in high business process and overhead costs in the United States and cannot be explained by mere differences in the market size. In order to reduce these costs, the United States could introduce policies that enable a large durable market while minimizing market fragmentation. Incentive structures offering a simple, transparent, and certain value proposition combined with simple interconnection, permitting, and inspection requirements should be complemented by regular incentive declines that drive and follow cost reductions.

6. ACKNOWLEDGEMENTS

This work would not have been possible without the friendly assistance of many residential PV installers in both the United States and Germany, data support by the firm EuPD and collaboration and guidance by our colleagues at NREL, in particular Kristen Ardini's work of surveying US installers.

This work was supported by the Solar Energy Technologies Program, Office of Energy Efficiency and Renewable Energy of the U.S. Department of Energy under Contract No. DE-AC02- 05CH11231.

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