WREF 2012: BENCHMARKING NON-HARDWARE BALANCE OF SYSTEM COSTS FOR PV SYSTEMS IN THE UNITED STATES USING A BOTTOM-UP APPROACH

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ABSTRACT

This paper presents results from the first U.S.-based data collection effort to quantify non-hardware, business process costs for PV systems at the residential and commercial scales, using a bottom-up approach. Annual expenditure and labor hour productivity data are analyzed to benchmark business process costs in the specific areas of: (1) customer acquisition; (2) permitting, inspection, and interconnection; (3) labor costs of third party financing; and (4) installation labor. Annual cost and labor hour data were collected from 87 installers. After eliminating outliers, the survey sample consists of 75 installers, representing approximately 13% and 4% of 2010 added PV installations at the residential and commercial scales, respectively. Results indicate that business process costs benchmarked in this analysis (including assumed permitting fees) total $1.52/W for residential systems (ranging from $0.66/W to $1.66/W between the 20th and 80th percentiles). For commercial systems, the survey results suggest business process costs of $0.99/W for systems <250kW (ranging from $0.51/W to $1.45/W between the 20th and 80th percentiles), and $0.25/W for systems >250kW (ranging from $0.17/W to $0.78/W between the 20th and 80th percentiles). We conclude that business process costs present significant opportunities for efficiency gains and cost reductions.

1. INTRODUCTION

The global average selling price for PV modules fell from $3.55 per watt ($/W) in 1998 to $1.25/W in 2011\(^1\), while average installed costs declined from $11.00/W to $6.20/W over the same period. With reduction in module price accounting for 52% of the total decline in average installed system cost, non-module components represent a significant, and increasing, portion of PV system prices in the U.S. Thus, in order to track and analyze the rapidly evolving price structures of PV systems, a thorough understanding of non-module cost components is needed.

To date, a number of analyses have examined non-module PV system hard costs, including power electronics and hardware balance of system (BOS). However, a more thorough bottom-up examination of non-hardware BOS costs of PV installations has not been published to date. Total non-hardware BOS elements such as customer acquisition costs, permitting, interconnection, financing, installation labor, taxes, operating overhead, and profit, etc. contributed up to 52% to total installed PV system price in 2011, depending on system size, location, and other factors.\(^2\) The purpose of this analysis is to provide further

\(^1\) Module prices for large quantity buyers in unrestricted international commodity market; module size typically >150 watts sold in quantities of 500-1,000 unit minimums.  
\(^2\) 52% for residential PV systems, 45% for commercial systems <250 kW, and 36% for commercial systems >250kW
granularity to total non-hardware BOS cost estimates and quantify certain business process costs for PV systems, previously unmeasured. We acknowledge there are non-hardware cost and end consumer price components, including profit, overhead, financing, and contracting that are not benchmarked by this analysis using a bottom-up methodology. We focus on the non-hardware BOS costs for which bottom-up data was collected, defined as business process costs for the purpose of this analysis. The business process costs benchmarked in this study compose an estimated 46% of total PV non-hardware BOS for residential systems, 40% for systems<250kW, and 15% for systems>250kW.

2. METHODOLOGY OVERVIEW

An 18 question online survey was disseminated to a solar industry association’s network of U.S. PV installers to benchmark average time and cost of PV business process for systems installed in 2010. Total annual expenditure data was collected for customer acquisition costs, delineating between 3 cost categories- marketing and advertising, system design, and all other customer acquisition costs. Annual expenditures were translated to dollars per watt, for each cost category, based on reported number of installations and PV system size.

Labor hours per installation data were collected in the areas of permitting, inspection, interconnection, arranging 3rd party financing, and installation. Reported average labor hours per installation were translated to cost per watt using labor class proportion assumptions based on interviews with installers, fully burdened labor rates, and PV system size.

3. RESIDENTIAL

3.1 Sample Market Representation and Characterization

A raw sample size of 70 residential PV installers, representing 18% of added residential installations in 2010, was cleaned for outliers on a per question basis by eliminating the highest 5% and lowest 5% of cost/W values and erroneous responses. The cleaned sample size ranges by cost category from n= 47 to n=60 and represents between 13% and 16% of added residential PV installations in 2010. The sample is predominately comprised of small volume installers, with 18 out of 70 respondents completing more than 100 installations in 2010. Moreover, the 4 largest volume installers completed a total 4,315 installations, approximately 50% of total systems sampled. Table 1 presents the cleaned residential sample market representation.

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>n</th>
<th>Installations (%)</th>
<th>U.S. Residential PV Additions 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer Acquisition</td>
<td>47</td>
<td>6,197</td>
<td>13%</td>
</tr>
<tr>
<td>System Design</td>
<td>48</td>
<td>4,601</td>
<td>10%</td>
</tr>
<tr>
<td>Marketing/Advertising</td>
<td>47</td>
<td>6,197</td>
<td>13%</td>
</tr>
<tr>
<td>Permitting, Inspection,</td>
<td>60</td>
<td>6,897</td>
<td>14%</td>
</tr>
<tr>
<td>Interconnection Labor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Financial Incentive Application Process</td>
<td>60</td>
<td>6,726</td>
<td>14%</td>
</tr>
<tr>
<td>Installation Labor</td>
<td>56</td>
<td>6,038</td>
<td>13%</td>
</tr>
<tr>
<td>3rd Party Financing Labor</td>
<td>60</td>
<td>7,882</td>
<td>16%</td>
</tr>
</tbody>
</table>

3.2 Residential Results

We assume an average system size of 5kW when calculating cost per watt for all non-hardware cost categories examined at the residential scale, except installation labor. For the category of installation labor, we calculated cost per watt using the reported average system size, for we assume installation labor costs for residential systems scale with system size, while the other non-hardware costs measured do not. Average cost per watt, weighted by total number of installations per respondent, is reported for all cost categories at the residential scale.

Customer Acquisition- Customer acquisition activities can add considerable time and cost to PV installations, especially in states with less mature markets where perceived technology risk and unfamiliarity with PV increases bid failure rates. Expenses related to customer acquisition, such as lead generation, bid and pro-forma preparation, contract negotiation, and system design, increase sunk costs to the installer in the event of project drop out, increasing the overall cost of doing business. Installer expenditures on customer acquisition activities totaled $.67/W for a typical 5kW residential PV installation; $.11/W for system design, $.33/W for...
marketing and advertising, and $.23/W for the category of all other customer acquisition costs\(^2\) (see figure 1).

\[ \text{Customer Acquisition Costs} \]

\[ \text{Residential System Size} \]

Fig. 1: Customer Acquisition Costs for Residential PV Installers

**Permitting, Inspection, Interconnection (PII)** - The United States’ regulatory requirements and permitting processes for PV installations are often burdensome and costly compared to PV market leaders, such as Germany (Langen 2010). Installers expend significant resources on paperwork completion and compliance. Additionally, the lack of standardization in permitting requirements, fees, and interconnection standards across more than 18,000 authorities having jurisdiction (AHJ) and over 5000 utilities, impedes installers’ ability to rapidly deploy solar technology across numerous jurisdictions and utility service territories. Absent fees, the labor costs of completing permitting, inspection, and interconnection benchmarked by this survey totaled $.15/W, including typical delays, wait times, and labor requirements for the financial incentive application process. Permitting and interconnection fees significantly impact total permitting costs, with total fees in the U.S. ranging from a low of $0/W to an approximate high of $2500/W. However, typical permit fees at the residential scale in the U.S. range from $200-$450 per installation.

When examining total PII labor hour requirements/installation, most installers reported total hours within the range of 15 to 25 hours, or $.08/W-$1.15/W. The two largest volume installers (total # systems installed \( x > 1000 \)) reported total PII labor hours \( \approx 20 \), indicating no definitive economies of scale between PII processing times and installer volume. As such, data results indicate that total PII costs may be more dependent on jurisdictional factors than installer experience in the market place, though further data collection is needed.

In determining PII labor requirements, the following costs are included:

- **Permit Preparation** - determining a jurisdiction’s permitting requirements, travel time to site/verification, drawing system plans, structural calculations, zoning application, and delays
- **Submit Permit Package** - travel time to and from the permitting office and wait time at the permitting office
- **Permitting Inspection** - paperwork, travel time to and from the site, wait time for inspector, and physical inspection
- **Interconnection Process** - paperwork, travel time to and from the site, wait time for representative from utility, and physical interconnection
- **Financial Incentive Application Process** - determining eligibility, paperwork, travel time to and from the site, wait time for inspector, and physical inspection

See table 2 for capacity weighted average labor costs for permitting, inspection, and interconnection. Total PII labor hours/installation, by installer volume, are summarized in figure 2.

**TABLE 2: PERMITTING, INSPECTION, INTERCONNECTION LABOR COSTS ($/W)**

<table>
<thead>
<tr>
<th>Cost Component</th>
<th>Cost ($/W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permit Preparation</td>
<td>.05</td>
</tr>
<tr>
<td>Permit Submittal</td>
<td>.03</td>
</tr>
<tr>
<td>Inspection</td>
<td>.03</td>
</tr>
<tr>
<td>Interconnection</td>
<td>.01</td>
</tr>
<tr>
<td>Financial Incentive Application Process</td>
<td>.02</td>
</tr>
<tr>
<td>Total</td>
<td>.15*</td>
</tr>
</tbody>
</table>

\(^{2}\) including sales calls, site visits, travel time to and from the site, contract negotiation with system host/owner, and bid/proforma preparation, but excluding marketing/advertising and system design
Fig. 2: Total PII Labor Hour Requirements/Install, by Installer Size

Installation Labor- Survey results indicate that installation labor costs total $.59/W, $.33/W for construction labor and $.26/W for electrician labor (see figure 3). Despite a lower assumed construction labor wage ($40.49/hr), compared to electrician labor ($60.12/hr), higher average construction labor requirements (49 hours/installation) compared to electrician labor (26 hours/installation) lead to overall higher construction labor costs than electrician. These findings are consistent with prior analysis in which installation labor costs were benchmarked using the same labor wage and class assumptions (Goodrich et al 2011).

In general, installers with higher average system sizes exhibit greater installation labor requirements, indicating that gains in module efficiency and decreases in hardware requirements have potential to significantly decrease installation labor costs per watt (see figure 4).

Fig. 3: Installation Labor Costs for Residential PV Installers

Labor Costs of 3rd Party Financing - The up-front capital requirements of PV installations often deter PV adoption. Innovative 3rd party financing schemes that address high up-front capital requirements, such as solar leases and power purchase agreements (PPA), are becoming more prevalent. In Q1 2011, approximately 61% of residential systems installed used 3rd party financing arrangements. However, such systems were also, on average, 10% more expensive than self-owned, self financed installations. To benchmark the additional labor costs of arranging 3rd party financing, the survey asked installers to report the average number of labor hours required for installer assisted 3rd party leases, PPAs, direct cash purchase, and other financing arrangements (including commercial bank financing and government loan programs). It took 2.4 labor hours on average to work with fund providers for third-party systems, translating into $0.02/W for a 5 kW system. Of all respondents, 18 installers assisted third-party leases while 7 assisted third-party PPA’s; Moreover, PV systems completed by smaller volume installers were more likely to be financed through direct cash purchase compared to large installers, with 46% of all installations in the sample financed through 3rd party schemes. Figure 5 exhibits the use of 3rd party financing, by installer size.

Fig. 4: Total Installation Labor Requirements and Residential System Size

Fig. 5: Financing Structure, by Installer Volume
4. COMMERCIAL

4.1 Sample Market Representation and Characterization

A total of 17 commercial PV installers responded to the survey, representing roughly 5% of all commercial PV systems installed in the U.S. in 2010 but 23% of all commercial PV capacity installed in that year. As with the residential surveys, the data were cleaned for outliers, with 13-15 valid responses remaining per question. Given the small sample size for the commercial survey results, we urge caution in generalizing from these findings.

The sample primarily consists of relatively small-volume commercial installers, with only two survey respondents having completed more than 20 commercial systems in 2010. The large majority (12 out of 17) of respondents completed fewer than 10 systems in 2010, reflecting the fact that some have a broader scope of business (e.g., electrical contractors or engineering firms) and do not exclusively focus on PV or solar installations.

Commercial PV systems vary considerably in size, and the survey respondents correspondingly include installers specializing in both small and large commercial systems. Of the 17 installers surveyed, 6 installed systems averaging <100 kW in 2010, while 5 reported an average system size >500 kW (with the remainder falling in between those average system sizes).

4.2 Commercial Results

For most business process cost categories examined, survey questions were denominated in terms of average labor hours per system installed. For each installer surveyed, these responses were translated to units of dollars per watt based on the average system size of that particular installer and assumed labor rates. For customer acquisition costs, survey questions were, instead, denominated in terms of annual dollar expenditures. These survey responses were translated to dollars per watt for each installer based on the total capacity of commercial systems installed in 2010.

Survey responses for commercial installers are summarized here in terms of the median value across respondents. Given the relatively small sample size of commercial installers surveyed, this statistical metric was deemed more meaningful than an average or capacity-weighted average (as was used for residential PV). In order to illustrate how business process costs for commercial PV may differ depending on the size of the system installed, we separately report median values for installers with average system size <250 kW and those with an average system size >250 kW.

Customer Acquisition – Across all commercial PV installers surveyed, median customer acquisition costs totaled $0.10/W, consisting primarily of system design related costs (see Figure 6). Customer acquisition costs exhibit strong economies of scale, with median customer acquisition costs of $0.19/W for installers with average system size <250 kW, compared to roughly $0.03/W for commercial installers with an average system size >250 kW. The scale economies are also evident in comparing between small commercial installers and residential installers, who exhibited even higher customer acquisition costs ($0.67/W, as reported previously). Of particular note is the much lower costs associated with marketing and advertising reported by commercial installers (roughly $0.01/W), compared to residential installers ($0.33/W).

![Customer Acquisition Costs for Commercial PV Installers](image)

**Fig. 6: Median Customer Acquisition Costs for Commercial PV Installers**

Permitting, Inspection, Interconnection (PII) – The commercial installers surveyed reported widely varying estimates for the average number of hours per installation associated with PII activities, ranging from roughly 20 hours to almost 500 hours per system, with a median response of 67 hours. Reported PII labor requirements were typically higher for larger systems; installers with average system size >250 kW reported 72 hours/system in the median case, compared to 41 hours/system for installers with average system size <250 kW. This difference is to be expected, given the generally greater complexity of permit application processes for larger systems.

Based on assumed labor rates and each installer’s average system size, PII labor costs amount to less than $0.01/W across the full set of commercial installers surveyed, with permit preparation constituting the largest underlying labor cost (see Figure 7). Although labor requirements are
greater for larger commercial PV systems in terms of the number of labor hours per installation, the associated costs on a per-watt are lower, as the absolute dollar costs are spread across a larger number of installed watts.

Note that, as with the residential survey results, the PII labor costs reported here for commercial PV do not include the cost of permitting or interconnection fees, which may significantly exceed the direct PII labor costs. For illustrative purposes, a $25,000 permit fee (not atypical for commercial PV systems) would equate to an additional $0.35/W, in the median case, among the survey respondents with an average system size <250 kW and $0.03/W among the respondents with an average system size >250 kW.

<table>
<thead>
<tr>
<th>Average System Size</th>
<th>PII Labor Costs ($/W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;250 kW</td>
<td>0.00</td>
</tr>
<tr>
<td>&gt;250 kW</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Fig. 8: Median Installation Labor Costs for Commercial PV Installers

Based on assumed labor rates and each installer’s average system size, installation labor costs amount to roughly $0.21/W across the full set of commercial installers surveyed, (see Figure 8). Given the lower labor productivity rates mentioned above, installation labor costs are appreciably higher for small commercial systems, with a median value of $0.42/W among survey respondents with an average system size <250 kW.

**Labor Costs of 3rd Party Financing** – Among the commercial installers surveyed, roughly 35% of all systems completed in 2010 involved some form of third-party financing (either leases or power purchase agreements). The remaining installations were either direct cash-sale transactions or involved installer-assisted bank or government loans.

Installers bear additional labor costs when providing third-party financing to their customers – for example, the labor costs of working with fund providers or other contractual counterparties. The commercial survey respondents reported that the labor costs associated with providing third-party financing totaled 60 hours per system, in the median case. Based on assumed labor rates and each installer’s average system size, these labor requirements equate to roughly $0.02/W for the survey respondents with an average system size <250 kW and less than $0.01/W for respondents with an average system size >250 kW.

5. **LIMITATIONS**

This report summarizes the non-hardware balance of system costs that PV installers incurred when completing residential and commercial projects in 2010. However, certain limitations to the analysis exist. First, after eliminating the top and bottom 5% of responses, the sample size of installers across the United States is small.
(n=60 residential; n=17 commercial\(^5\)), potentially magnifying the effect of response error. Secondly, when assessing bottom-up cost structures, the inability to identify whether some questions may be inapplicable or only marginally applicable to respondents that serve primarily as subcontractors to engineering procurement and construction firms may result in an underestimation of costs. Thirdly, while this soft cost data collection is the most granular to date, further data collection is necessary to capture certain costs not explicitly addressed by the survey design. For instance, while the analysis benchmarks the labor costs of arranging 3rd party ownership and the financial incentive application process, there are additional financing related costs to be considered such as legal fees, interest during construction, and working capital. Lastly, the data set could be enhanced with increased geographic variability, for the sample representation is heavily weighted by installers based in California, with the exception of a few large scale installers from the east coast. This lack of geographic representation has the potential to misrepresent costs on a national basis, given the differences in market maturity across states.

6. SUMMARY OF KEY FINDINGS

6.1 Residential

The results of the residential installer survey suggest that business process costs can add significantly to the cost of residential PV (see Figure 9). For residential systems, business process costs (including assumed permitting fees) total $1.52/W, equivalent to roughly 46% of total PV non-hardware costs ($3.33/W) and 24% of total PV system price in 2011 ($6.35/W). Customer acquisition and installation labor costs are the most significant of those benchmarked in this analysis, suggesting considerable efficiency gains can be made in these areas. However, the importance of streamlining permitting, inspection, and interconnection requirements should not be disregarded. Given that PII accounts for a significant portion of the price difference between market leaders, such as Germany, and the U.S., permitting, inspection, and interconnection present opportunities for significant cost reductions as well. Lastly, while the costs of arranging 3rd party financing are negligible, additional data on financing costs is needed to more accurately depict the true cost of financing and contracting PV systems.

6.2 Commercial

As indicated in Figure 9, business process costs can also constitute a significant portion of the cost of commercial PV, though the impact depends significantly on system size. For commercial systems <250 kW, business process costs (including assumed permitting fees) total $0.99/W, equivalent to roughly 40% of all non-hardware costs ($2.50/W) and roughly 18% of total system price in 2011 ($5.57/W). In contrast, business process costs are just $0.25/W for systems >250 kW, or 15% of all non-hardware costs ($1.72/W) and 5% of the total system price in 2011 ($4.79/W).

Of the various labor-related business process costs, installation labor is by far the most significant, suggesting that efforts to reduce commercial PV system costs ought to focus on this particular cost category. System design and customer acquisition add moderately to the cost of small commercial systems, but are negligible for large (>250 kW) systems on a dollar-per-watt basis, given economies of scale and the ability to spread those (relatively) fixed costs out over a larger number of installed watts. Labor costs associated with permitting, interconnection, and inspection, as well as labor costs associated with financing and contracting, are generally negligible for commercial PV.

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\(^5\) Sample size and representation vary by cost category.

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Fig. 9: Total Non-Hardware BOS Costs, by System Size
* all other non-hardware BOS includes profit, sales tax, non-labor financing and contracting costs, and additional costs due to market friction and inefficiencies

7. ACKNOWLEDGEMENTS

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8. REFERENCES


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